Pers Ubiquit Comput (2003) 7: 176–181
DOI 10.1007/s00779-003-0223-1

ORIGINAL ARTICLE

Irene Mavrommati · Achilles Kameas

The evolution of objects into hyper-objects: will it be mostly harmless?

Received: 10 February 2003 / Accepted: 3 March 2003

Abstract Objects may in the future become enhanced with new digital properties and information-communication capabilities, thus turning them into Hyper-Objects. This paper describes an approach towards defining Hyper-Objects, and examines to what extent their advance affects our existing lifestyle patterns.

Keywords Artefacts · Disappearing computers · Ubiquitous computing

1 Introduction

In the last few years there has been a growing interest in ubiquitous computing environments. Although ubiquitous computing is not a new notion [1], in the light of two European funded FET initiatives of the Disappearing Computer (DC and DC2) [2], in the last few years there has been growing interest in the technological as well as human aspects of research in the area of the Disappearing Computer. As a consequence of this type of research, miniaturised, 'disappearing' computers are being embedded into various kinds of artefacts; thus artefacts become enhanced with new digital properties and information-communication capabilities.

The view presented in this paper on disappearing computer artefacts stretches to involve interfaces that differ from information appliances with centralised processing power (such as Personal Digital Assistants (PDAs), mobile phones, etc.). The function the user aims for when using the artefact may no longer be treated by a single processing appliance, but by a collection of tangible objects in some applications. These objects may vary in shape, materials and capabilities, but they are able to communicate with each other through an invisible network, and share the processing capabilities they may individually have. Collective functionality emerges within a group of such artefacts that can work synergistically together in an environment, through invisible links. Such artefacts have a dual nature: a tangible self and a software self. In addition to processing, they may be enhanced with sensing or actuating capabilities of their own.

This paper describes an approach towards defining Hyper-Objects, and examines to what extent their advance can be considered 'harmless' to our existing lifestyle patterns.

I. Mavrommati (✉)
University of Aegean/Computer Technology Institute (C.T.I.),
P.O. Box 1122, GR-261 10 Patras, Greece
E-mail: Irene.mavrommati@cti.gr

A. Kameas
Computer Technology Institute (C.T.I.) P.O. Box 1122,
GR-261 10 Patras, Greece
E-mail: Achilles.kameas@cti.gr

2 What are hyper-objects?

Hyper-objects are a subset of information appliances, where the term 'information appliance' is used in the broader sense of the word [3]. Hyper-objects are ordinary objects that are commonly used for everyday, even mundane tasks (objects such as tables, chairs, cups, shelves, lights, carpets, etc.), and which in the future can be enhanced with communication, processing and sometimes sensing abilities.

Moore's law predicts a doubling of processing power every 18 months, and it has held true for the last 30 years. If such predictions regarding developments in processing power continue to come true, we assume that a day will come in future when processing power will become widely available and cheap, so as to even be disposable. Drinking straws, paper bags, even milk bottles will be able to have processing capabilities, and with those, communication modules and perhaps sensors may come into play in the manufacturing procedures. Less disposable items we surround ourselves with, such as furniture, decorative items, lights, carpets, flower pots, even architectural elements of buildings, can be potentially enhanced by advances in Information

Technology. We describe these objects as 'hyper-objects', as they are capable of interlinking with other objects in various possible associations, in more or less a similar paradigm with the hyper-text of the late 1980s.

The question is: assuming that such a world will be possible, under which conditions it could be beneficial; and what would be the 'lifestyle' challenges brought about by this type of development in appliance design? This is what we address further in this paper.

3 About objects, hyper-objects and appliances

The shape of many commonly used objects has adapted over an extended period of human use so that it can enable a certain context of use. A table, for example, is a lifted surface at an appropriate height, which in some cultures serves the function to put things on and then use those things while sitting in front of it. There are more specialised uses of a table, i.e. a table that is used for the purpose to facilitate study or work is a 'desk'; a table to eat on is a 'dining table'; a shorter and smaller version may be a 'coffee table'; while there may also be a co-existence of the many purposes of use in one instantiation of a table.

Let's assume a second example, that of a cup. Leaving aside attempts to draw conclusions beyond the object's physicality, a cup can be categorised as a container-object, and can be used to contain things, whether this is liquid, sea-pebbles, pencils, flowers, or alternatively someone can think of different uses for it, such as trapping a spider with it, or using it as a paperweight. Depending on the properties of the material it is made of, the capabilities the exact shape offers, as well as other objects/substances it relates with, this container object may be used to drink from, to pour with, to carry liquid with or to keep things in.

An everyday object can thus have functions, depending on what it offers in its tangible shape and capabilities. Although it is mostly used for one purpose at a time, over time it may change purpose of use. A cup with a broken handle, for example, is then transformed into a toothbrush or pencil holder. People are flexible, adjustable and inventive when it comes to using objects to fulfil their needs. Purposes of use may change over time, providing that the object's physical properties are not violated, and allow for these new purposes.

Hyper-objects express their capabilities to other objects through their digital selves; hyper-objects can work synergistically together by linking to each other and sharing their capabilities within a communal pool. The observations regarding the use of normal objects, mentioned in the previous paragraph, also apply to the use of hyper-objects; nevertheless, variations of use can be taken to a much greater extent because of the hyper-object's inherent connectivity and collectivity in behaviour.

The notion of the appliance as defined by Bill Sharpe [3] is 'a device of specialized and widespread use; a device that does one specific thing to information of a certain type'. Based on this notion, a hyper-object can be considered as a subset of appliances. Hyper-objects originate from an evolution of common everyday objects, and therefore are of widespread use. Hyper-objects' material shapes, coupled with additional digital capabilities, enable them to be used collectively to achieve a superset of functions. Therefore, hyper-objects are capable of doing a *range* of 'specific things to information of certain type'.

4 Allowing openness and flexibility – rationale

The use of material objects does not remain static over time. Neither is the use of more solid structures, such as buildings and architectural constructions [4]. Human environments are 'object-scapes', spaces that are constituted from collections of objects, positioned in ways that facilitate or express the life of their owners.

People buy objects and make their surroundings from them, arranging them and rearranging them as fits their needs. They buy furniture, decoration and utility objects from shops, but then they use them to make up their own home landscape as they want; they rearrange the objects at times, according to necessity or aesthetics, until they are satisfied. They may rearrange them at times if they move in a different environment, or if the family needs are changing (i.e. when there is a new family member). As Tom Rodden has pointed out [4], people do that even in the construction of their houses. Houses are perceived as non-changing, solid architectures; yet, over time, new plumbing is installed, walls are demolished and new ones are built, kitchens are redone, ironwork changes – the whole look, feel and functionality of the building may change. People adapt and change the things they use and they should remain able to continue doing this within forthcoming, digitally enhanced environments.

The arrangement of objects, their location and clustering with other objects, makes for different purposes of use at different times. In the previous example of a cup, the object was largely kept in the kitchen, had a relationship with the kettle, and was quite mobile within the home. Later on, as it becomes a pencil holder, it becomes more static and contains an organised collection of pencils and pens.

Although things should be designed to serve a purpose, and serve it well, they should also be allowed to deviate from it when required. People often put effort into keeping some objects in use even when they are quite old or have deteriorated (sustainability is often achieved by alteration of use). People can be very creative in the way in which they use things. So far this has happened in a rather natural way – and sometimes even to the designer's distress! It is in human nature to use things in other than predetermined ways, as long as the physical properties of objects allow for that. If future objects have not only physical properties, but digital capabilities too, designers should allow for this normal

human behaviour. It is indeed in the very core of design disciplines to propose styles that allow for human experience and expression.

By observing these natural changes in uses of normal objects, it becomes evident that we should allow for hyper-objects to be used creatively by people, let alone by designers. This can prove crucial for the successful adoption of hyper-objects: because of the inherent connectivity of hyper-objects, additional 'hyper'-functions can be supported that can be tailored better to their owners use [5]. Let's get back to the example of the hyper-cup: it can be used by someone for drinking, as a primary function, but also as a part of a greater system of objects that is assigned to do health monitoring of the owners. Alternatively, for someone else, it can be part of a different grouping of objects that facilitates ordinary tasks (Fig. 1), i.e. when the level of tea drops, it may be so assigned for the kettle to switch on to boil water for more tea. When, over time, the hyper-cup's purpose is deviated to that of a pencil-holder, that object should be able to identify missing pens, or faulty ones, and play a different role in the everyday life of the household.

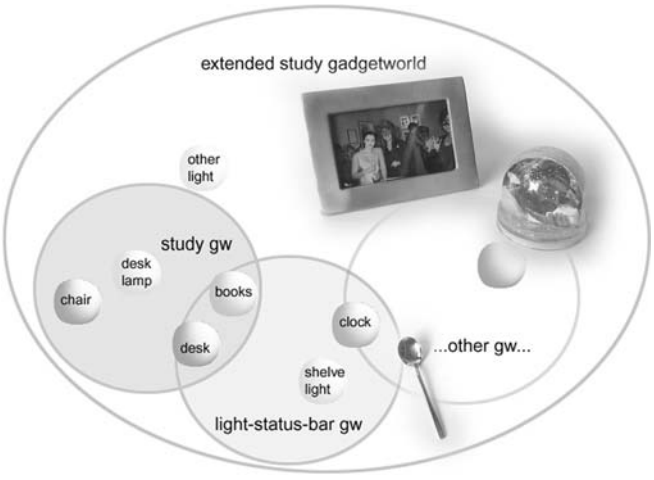

Fig. 1 One hyper-object may participate in many different functional clusters; each of those clusters can function towards a different goal or serve a different user

5 Approaches to creating hyper objects

What is the underlying methodology to create hyper-objects? A simple way to explain this is that hyper-objects are created by adding the ability to have links to objects. This in turn translates to different methods for embedding the hardware, software and design aspects that are added to objects, so as to include, make visible, manage and utilise these links. This not only involves solutions for embedding processors, sensors and communication modules to objects, but also developing appropriate mental models on how these objects can be used, and re-designing objects to suggest their new affordances.

In the context of the disappearing computer initiative, the project 'Smart-Its' [6] aims at developing small devices which, when attached to objects, enable their association based on the concept of 'context proximity' The collective functionality of such a system is mainly composed of the computational abilities of the Smart-Its, that work as added tags to the physical self of the participating objects.

A more generic approach is undertaken by the project 'Oxygen', which enables human-centred computing by providing special computational devices, handheld devices, dynamic networks and other supporting technologies [7]. Another interesting disappearing computer project is 'Accord', which is focused in developing a Tangible Toolbox (based on the metaphor of a tangible puzzle) that will enable people to easily embed functionality into existing artefacts around the home [8].

The Gadgetware Architectural Style approach [9] lies in viewing the process where people configure and use complex collections of interacting extrovert-Gadgets, as having much in common with the process where system builders design software systems out of components. In this approach, the everyday environment is seen as being populated with many different objects, which people associate in *ad hoc* and dynamic ways. [10,11] In the GAS style approach, a vocabulary is developed so that people can reason about the nature of hyper-objects and subsequently manipulate them (Fig. 2).

This approach can scale both 'upwards' (towards the assembly of more complex objects, i.e. from objects to rooms, up to buildings, cities and so on), and 'downwards' (towards the decomposition of eGadgets into smaller parts, i.e. towards the concept of 'smart dust'). Moreover, it treats evenly different objects that may range from powerful ones (having their own processing and communication), to very minimal ones (that can be considered as tagged artefacts, which borrow processing and storage capabilities from servers, for example).

An Editor is also added in the picture of hyper-objects, as an external super-device that is needed to review and associate hyper-objects and their collections [12]. The Editor is an information appliance or a software program that is run by an information appliance (for example as editor, a PDA, a mobile phone, or even a laptop can be used, with the prerequisite that the information appliance runs the operating system that also makes it an e-Gadget).

6 Vision

The argument of several design researchers (among others Dunn and Raby, Bill Gaver, Philips Design) is that people should be the ones to add interpretation and meaning to designs that are intentionally left open for imagination and experimentation [13]. People are the interpreters of open scenarios of technological objects [14], while designers are allowing for these interpretations to occur by providing intentionally open-ended

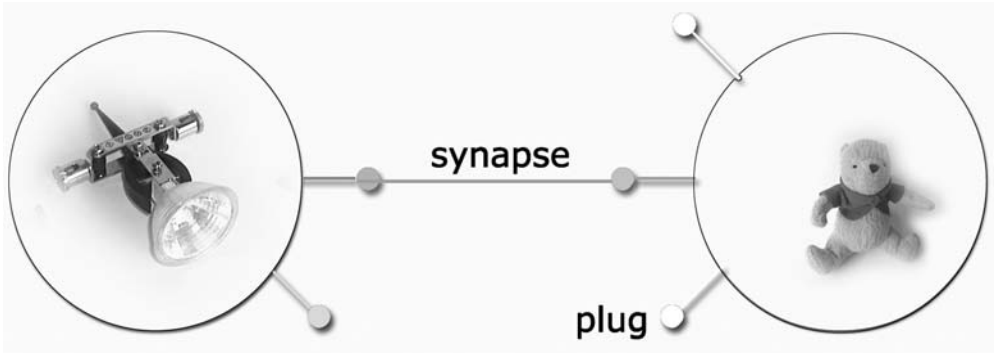

Fig. 2 In the GAS approach a vocabulary acts as a common referent between people, objects and their collections: the hyper-objects' (*eGADGETS'*) capabilities (*PLUGS*) can be associated together via invisible links (*SYNAPSES*) in many possible ways. Thus, the adopted style provides an infrastructure for open applications. A collection of objects functioning together in this way to serve one specific purpose is a *GADGETWORLD*

designs. A constructivist, engineering element to this approach is that hyper-objects can be the building blocks that enable and inspire unique individual applications to be created. Provided that flexible infrastructures are supporting the use of hyper-objects, niche applications can be created and shared between people, while experienced designers can also orchestrate other applications types. However, before we can get to this point, we need the appropriate concepts and the enabling tools that people and designers can use, and these in turn need to be based upon open approaches from the level of the technological infrastructure.

7 Usage, interface issues

Each object that participates in our everyday world has been designed with certain tasks in mind. The ways that we can use an ordinary object (sometimes implied by the 'object's affordances') are a direct consequence of the anticipated uses that object designers 'embed' into the object's physical properties. This association is in fact bidirectional: the objects have been designed to be suitable for certain tasks, but it is also their physical properties that constrain the tasks people use them for. As everyday objects are 'enhanced' with a computing and communication capability, the user has to learn the new ways in which they can be used (indicated by designing new affordances) and the tasks they can participate in. This ubiquitous computing paradigm introduces several challenges for human-computer interaction. First, users will have to update their task models, as they will no longer interact with an ordinary but with a computationally enabled object. Secondly, people will have form new models about the everyday objects they use, and thus they may change their habits.

The human-computer interface starts to transcend into the physical world, as computing becomes distributed in objects around us. In such a world, the direct manipulation paradigm will have to include metaphors describing interaction with tangible objects. Unlike some parts of Weiser's vision [1], it may not be appropriate to the nature of many artefacts to have screens added to them, Such an interface approach applies to the more specific category of information appliances, and although it is convenient for interaction, it does not always fit in the nature of objects and environments of the disappearing computer. The design of the object's form and physical properties will also affect the interaction. In fact the design of objects – which constitutes their interface – may have to be reconsidered so that their new capabilities can be promoted to the user (indicated by appropriate elements for the nature of each object). In this broad picture, information appliances as we know them are only a subset of these objects. Current information appliances are often screen-dominated. Yet, the subset of hyper-objects is passing the point of on-screen-feedback (defining the interaction with many information appliances). This can be a challenge for designers; this involves a holistic approach, whereby the tangible interface of the object not only provides for an optimal user-experience, but is also assuming the role of the interface to a larger set of interconnected causes and effects.

8 Meta-issues of use

People can then act upon their environments, be it physical or enhanced ubiquitous computing environments, by setting goals, forming plans and perceiving results. At the cognitive level, the disappearance of the computer forces people to form new mental models about their tasks that involve objects and environments (that now may start to involve using hidden IT capabilities). On the other hand, if the appearance and function of everyday objects/environments change (or new objects appear into our everyday life), then people will have to adapt or form new models of tasks involving these objects [15].

Most objects in our everyday lives have been designed for specific tasks; but this specificity constrains the ways in which we might use them. In general, everyday objects can be used in different ways, providing that the limits of their physical properties are not violated. As everyday objects are 'enhanced' with sensing, computing and

communication capability, to become artefacts, people have to learn any new ways in which they can be used (that may have to be indicated by appropriate new affordances), and the tasks these objects might participate in. People may initially have to use objects in more complex ways. Moreover, people may end up interacting at the same time with individual objects and with their configuration.

Living with and using hyper-objects may not seem easy at first, and may require certain new skills to be developed (including abstractions and models to reason about them). Nevertheless, it may be the case, as it is for example with writing, that once the skill – however complex it may be – is acquired, over time it feels natural, easy and transparent in use [3]. The case of writing is a complex skill; it involves an understanding of the abstraction of sounds into written symbols, recognising these symbols, but also reproducing them, without consciously thinking about the process of doing it. The process of people growing into the skill-set needed for using hyper-objects and their associations can be viewed in the same light as acquiring the mental and kinetic skills for writing, and its relation to oral speech. Nevertheless, people are acculturated to recognise and to use the tangible part of the hyper-object as is, as this knowledge has already been attained through their cultural history.

The introduction of artefacts is expected to affect people's everyday lives in several ways. People may have to change established habits, learn new skills, and form new mental models for the objects and spaces that surround them. Task models may need to be updated, as people will start interacting with hyper-objects (that are capable of participating in many more new and complex tasks) rather than the accustomed ones. The conceptual models people have of objects and of computing may have to evolve for them to utilise the new possibilities offered by the computationally enhanced hyper-objects.

There are several issues to be investigated at this level, which we may call the 'syntactic' level:

- Which is the set of people's actions that artefacts should perceive? How are these manifested into objects' capabilities (expressed via capability-plugs)? How will context affect perception?
- How will people perceive artefacts? What patterns of usage are expected to emerge?
- How can they be designed so as not to contradict our existing models? Is there a general architecture upon which artefacts could be based?

9 What are the benefits?

Why should all the trouble of acquisition of new skills be taken? To do it, people have to see clear benefits from it. Currently, being at the early stages of beginning to understand how to use and what to do with these technologies, the applications that researchers currently come up can be criticised as being uninteresting, of no potential, and of understating the potential of ambient technologies. There are some factors that can be motivating to the use of hyper-objects:

- New tasks and new enhanced services become possible.
- Better response rate in ordinary services, and savings in effort and time in carrying complex tasks can be achieved. Living an ordinary life takes a lot of effort; this can be seamlessly facilitated.
- Particular and special needs of targeted groups can be better met. (For example, fitting the individual needs of young children, elderly, impaired people, or other groups where the applications have clear and strong benefits.)
- Unpredicted niche applications can be made possible, by empowering end-users to act according to their needs and wishes.
- People can initially ignore the difference between objects and hyper-objects. They may begin using hyper-objects according to their habits, while they can gradually grow into using their added digital capabilities. People may choose to use hyper-objects after a time of initial apprenticeship (thus the intrusion of the hyper-object in existing task models will be perceived as low).

Let's also assume that, as is often the case with fundamental technology advances [16], once we get more accustomed to the new medium, people would come up with applications and uses that could not have previously been perceived. Later generations of applications may be nothing close to what we are currently capable of imagining.

10 Conclusions

Hyper-objects may potentially gain a place in our future everyday life. Designers need to aim for a smooth transition in order for people to adopt hyper-objects and embrace their benefits. To be effective in this transition we need to:

(a) Develop or adopt visions on how even the more mundane tangible objects may evolve in future, and what role people may have in this landscape. One such vision supports the role of people creating the ambient applications they want, or altering the pre-constructed ones they are given.
(b) Consider approaches that are scalable. Approaches that cover in their conceptual framework a wide range of objects of different kinds (from a tag to a desk to a house, from service carriers such as heater, TV, light, stereos, to tangible furniture, flowerpots, clothes, carpets, boxes, etc.).
(c) Consider and develop referents between designers, people and artefacts, giving a bridging technological solution (this can lie in middleware, for example).

Acknowledgements We would like to thank Fiona Raby, Tony Dunn, Panos Markopoulos, J. Darzentas and Philips Design (special thanks to L. Goulden, J. Cass, F. Rees, among others) for discussing extensively and sharing with us their vision and inspiration.

References

1. Weiser M (1993) Some computer science issues in ubiquitous computing. Commun ACM 36(7):75–84
2. The Disappearing Computer initiative: http://www.disappearing-computer.net/
3. Sharpe B. Information Appliances, an introduction. Downloadable white paper, downloaded on Jan. 2003 from http://www.appliancestudio.com
4. Rodden T. Closing speech at Ubicomp 2002, Goetenburg, Sweden
5. Markopoulos P et al. Interaction design for home information appliances. PC-CHI 2001, Patras, Greece
6. Holmquist LE, Mattern F, Schiele B, Alahuhta P, Beigl M, Gellersen HW. Smart-Its friends: a technique for users to easily establish connections between smart artefacts. Proceedings UBICOMP 2001, Atlanta, GA, 2001
7. Oxygen project website: http://oxygen.lcs.mit.edu/
8. Accord project website: nhttp://www.sics.se/accord/home.html
9. e-Gadgets project website: www.extrovert-gadgets.com
10. Kameas A et al. An architecture that treats everyday objects as communicating tangible components. Proceedings PERCOM 2003, USA, 2003
11. Mavrommati I, Kameas A. e-Gadgets case description. Doors of Perception 7 @ flow, 14–16 November 2002, Amsterdam. http://flow.doorsofperception.com
12. Markopoulos P et al. Visibility and accessibility of a component based approach for ubiquitous computing applications. CHI International 2003, Krete, Greece, 2003
13. Gaver W (2002) Designing for Homo Ludens. i3 Magazine 12
14. Dunn T, Raby F (2002) Design Noir: The secret life of electronic objects, ed. August/Birkhäuser
15. Kameas A, Mavrommati I. Interacting with ubiquitous computing applications: issues and methodology. Proceedings Panhellenic Conference on Computer Human Interaction (PC-CHI) 2001, Greece
16. Norman D. The Invisible Computer. MIT Press, 1999