

# Moving from Internet Appliances to Internet Intelligent Environments: Challenges and Directions

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## ABSTRACT

Although various research efforts have reported some success in solving difficult problems related to intelligent environments, very little progress has been made in implementing a truly intelligent system in reality. This paper looks at intelligent environments from a networking and connectivity point of view in order to gain a fresh perspective. First, we review intelligent environment qualities and projects so that we may ascertain the current state of intelligent environment research. Next, we present a classification of the essential components of an intelligent environment, and observe that a connectivity infrastructure does exist in the form of a network of Internet Appliances. We also note, however, that the intelligence components necessary for an intelligent environment are lacking. Therefore, we discuss challenges and provide directions for future research so that we can move from a network of Internet Appliances to Internet Intelligent Environments.

## 1 INTRODUCTION

Since the beginning of the computer age, extraordinary predictions have been made about computers revolutionizing our lives. Early predictions were based on the perception that computers could eventually perform the same tasks as humans, and possibly even exceed human intelligence. Although computer performance has significantly increased over the years, many of these predications have failed to materialize due to the difficulty of learning even simplistic human tasks. For example, consider the prediction of intelligent home automation. Widespread automated homes do not exist to date. For most of us, perhaps a VCR that could program itself would be a significant step towards an intelligent home.

Two observations clarify the difficulties with intelligent environment systems. First, an intelligent environment needs to be an intelligent being [Dilger, 1998]. The environment must possess a degree of autonomy, adapt itself to changing conditions, and communicate with humans in a natural way. Second, adaptive software will be necessary for environment automation to become commonplace [Mozer, 1998]. It is unreasonable to assume the inhabitants will want to program the environment in order to customize the behavior, especially if the term "programming" implies traditional computer programming. Traditional approaches to user interfaces and software applications are not appropriate for intelligent environments.

This paper looks at intelligent environments from a networking and connectivity point of view in order to gain a fresh perspective. First, we define the qualities of an intelligent environment and present related research. Next, we provide a classification of the major components of an intelligent environment system. Then, we discuss Intelligent Internet Environments, and we describe several scenarios and associated challenges. Finally, we conclude with recommendations to guide future intelligent environment research.

## **2 CHARACTERISTICS OF INTELLIGENT ENVIRONMENTS**

We begin by discussing common characteristics found in intelligent environments, such as *environment automation*, *natural interfaces*, *multimodal inputs*, *ubiquitous computing*, *aware computing* and *adaptable computing*. These qualities differentiate an intelligent environment from traditional environments, and are discussed below.

?? The goal of any intelligent environment is to automate the usage of the devices within the environment. The system automatically turns devices on and off, directs information to the appropriate devices, and simplifies the coordination of multiple devices. *Environment automation* allows an inhabitant to concentrate on the task at hand, rather than on the devices necessary to perform the task. It is important not to confuse centralized device control with environment automation. We do not consider an environment that only provides device control to be an intelligent environment. Automation is the key characteristic of an intelligent environment.

?? In general, computers do a poor job of supporting our daily activities, because they communicate with users via devices that are suitable to the computer. Unfortunately, the commonly used WIMP (windows, icons, menus, pointer) interface is exactly what

limits the usefulness of a computer. The paradigm is not an acceptable form of human-computer interaction for future computing environments [Turk, 2000]. In an intelligent environment, Human-Computer Interfaces (HCI) should be *natural interfaces* designed for the human inhabitants and not for the computational system. Spoken language and human behavior should be used to communicate with the system, rather than pointing and clicking. A computational system should perform tasks in support of the human occupants naturally and non-intrusively. The goal of current HCI research is to remove the barriers of traditional computer interfaces. To date, almost all computer interface effort has concentrated on graphical user interfaces (GUIs). Work on the next generation of interfaces, namely Perceptual User Interfaces (PUIs), investigates techniques that seek to make natural interfaces by understanding how people interact [Turk, 2000].

- ?? The term *multimodal* is often used when discussing intelligent environments, because completely understanding an environment requires multiple sources of input. Multimodal interfaces can interact naturally with a user by using voice, hands, and even the entire body as communication devices. In a multimodal system, two or more sources of information are fused in order to reduce uncertainty [Oviatt, 2000]. An intelligent environment will be rich with devices, and thus must process multimodal information.
- ?? An intelligent environment requires *ubiquitous computing*, which is distributing the computation and network capability into the environment while also providing natural interfaces [Abowd, 1997]. Ubiquitous research concentrates on techniques that limit the intrusion on the physical environment. For example, furniture does not have to be "wired" in order to detect the presence of an occupant. Instead, vision and detection algorithms could be used to identify, locate, and track an individual. Ubiquity is the idea that the environment must be able to process information *as if* computational devices were everywhere, rather than actually embedding devices everywhere. It has been proposed that ubiquitous computing is the third wave of computing, following mainframe and desktop computing [Weiser, 1996].
- ?? A concept closely related to ubiquitous computing is *aware computing*. A system is provided knowledge about the user and environment in order to identify users, determine their focus of attention, and ascertain their intentions [Abowd, 1997]. The combination of ubiquitous and aware computing allows an intelligent environment to react to the desires of the inhabitants.