

Who is in Control of Intelligent Environments? A Question of Autonomy

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ABSTRACT

There are many arguments for and against the use of autonomous-agents in intelligent environments. Some researchers maintain that it is of utmost importance to give complete control to users, and hence greatly restrict autonomy of agents; whereas, others believe that it is preferable to increase user convenience by allowing agents to operate autonomously on the user's behalf. While both of these approaches have their distinct merits, they are not suitable for all users. As people's opinions and concerns regarding agent autonomy are highly individual, depending on a wide range of factors and often changing over time, a much more dynamic approach to agent autonomy is needed.

Keywords

Intelligent environments; agent autonomy; adjustable autonomy; pervasive computing

1. INTRODUCTION

As the computing systems we interact with in our daily lives become increasingly complex, intelligent and pervasive, they become more and more difficult for the every-day user to monitor, understand and manage. Hence, many researchers seek to employ autonomous-agents in their systems to assist the user in dealing with the information and work overload [1]. However, the use of autonomous-agents in pervasive computing and intelligent environments can engender fears of creating some notion of 'Big Brother' being able to monitor our every move and know all of our personal interests, as in the famous book *Nineteen Eighty-Four* by George Orwell [2]. Hence, many researchers in intelligent environments take the stance that the use of autonomous-agents should be greatly restricted, and instead the end-user should always be given complete control over all systems. In these end-user driven approaches, it becomes the responsibility of the user to govern the intelligent environment, although the user of the system may not actually have any knowledge of computer programming nor any technical knowledge of the system. These end-user driven approaches usually adopts a simplified interface to enable the end-user to configure the system and program

behaviour rules to automate the environment more easily, as in [3]. In most situations, producing a system that empowers the user might seem the logical choice; however, problems can arise in an end-user driven system since the intelligence and adaptability of the system depends heavily on the creativity, intelligence, willingness and ability of the user. In these situations, autonomous-agents can be very useful as they are designed to operate on the user's behalf and greatly increase user convenience in managing the intelligent environment. In high level terms, autonomous-agent driven intelligent environments employ artificial intelligence and machine learning mechanisms to learn from the user's behaviours and interactions with the environment, and configure the system and create automated behaviours in an appropriate way, as in [4].

Although both autonomous-agent driven and end-user driven approaches have their distinct merits, neither are suitable for all people in all situations. Hence, many researchers in pervasive computing are beginning to recognise the need for a hybrid approach to the problem of governing the system that allows both agents and users to work in collaboration [5]. To take this a step further, some researchers are investigating how it's possible to take a more dynamic approach to agent autonomy and create adjustable-autonomy systems that allow the user to find their own personal sweet-spot between the convenience of agents governing the system on their behalf and the importance of maintain direct control over the system [6].

2. AGENT AUTONOMY IN INTELLIGENT ENVIRONMENTS

At the University of Essex, an online survey was recently conducted, which aimed to investigate people's opinions of the use of autonomous-agents in intelligent environments [6]. As a follow up to the online survey, a working adjustable autonomy intelligent environment was implemented and a series of user trials conducted, which aimed to gain deeper insights into the reasoning behind people's attitudes of different levels of agent autonomy and explore how using adjustable autonomy can change people's opinions of intelligent environments [6]. The results showed that people have many different concerns when it comes to ambient intelligent systems and their attitudes towards autonomous-agents are highly individual and differ greatly between people. Furthermore, the results strongly indicate that different people may prefer different levels of autonomy in different situations and for different sub-systems of an intelligent environment, plus their views may drift over time (e.g. as they learn more about consequences of using the technology). There

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are many factors and concerns of users that determine their attitudes and preference towards autonomy in intelligent environments. These studies have highlighted the issues of control, privacy, cognitive workload, reliability of the agent, and cost of failure as the most paramount [7].

Control: feeling in control over what happens in the environment was one of the biggest concerns of the participants. Many expressed concerns relating back to awareness of what's happening in the system when using agents with full autonomy. However, it was found that people's concerns of control were greatly reduced if the agent's autonomy was restricted so that a user had the change to confirm agent decisions before they were carried out. The participants preferred this as the agent had to "put it in writing first" and hence they maintain direct control over the agent.

Privacy: people's homes are perhaps the most intimate and personal environments in our lives; it follows that people would want most if not all of their activities in the home to be kept private. It was found that many people's privacy concerns were eased somewhat with the inclusion of the adjustable autonomy mechanism as this gave the user the ability to stop agents from monitoring parts of the environment (by switching the agent to no autonomy). Although, there were some that still feared others having external access to their personal data even with agents operating with no autonomy; for example, one experiment participant said they would be worried if the government could access the data and how it might be used, or rather misused as in Orwell's Nineteen Eighty-Four [2].

Cognitive Workload: the vast majority of those that took part in the studies did recognise the benefit of using autonomous agents and could see how it potentially could reduce the cognitive load placed on them in governing the intelligent environment's rule-based system. Many identified agents with high autonomy as being especially useful for people with a "busy life style". Conversely, many were concerned that the agent was "clumsy" or would simply be unable to learn from their behaviours and daily routines, and hence felt that allowing an agent full autonomy may in fact mean they repeatedly have to correct the agent's mistakes, which would increase their mental workload and greatly decrease the convenience offered by the system.

Reliability: Along with control, this was also one of the biggest concerns expressed by the participants. As previously mentioned, many doubted the ability of autonomous-agents to recognise their more complex behavioural patterns, which depend more on personal feelings and mood. Hence for activities such as control of entertainment and media devices it was found that many would prefer to set an agent to low or no autonomy and maintain more direct control over these devices; however, for devices such as lighting and air conditioning, quite a few said they would rather allow agents to have higher autonomy as they felt the usage of these devices is more 'routine' depending more simply on the time of day and/or state of the environment. It should also be noted that many said they would give the agent a chance to prove itself, and if it could perform well in handling these more complex tasks then they might assign it more autonomy.

Cost of failure: it was found that the perceived cost of (erroneous) decisions and actions is heavily dependent on the type of device being controlled. For example, in the user trials it was found that many people wouldn't mind giving control of air conditioning and lights to an agent as the usage of these devices is generally not too

delicate or sensitive, hence it doesn't matter too much if an agent makes mistakes. With the curtains, however, many did not want to give too much autonomy to the agent as they would be worried that the curtains could open unexpectedly at inappropriate times.

With such an array of mixed opinions, which often change over time, these concerns in fact go far beyond the perception and understanding of the system designer. Hence there is a real need to employ adjustable autonomy mechanisms in intelligent environments, which allow a user to explore the trade-off between convenience of higher autonomy and control of lower autonomy and to find their own personal sweet-spot, and alter it at a later date if they see fit.

3. CONCLUSION

There is a long-standing debate over the use of autonomous-agents in intelligent environments. While many believe that research should focus on developing end-user driven systems, seeking to empower the user, many others maintain that intelligent environments should be autonomous-agent driven, minimising the work and effort required from the user. Both of these approaches have their distinct advantages, but they are not suitable for all. Intelligent environments can be made more dynamic and personalisable by equipping them with adjustable autonomy, which allows the user to alter the amount of influence autonomous-agents have over managing their intelligent environment. A recent online survey and user study was conducted to gauge people's opinions on the use of autonomy in intelligent environments. Some of the key factors and concerns of users that determine their personal preferences towards different levels of autonomy are control, privacy, cognitive workload, reliability of the agent, and cost of failure. Given the sheer diversity between these variables, there is a real need to employ adjustable autonomy in our agents for intelligent environments, so that a user is able to explore the trade-off between convenience of high autonomy agents and control of using lower autonomy agents and to find their own personal sweet-spot, rather than the decision being left to the system designer.

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