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Soft-appliances: A vision for user created networked appliances in digital homes

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Abstract. In this paper we introduce a vision for a new type of domestic appliance, a soft-appliance, constructed from aggregations of elementary network services. The vision is based on the possibility of 'deconstructing', logically, conventional home appliances such as TVs into their elemental functions which may then be combined in novel ways with other deconstructed services to generate soft-appliance of a person's own choosing. Additionally our aim is to describe the computer science challenges involved in fulfilling this vision. An essential component of this vision is a concept called a MAp (meta-appliance/application); a semantic data template that describes the soft or virtual-appliance that can be instantiated by manufacturers and end-users in a way that redefines the nature of an appliance and which can be created, owned and traded. We also present a socio-technical framework to motivate the discussion of this research agenda, especially the use of the agent technology that would be needed to realise this vision.

Keywords: Digital homes, virtual appliances, service aggregation, disruptive technology, future homes

1. The vision

Underpinning the vision for soft-appliances are the plethora of inexpensive embedded computer processors that make it economically viable for common electrical appliances to have computational and networking capabilities. Networking allows previously isolated devices, to coordinate actions in a way that can yield higher-level functions beyond the capability of any single device (Fig. 1).

Consequently, what were hitherto monolithic devices such as televisions can be decomposed into more 'atomic' network services (e.g. 'display', 'audio transducer' etc.) which, could be combined with other services to allow people to re-configure them into novel combinations, forming personalised soft-appliances or 'meta-appliances'.

This same principle of decomposition could be applied to deconstruct monolithic software applications such as word processors into more atomic elements, which could then be recombined to form customised 'meta-applications'.

In the following section, we begin this discussion by introducing the concepts that underlie soft-appliances.

2. Soft-appliance concepts

2.1. Deconstructed appliance model

The process of decomposing traditional appliances into more elementary network accessible functions, together with their reconstruction, is referred to as the 'deconstructed appliance model'.

2.2. Atomic & nuclear functions

The deconstructtion of monolithic appliances creates a number of elementary network services which are referred to as atomic functions. Recombined functions are termed nuclear functions.

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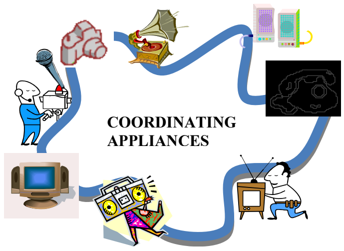

Fig. 1. Coordinating Functions.

2.3. MAps – (Meta-Appliances/Applications)

From a user viewpoint, a MAp is a virtual appliance, formed from sets of coordinating network entities. From a computational perspective, a MAp is a data item, consisting of a set of semantic associations and rules that collectively determine the nature and behaviour of the soft appliance. MAps can be created, owned, traded, by manufactures and end-users in a way that challenges the nature of an appliance and the current market.

3. Scenario

An interesting question for those pursuing the ambient intelligence vision is to what extent agents can contribute to this vision. To help understand this, together with the wider research needs, we present a scenario together with a *socio-agent* framework that better exposes the vision, concepts and issues [3].

3.1. Background

In the not too distant future Tessa moves into her new home and the network was awash with services that are available for her to use. Many of these services are local e.g. lighting, telephone, whilst others are remote e.g. media feeds. Monolithic appliances have, by this time, given way to soft appliances and applications where, for example, the TV, computer and phone all share devices such as the room display. Tessa was able to interact with the environment via her '*proctor*' (programmer-communicator), a smart phone that contained her private preferences and soft-appliance descriptions.

3.2. Soft-appliances and MAps

Although monolithic appliances were now considered old-fashioned, the concept lingered on as people still needed to utilise functions akin to TVs and telephones. Thus all environments had default soft-appliances that functioned as conventional appliances. However, it was also possible for users to both purchase MAps for new soft-appliances or, for creative individuals, to devise their own.

3.3. Mobility (people)

On entering a new environ-ment, Tessa was able to use her '*proctor*' to select MAps which the system would then use to construct the nearest replicas it could. Of course this was not always possible but her '*proctor*' would indicate what was missing so she had the option to borrow, buy or make a failed or missing device.

3.4. Ontology

Stored inside Tessa's '*proctor*' were a number of ontology-based descriptions of coordinating communities of devices that collectively formed the MAp. They defined the membership of the community, the capability of the community and contained the coordination rule sets (i.e. the behaviour of the soft-appliance). One such MAp was her 'com-centre', the description of which defined a community consisting of an audio transducer, a micro telephone exchange, room lighting and mp3-streaming services. An example of one of its many rules was, "on receipt of a call, pause other incoming media streams (she liked music and was generally listening to MP3 files), divert the call to whatever audio-transducer she was using (or was nearest) at the time, and raise the light levels (if it was dark)".

3.5. Mobility (devices)

Whilst staying in the Digital Home, the audio transducer failed. However, Tessa's '*proctor*' was quickly able to offer her a choice of alternatives, and as a temporary solution she chose to use the transducer on her wearable entertainment centre.

3.6. Programming

The original 'com-centre' MAp based soft-appliance simply consisted of a telephone service, audio transducer, micro-exchange and mp3 service. The configuration and rules could be created or altered via an end-user programming (described later). Tessa had modified the MAp to add the light and associated rules.

3.7. New businesses

Whilst Tessa generally only modified existing MAps, there were numerous hobby clubs and even small industries that generated novel and sometimes highly complex MAps which they then traded. Tessa smiled as her ‘proctor’ suggested buying a new networked function that would add functionality to her ‘com-centre’ soft-appliance. The producers of ontology engines had discovered an additional commercial opportunity by linking ontology driven recommendations for new and replacements devices to commercial sponsors!

4. Research agenda

In order to realise the above vision, a number of research challenges need to be addressed which we discuss, briefly, in this section.

4.1. A socio-agent framework

Unlike some areas of science, technology for the digital home has an intimate relationship with people. Homes are among the most private spaces in people’s lives and people take great pride in customising their homes to reflect their individuality and needs.

Therefore this technology cannot be designed in isolation from social factors. It has been argued that user acceptance of technology in personal spaces is linked to perceptions of privacy which in turn is linked to choices based on the technology’s use of agents versus end-user programming [3]. It has also been argued that control and creativity are fundamental human values. Thus there is a need to find a way of categorising the social and technological relationships, and using this to motivate our discussion on the development of the soft-appliance vision (and ambient intelligence in general) ranging from the exclusive use of intelligent autonomous agents, to user-controlled approaches.

For this we have devised a framework illustrated in Fig. 2 in which there is a technical and sociological dimension; the Callaghan-Clarke-Chin (3C) model [3]. The X axis shows the possibilities for configuration from manual (end-user) to automatic (agent based). The Y axis shows user reaction (phobia versus philia) to these different possibilities. The quadrants describe potentially significant positions within this space. A general assumption underpinning this model is the view that the less understanding of, and control over, their environment that people have,

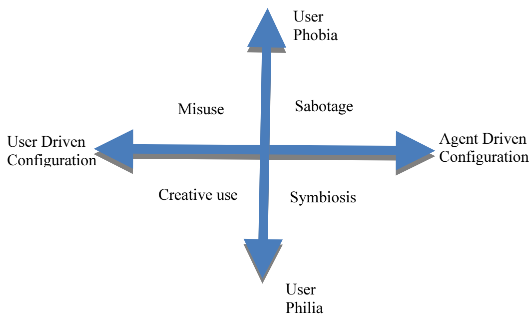

Fig. 2. A Socio-Agent Framework for Intelligent Building Research (3C model).

the more resistant or fearful they will be of it (and vice versa). The model is not normative but depicts a conceptual space of possibilities drawn from experiences with our technological work. A more detailed three-dimensional version of this model, accommodating more finely granulated descriptions of user responses, is provided elsewhere [3].

The 3C model provides a convenient way of beginning to expose the research issues associated with people living in technologically sophisticated environments. In such environments, MAps potentially enable people to decompose traditional appliances into more elementary network accessible functions (atomic functions), thus allowing users to construct a variety of both conventional and novel soft-appliances (virtual appliances). This enables people to be designers of their own ‘electronic space’. This approach is a radical departure from conventional manufacturing practices and requires both manufacturers and their customers to be convinced of the merits of this approach. In part, this is a question of what is socially acceptable; but it is also a scientific question since the challenge will be to create a new technology that can deliver on this vision.

Examples of technical issues include the nature of the hardware, the form of the software, how communities of devices can be formed and managed, how group coordination is programmed, how relationships are described, how the system is maintained and debugged as well as how the system deals with mobility of devices and users. In the following sections we review the state of research in these areas.

4.2. Agent research

One of the key challenges is addressing how a non-technical person can program collectives of decomposed ubiquitous appliances to do their bidding. There are various approaches to solving this

Fig. 3. Creating MAps via physical interaction.

problem. For instance A.I. or agent techniques can monitor, model, pre-emptively configure and control the environment [2,4,7,15,24]. Such agents often employ life-long learning, in which they monitor and record the users habitual behaviour so as to adapt to the changing needs of the occupant and environment. For example by dispensing with learning while retaining reasoning it is possible to build context aware systems in which the interface and functionality can adapt to the context [1,8,9]. Thus, context aware systems tend to be self-adapting rather than user programmable.

4.3. End-user programming

Explicit end-user programming can be accomplished using a variant of Programming-By-Example (PBE) [21] called Pervasive interactive Programming (Fig. 3) [6]. Pervasive interactive Programming differs from PBE in that, firstly it aims at real rather than graphical objects, secondly it is directed at distributed computing rather than a single processor, and thirdly it spawns distributed non-terminating sequence independent MAps (soft-appliances) rather than creating macros or other procedural structures.

A related paradigm, 'task based computing', was pioneered by Wang and Garlan of CMU [32] and Fujitsu [23] which seeks to provide a programming environment that allows users to interact with computing spaces in terms of high-level tasks. In this approach, tasks require similar descriptions to MAps, but task-computing does not embrace the notion of user constructed soft-appliances. Examples of other approaches to programming digital homes includes Media Cubes [16] which offers a tangible interface for programming an environment where each face of a cube is represented by a set of program structures. Specific programming operations are achieved by turning the appropriate face of the cube towards the target device. Humble [18] uses a jigsaw metaphor, enabling users to 'snap' together puzzle-like graphical representations as a way of building applications. Truong's CAMP project [31] places the end-users at the centre of the design experience by using a fridge magnet metaphor, together with a pseudo-natural language interface that collectively enable end-users to realize context-aware pervasive applications in their homes. The Alfred project [13] proposed a macro programming approach to enable a user to compose a program via 'teaching-by-example' using verbal or physical interactions. From these descriptions, it can be seen that methods of programming environments range from highly automated implicit approaches (strong agent involvement) to manual user centred approaches (weak agent involvement). From the 3C model it is evident that these approaches may have very different advantages and disadvantages. Intensive use of autonomous agents has the advantage of reducing the cognitive loading on the user whereas end-user methods empower the user giving them a sense of control over what is recorded, when its recorded and to whom it is communicated.

4.4. Hybrid approaches

Whilst this discussion assumes that the system would be programmed exclusively by either agents, or end user programming methods, the more likely reality is that it would be a hybrid solution, with either technique being used where it is most appropriate. Thus an important line of research would be to investigate which parts of the system users would be happy to leave responsibility to autonomous agents. One way to tackle this might be to adopt a metaphor from a music mixing desk, in which a user could vary the autonomy of differing parts of a system, and see what levels of autonomy versus end-user control real users were happy with (variable autonomy).

4.5. Interfaces

Central to the MAp paradigm is the interface to people. The variable and novel nature of the appliances that users can build provides an additional research challenge to the HCI, as it too needs to be adapted to the needs of the user. In earlier work [27] has been shown that it is possible to build dynamically configured user interfaces to support an underlying pervasive computing environment but their remains considerable scope for research. For instance what is the role of artificial intelligence or agents [14]. In addition to dynamic GUIs, another attractive form of programming interface would be via spoken dialogue. Evidence from projects such as the EUfunded D'Homme [28], showed that dialogue systems offer an easy to use interface to intelligent environments, making it possible for users to issue simple device-control orders. However, simple utterances are severely limited for creating programs that have complex sentence structures and generally need interactive dialogue to seek clarifications to avoid misunderstandings and to provide rich feedback [11,12]. Additionally, another issue is that 'talking to the air', whilst creating MAps is not the most natural form of interface and animated characters could make dialogue interaction more natural [20]. Thus both better speech dialogue and animation could be usefully included in the research agenda for this area.

4.6. Middleware

Additionally, the underlying technical framework needed to support MAps calls for work on architecture and middleware. For example, distributed architectures bring many advantages, such as scalability but suffer from increased programming complexity and sometimes instability [34]. Communication can be conducted via a variety of different network technologies making this a challenging area [30]. Middleware needs to cope with highly dynamic, real-time, semantically rich environments. Ideally such middleware would be adaptive, supporting intelligent adaptation based on continuous monitoring of their environment [10] of the type found in reflective (adaptive) middleware infrastructures [26].

4.7. Ontology

To enable MAps it is necessary for networked entities (both atomic and nuclear functions) to provide descriptions of their capabilities; ontology can provide such a description. MAps leverage ontology semantics as their core vocabulary. Whilst, in principle, middleware could offer such functionality, current middleware such as UPnP falls short of providing sufficient information on the capabilities of network devices [17]. As a result, effort is being expended in developing an ontology as a possible way to provide sufficient information on network devices so as to reason about how they might be synergistically combined [29]. For example, the SOUPA ontology from Ubicomp [5] is aimed at pervasive computing and OWL-S [25] is based around the notion of services but primarily targets the World Wide Web, enabling agents to evoke services thereby facilitating the automation of web tasks.

4.8. Service-oriented architectures

The Web, which is directly related to the emergence of Service-Oriented Architectures (SOA), is a very useful example of an environment with a huge and rapidly growing number of heterogeneous services. Indeed there is much activity relating to composition of services which, whilst somewhat different in nature to soft-appliances, share challenges such as the need for more research on the semantics of deconstructed functions [33].

4.9. Discussion

Whether, this vision for soft-appliances will ever come to fruition is difficult to tell. Manufacturers and consumers will be the ultimate arbiters on this, and only time will be the ultimate judge However, an initial evaluation by Chin of some 20 users, produced encouraging results which suggested that non-technical users liked the concept of designing or adapting their home appliances, and found the methods relatively simple [6]. We have worked with both Intel [19] and British Telecom [22] on aspects of the concept, which we expect will evolve considerably as more research is completed.

5. Summary

In this paper we have presented a vision for a digital home environment in which monolithic appliances (e.g. TVs) are replaced by soft-appliances many of which may be user designed and constructed. However, numerous obstacles need to be overcome before this vision can be realised. Some issues are commercial, several are rooted in the historic nature of appliances, others are relate to user or manufacturer acceptance whilst others are technical. For example the issue of autonomous agents versus end-user programming will be crucial. Finally, whilst this is only a brief overview of the vision and agenda for soft-appliances, we hope it may inspire other people to add to the body of research that will turn this research vision into a commercial reality.

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