Ecologies of Interactive Artifacts

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Abstract
With the increasing ubiquitous presence of technology, we as designers must start to look at the way these technologies support, interfere with, and compete with each other in our homes and workplaces. This paper looks at the network created by these artifacts as an ecology that an individual must strive to maintain. We propose an early theoretical perspective and a preliminary research framework to analyze this phenomenon that models both the artifact itself and its value to the user. Our goal with this research is to understand the strategies that users employ to maintain their personal ecology to support the design of artifacts integration with these ecologies.

Keywords
artifact, personal ecology, network, interactivity, design

ACM Classification Keywords
H5.m. Information interfaces and presentation: Miscellaneous. H1.m. Models and Principles: Miscellaneous.

Introduction
Our reality is becoming increasingly interactive. Our everyday environments are flooded by new digital interactive artifacts and with traditional artifacts enhanced by digital technology [1, 5, 9, 22]. In many cases, these artifacts are connected to the Internet—

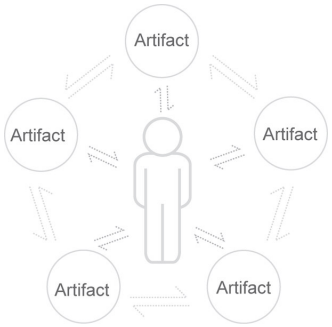

Figure 1. A personal ecology of interactive artifacts

creating a *network of artifacts* where artifacts communicate with each other, exchange information, and share content and data [4, 6, 19].

To live within and to use such networks of artifacts is quite challenging and is today a source of frustration for many individuals since they do not feel as if they understand or have control over their own immediate personal information environment [22, 27]. At the same time, most people continue to expand and develop this network by adding more artifacts and through an increase of interactivity and connectedness. This reality of being a "user" of not one distinct artifact, but of a large set of interconnected artifacts is a growing concern that does not get enough research attention, even though these intricate and complex relationships between artifacts have been addressed by researchers from different fields [10, 11, 16, 22, 24].

Our study is based on the assumption that there is a twofold need to better understand these new personal networks of artifacts: (i) there is a need for ways to describe, analyze, and interpret what it means for individuals to live with and use a network of interactive artifacts, (ii) there is also a need for a better understanding of how people relate to their network of artifacts from a design perspective. Our assumption is that any designer designing new interactive artifacts would benefit from a deeper understanding of these new complex use situations of which their designs will be an intricate part. We suggest that a productive way to approach and understand such a network is to examine it as an *ecology of interactive artifacts*. The proposal is aimed at the analysis and examination of such ecologies with the *purpose to create knowledge about how people experience and strategize the use and development of their ecologies of interactive artifacts over time*.

We define a personal ecology of interactive artifacts as *all physical artifacts with some level of interactivity made possible by digital technology that a person owns, has access to, and uses*. The number of artifacts that fits this description is growing, and physical objects, traditionally not seen as interactive, are transformed by the infusion of digital technology into their design. For instance, the TV has been seen as a distinct analog artifact, but is now transformed into a digital artifact connected to other artifacts such as DVD players and computers, and thereby becoming an increasingly interactive artifact.

The key properties of artifacts in an ecology are their abilities to be interactive, to communicate, to share information, and to react to and act upon the users' behavior and actions as well as act between other users (see Fig. 1). When these artifacts act as one "system," a new behavior emerges, and we approach a situation where our artificial environment can almost be seen as "living." One assumption in this study is that the notion of *ecology*, with its biological roots, serves well both as a metaphor and as a theoretical construct to support the analysis and examination of complex networks of interactive artifacts.

Background

The reason behind the proposed research is that the growing complexity in people's everyday lives tends to lead both to excitement and frustration [4, 9, 17, 22]. Based on our preliminary research, we have found that the complexity of an interactive and dynamic reality can cause unease and stress [13, 14]. For a normal,

non-technical person, it is already quite challenging to set up and manage one's personal ecology of interactive artifacts. It is as if each of us needs a "systems administrator" to handle our personal ecologies of artifacts. In our preliminary studies, we have found that people develop different *strategies* for how to design, develop, maintain, and use their ecologies of interactive artifacts. For instance, one strategy is to take complete control of the ecological complexity by learning how to fully "manipulate" each of the artifacts and their relationships, while others try to "divide" the network of artifacts into separate units in an attempt to reduce the interconnectivity and dynamic complexity. These often tacit and non-conscious strategies support people in situations when they have to expand their ecology (add new artifacts), exchange an artifact (get a new artifact instead of using an old one), and manipulate the dynamics of the ecology as a whole. For instance, exchanging a cell phone is for many no longer only a question of getting a better phone; there are many issues that have to be considered such as synchronizing information with other artifacts, sharing functionality between the cell phone and other artifacts, and so forth.

We have found that most existing approaches in HCI or related fields are based on the notion of a single well-defined artifact in relation to a single user or possibly group of users (for overviews see Carroll [3] and Rogers [23]) instead of addressing the issues of emerging from considerations of networks of interactive artifacts.

In this study, we believe that when it comes to how designers deal with this perspective of artifact ecologies, we will find different design approaches and strategies. For instance, one strategy would be to design the artifact to automatically adapt to the existing ecology, while another would be to design the artifact in such a way that it gives the user full control of how it is integrated into a specific personal ecology. We are convinced that designers, in most cases, do not have any explicit strategies for dealing with this except for on the technical infrastructural level, and there are no theoretical or other approaches, as far as we know, proposing how it should or could be done.

Our hope is that our proposal will lead to knowledge and insights that can support students and professionals designing interactive artifacts. Every designed new interactive artifact will inevitably become a part of someone's ecology. The challenge for any designer is to know how to think about an individual artifact in relation to an ecology [18]. There is already an intense artifact "competition" for a place within these ecologies and only those devices which provide the greatest sustained value in an ecology will become more than a fad.

Theoretical Foundation

While the philosophy of technology has extensively explored how humans relate to their reality, there has been less interest in the more concrete relationship between humans and their artifacts. In recent years, however, we have seen several new theoretical attempts in the philosophy of technology bringing artifacts and "things" into focus. These attempts create an overall framework or "map" of existing philosophy of technology approaches. All attempts mentioned below can be viewed as striving towards what Mitcham [20] labels as a *phenomenology of artifacts*. He describes this school of thought as dominated by the idea that

technology can be studied as consisting of artifacts that have inherent designed qualities that when placed in the world evokes a space of possibility and limitations to its environment and its users. In our study, we will incorporate some of the most prominent and recognized newer philosophical attempts within this *phenomenology of artifacts* philosophical tradition into a foundation for our reasoning around the constitution and status of artifacts in relation to humans and other artifacts.

From the works of Verbeek [25], we have been inspired by the notion that things "act." This is not an approach that makes artifacts "alive," but it does recognize the inherent behavior, particularly of digitally enhanced artifacts, that make them able to recognize their environment and act accordingly. From Borgmann [2], we have been inspired by his famous notion of the *device paradigm*. He is concerned with an increasing *commodification*. According to the device paradigm, there is a disconnect between the way we design modern artifacts and what people need to feel grounded and in contact with their reality. He argues that such a development restricts people from having close relationships with things (artifacts) in a way that really matters. From the work of Latour [16], we have been inspired by the notion of networks as aligned *actants* where artifacts in the network work in close relationships with humans to create combined realities shaping each other. From Krippendorff [15], we have been inspired to use the notion of ecology as a model in our analysis and examination of the network of artifacts.

It is obvious that these scholars cannot easily be combined into a coherent theory, and that is not our purpose. However, we fully recognize that any examination about the relationship between people and artifacts rests upon a conscious (or unconscious) philosophy of technology. In our project, we will therefore continue a philosophical examination and exploration to better understand how contemporary philosophy of technology approaches can support our understanding of the way people relate to their artifact environment.

In previous research, we have explored the notion of *interaction* and how the character of artifacts influences interaction, especially with a focus on the complexity of interactions (12, 13). These theoretical explorations of the *nature of interaction* serve as a conceptual ground for our investigations into the complexity of interactions in ecologies of artifacts.

Another aspect that we have explored in earlier work is the notion of *environment interaction* [26]. In this work, we have examined what the new interactive reality means from a design perspective. Design of interactive environments can be seen in relation to interaction design of single artifacts, in the same way as urban design relates to architecture [26]. This perspective is related to the last activity in our research plan (see below) where we focus on how designers approach these new challenges.

Finally, as a core and fundamental concept in our proposal we have chosen the notion of *ecology*. Some researchers have taken the ecological perspective to study human artifacts, since the metaphor provides meaningful analogies to explain complex interactions among artifacts, humans and environments. Gibson introduced *affordance* theory to explain how the

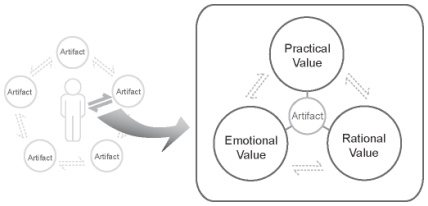

Figure 2. A possible way of analyzing the relationship between a person and individual artifacts (from Jung & Stolterman [14]).

environment influences the visual perception of individuals [8]. Nardi and O'Day defined the concept of *information ecology* as a system of people, practices, values, and technologies in a particular local environment [21]. Forlizzi introduced the concept of *product ecology* to analyze the social use of products [7]. Based on social ecology theory, she specified various interacting factors in a product ecology including people, activities, the built environment, and the social and cultural contexts, which can be used as a framework of designing social product. Krippendorff has emphasized the ecological meaning of an artifact consisting of its possible interactions with other artifacts, which successively evolve while guiding particular users' choices, driving an increase or decrease of species of artifacts, and thus transforming everyday life [15]. The message from these authors is that designers need to consider the ecological consequences to design for complex artifact ecologies.

Research Framework

Ecologies of interactive artifacts can be studied in many different ways. It is for instance possible to focus on different perspectives of an ecology such as a *technical perspective*, an *engineering perspective*, an *infrastructure perspective*, a *use/experience perspective*, or an *interaction perspective*. In this research, we will focus on the interaction perspective, that is, we are mainly studying how people interact with their artifacts and also how the artifacts interact with each other. We will also to some extent include the use/experience perspective. We will not in any detailed way approach the technical or engineering perspective of ecologies unless when needed for the purpose of understanding interaction.

Our *research framework* consists of two parts. The *first part* is aimed at studying how people *experience* and *value* their ecologies of artifacts. Our preliminary study has provided us with a first step in that direction. This *Value Centered Ecology Model* has to be further developed to include other relevant social and cultural factors. The *second* part is aimed at the study of ecologies of artifacts based on an *artifact perspective*, that is, with the artifacts as the core entity. As part of these efforts, we are developing a *model of artifact properties*.

Value Centered Ecology Model

In a previous study [14], we developed a model for analyzing networks of interactive artifacts in use from the perspective of three basic values: practical, emotional and rational (technical) values (see Fig. 2). Those values were initially conceived to include the overall ecological aspects of using interactive artifacts: why people *use* the interactive artifact (practical value), how people *feel* when using it (emotional value), and *how* the artifact is used (rational value).

We found that the *practical value* of an artifact can be measured by the *purposes or outcomes* of using an artifact. In the course of using an artifact, people may feel various emotional responses to it. The *emotional value* of an artifact can be measured by the *user's attachment* to the artifact. The *rational value* concerns how well an artifact is designed to support practical or emotional value of using an artifact. These three values are closely related to each other. Our initial model may be too simple to analyze values in a more complex ecology. However, with this simple model for analysis, we were able to compare different kinds of interactive

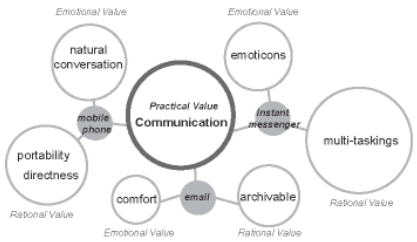

Figure 3. A Value Centered Ecology Map (from Jung & Stolterman [14]).

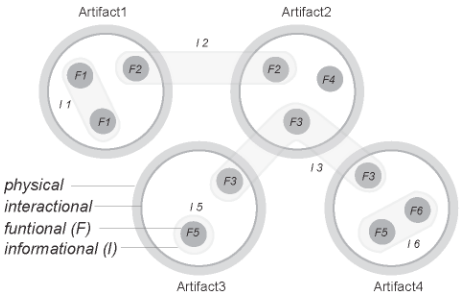

Figure 4. The composition of artifact properties and the ecology

artifacts in a whole ecology of people's daily activities [14].

Based on this study, we believe that a more developed study can support the examination of why people choose to use a certain artifact among many others, why they exchange one artifact for a new one, and how they ascribe value to a "network" of artifacts. This can be done through the analysis of how the three forms of values influence, compete with and connect to each other (see Fig. 3). This, in turn, can lead to findings that explain how the whole ecology of artifacts can be transformed through interactions among different values of each artifact.

Model of Artifact Properties

Based on our initial study we have developed a first tentative *model of artifact properties* that makes it possible to describe some core aspects of artifacts within an ecology (which is different from the value-centered model from our preliminary study). This model serves as a basic tool for examining artifact ecologies. This tentative model is based on several of our practical attempts to describe how people *use* their artifacts, how they *describe* their ecology, and how they see relationships between artifacts, etc. The model consists of four aspects that each artifact can be described by. The four are the *physical*, the *functional*, the *informational*, and the *interactive* (see Figure 4).

1. The *physical* aspect is the manifested artifact as a *physical entity*, as a thing, for instance the laptop, the cell phone, or the mp3 player. We are aware of the fact that there are many possible ways to define what an artifact is, but we have decided to use the physical manifestations as a core marker for what constitutes an artifact as a result of our initial studies (see Fig. 4).
2. The *functional* aspect of an artifact refers to what is possible to do or achieve with a specific artifact. This is in some cases based on the functionality built into the artifact, such as with a cell phone built to make phone calls. In other cases, it is a software application. For instance, on a computer you can also make "phone calls" with the use of software. Within an ecology, one specific functionality can cover several artifacts like a "calendar" function that can be on the computer, the laptop, the cell phone, the mp3 player, etc. This means that the calendar functionality is manifested or instantiated in several physical artifacts and thereby "cover" several artifacts (see F2 and F3 in Fig. 4).
3. The *informational* aspect is similar to the functional with the difference that it is about data and information (or content), instead of functionality. Some information "floats" between or "covers" several artifacts within the ecology, while some are contained in one and only one artifact (see Fig. 4)
4. The *interactive* aspect is the way a person can interact with a specific physical artifact. The way it is possible to interact with a specific artifact is a consequence of the other three aspects, that is, the physical (material) manifestation, the functional aspect, and the informational aspect.

With this model it is possible to capture some of the complexity inherent in ecologies of interactive artifacts. As seen in Figure 4, already in an ecology with only four artifacts the complexity can be quite substantial. We know that it is quite common with personal

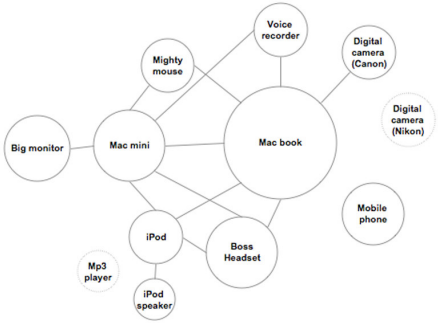

Figure 6. An example of a real Personal Ecology Map reflecting relations (links) and importance (size).

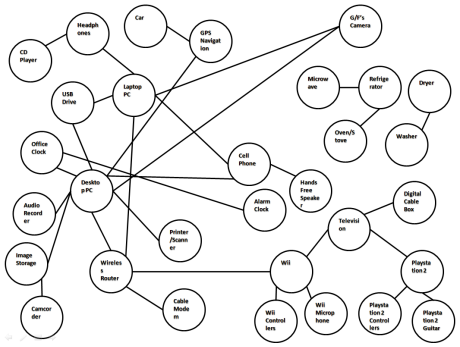

Figure 7. An example of a real personal ecology only considering artifacts and relationships.

ecologies that consist of 15-25 artifacts, plus shared and public artifacts. The model also shows that the replacement of one function might influence and be dependent on a number of artifacts. This is what makes the handling of these ecologies so difficult for normal, non-technical, people, and at the same time it is today very difficult to "escape" the ecological complexity that our everyday interactive artifacts create.

Research Plan

The project consists of four major activities (see above). Three of these will be conducted in parallel based on our initial attempts described above; theoretical studies, framework of analysis, and empirical study of personal ecologies. They will closely influence and hopefully enrich each other. The fourth activity, which is an explorative study with interaction designers to apply and evaluate the ecology framework, will start later in the project and further help us to refine our model of analysis and our theoretical development. In Figure 7, we describe how we see the relationship between the four activities.

These activities are all aimed at exploring and developing a suitable framework for analyzing and describing artifact ecologies. The core of the project, when it comes to time and effort, will be the third activity below, the empirical studies. The theoretical studies and the model development will be intimately related to and dependent upon the empirical studies.

1. We will conduct ***theoretical studies*** aimed at the examination and development of basic philosophical theories suitable for the study of ecologies of artifacts. These studies provide a solid conceptual grounding and will help in the construction of a suitable language for discussing and describing complex artifact ecologies at a discourse level.
2. We will conduct conceptual and intellectual investigations to further develop our ***framework of analysis*** of artifacts in an ecology. The framework consists of two kinds of models: (i) the *Artifact Properties Model* (see above) that will support our concrete analysis of the descriptions of personal ecologies, (ii) the *Value Centered Ecology Model* (from our preliminary study) that will support our analysis of people's experience of ecology values. Both of these models are still tentative, but will serve us well in the initial stages of our project. Our aim is to develop and refine an overall framework of analysis of artifact ecologies.
3. We will conduct ***empirical studies of personal interactive artifact ecologies***. This activity will be the most time consuming in the project. In these empirical studies the subjects will be samples of individuals representing different categories of "users." We will, of course, use students as subjects, since they in many cases have a well-developed and rich ecology of interactive artifacts. But, we will contrast these subjects against groups not recognized as avid users of interactive artifacts. We believe *contrasting* and *comparing* to be an important aspect of the studies, since we will not be able to reach comprehensive representation of all possible contexts and users.

   Specifically, we will develop some of the methodological approaches such as Personal Inventories and Ecology Maps. Some of them have been already tried in our pilot study for describing and analyzing relations among personal interactive

artifacts (see Fig. 5 and 6). Altogether, we have three basic approaches for analysis of our empirical studies. We will use developed versions of our two models, the Artifact Properties Model and the Value Centered Ecology Model. The third approach is a network analysis approach developed in relation with the Complex Systems & Network research group in the department. Our empirical studies can be divided into these activities:

- *Personal Inventories, Ecology Maps, and Strategies.* We will have people describe their own personal inventory of digital interactive artifacts by making simple lists of their interactive artifacts. We will let people create network descriptions of their artifacts, by visualizing their physical, functional, informational, and interactive relationships (for an example see Fig. 5). We will develop different forms of descriptive tools based on different aspects of our two models: the *artifact model* (physical, functional, informational, interactive) and the *value model* (practical, emotional, rational). We will explore as part of these studies the *conscious strategies* that people employ in their attempts to handle and manage their ecology. These strategies will then be used in our observations and interview studies.
- *Network Analysis.* We will use the Personal Inventories and the Ecology Maps as the material for network analysis. The purpose is to find and distinguish patterns, similarities, sub-ecologies, ecology center and periphery, growth and evolution, degradation and disposal, and other ecology oriented aspects of the network. The rationale behind network analysis is that such analysis can provide results about the networks and relationships that are not visible or possible to reveal with traditional observations or interviews.
- *Observations and Interviews*. Using common HCI research methodologies, such as contextual analysis, probes, interviews and observations, we will explore how people behave in and with their ecologies. We will pay attention to specific behaviors such as the replacement of an artifact, the incorporation of a new artifact, the removal of artifacts, and the attempts by people to control and manipulate the emergent overall behavior of the ecology.

4. Initial and explorative studies of ***how designers think and deal with the challenge of artifact ecologies***. This will be done through a number of interviews with practicing interaction designers to see how they design their artifact to become a part of an ecology. We intend primarily to interview designers found in professional design settings; we have established contacts with interaction designers at some premier companies including Google, Adobe, Intuit, and HP. These studies will be analyzed by comparing them with the way people describe and experience their ecologies. We believe that the view from the designers will help us to refine our understanding and further develop our framework.

Expected Outcome and Contributions

In this research, we addressed a notion of ecology of interactive artifacts upon the need for understanding complex relations of artifacts around personal environment both from users' and designers' perspectives. We suggested an initial research framework with two models of describing and analyzing personal ecologies of artifacts: value-centered ecology model and model of artifact properties, with further research plan for theoretical and empirical studies. The overall outcome of the project will be a well-grounded conceptual framework that can support and inform both the analysis and design of interactive artifact ecologies. Specifically, the results from the empirical studies will help us to form a more detailed knowledge about people's way of understanding, strategizing, and handling their ecologies of interactive artifacts. These theoretical studies will inform how we should approach the new phenomena of ecologies of interactive artifacts in relation to existing theories. All these foundational studies will be developed into a model of analysis that is suitable for the description, examination, and interpretation of artifact ecologies. Finally, the explorative studies with designers will help us to relate all these results to the way practicing interaction designers understand and approach the challenge of designing for a complex ecology of artifacts.

Since we see this research project as opening up a new field of studies, we see as our purpose to find ways to make this new field visible and interesting to fellow researchers. We are convinced that there is a need to expand existing theories and approaches in HCI and related disciplines to consider network of artifacts in complex and not well-defined environments. As a long-term plan, we will apply the notion and framework we have developed to pedagogical and methodological materials that can help others to engage in similar studies and examinations of networks of artifacts. We expect these educational attempts would be another initiation to further our research as well as disseminate our findings.

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