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Group preference modeling for intelligent shared environments: Social welfare beyond the sum

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A B S T R A C T

Ubiquitous computing technology can be effectively utilized in shared environments where groups of people are in close proximity. Shared environments are pervasive in the real world and hence the way of managing such environments will impact on not only quality of life but also business competitiveness. However, making decisions in an intelligent shared environment is never straightforward. The intelligence needs to be capable of choosing its parameters to satisfy all of its inhabitants, who have different preferences and are heterogeneous in their influences on decision. Till today, there has been no thorough research to scientifically investigate this type of decision making problems, though many systems have been already deployed. This research proposes a methodology for making decisions in such circumstances. The current and future works addressed in this paper are also conductive to any human-centric networks such as service systems, since the issues addressed here are also essential constitutes of such human-centric networks.

1. Introduction

Applying ubiquitous computing technology to shared environments will significantly improve our quality of life, but a number of challenging issues need to be addressed which are so far partly understood. Ubiquitous computing is a vision that our natural surroundings will adapt to the people by autonomous interactions between invisible embedded computers [43]. Such intelligent environments are becoming realized as a result of miniaturization of electronic devices, increase in connectivity, and decrease in cost. When a user is identified as an inhabitant of an environment, his/her preference model is transferred to and managed by the intelligence of the environment, in order to better suit the inhabitants through adjustable parameters available within the environment such as temperature, lighting, and background noise [1,2,39,42].

However, though most applications of ubiquitous computing focus on how these capabilities will affect an individual's interactions with the environment, this technology can be effectively used in shared environments where groups of people are in close proximity [26,27]. In fact, many environments are often shared by groups rather than exclusively occupied by individuals. For example, in MusicFX [28,33], people in a fitness center listen to the same music and a music genre is selected based on individual music preferences. Similarly, in many ubiquitous computing applications such as iROOM at Stanford University [41], BlueBoards at IBM [37], Google Home [31], EasiShop [19], and DigitalBeing [13], a need for considering

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the preferences of people currently participating in those applications arises. Shared environments exist everywhere in our everyday life and hence the way of managing such environments will largely determine the resultant utility added by the ubiquitous computing technology.

Accordingly, during the past few years several intelligent shared environments have been designed for diverse items such as music and movie [7,8,26–28,32,33]. However, the intelligent shared environments raise a number of issues, which are caused by the fact that people have different preferences. It would never be possible to satisfy all the individuals in a shared environment at the same time. Here, the first and the most fundamental issue is how to aggregate individual preferences into a group preference on which the decision is based [12,16]. One can imagine diverse forms of the aggregate function. However, in spite of the diversity, there has been no thorough research to evaluate potential aggregate functions, though many functions have been already deployed in shared environments. The second issue is how to incorporate social influence structure in aggregating preferences. Individuals in a shared environment are heterogeneous in reality, i.e. they have different influences on the decision [22]. For example, it would be more reasonable to listen to the opinion of a pregnant woman rather than a healthy man when choosing room temperature.

The solutions of these two issues are essential constitutes of any intelligent shared environment. Till today, there has been no thorough research to scientifically investigate these critical issues, though many systems have been already deployed. This research investigates basic sciences behind the decision making in intelligent shared environments. We redefine the goals of intelligent shared environments by borrowing the principles of social welfare functions from social sciences. As a result, this research creates a new pathway to the decision making in intelligent shared environments and the results of this research can easily be migrated to other human-centric information networks. Shared environments exist everywhere in our everyday life and hence the way of managing such environments will largely determine the resultant utility added by the ubiquitous computing technology.

The remainder of this paper is organized as follows. After providing the background of this research in Section 2, we introduce social agreeability and social welfare functions in Section 3. We evaluate alternative aggregate functions in Section 4 and provide the methodology of incorporating social influence structure in Section 5. Finally, we conclude our work in Section 6.

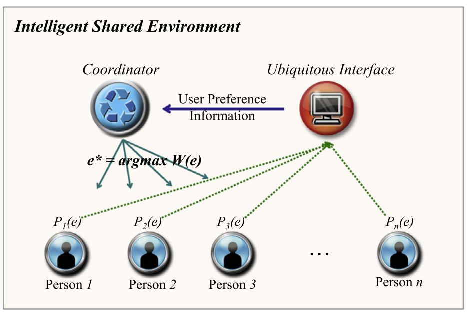
2. Background

The notion of intelligent shared environment is depicted in Fig. 1(a), in which there are a set $\boldsymbol{E} = \{e: e \in \boldsymbol{E}\}$ of alternative environments and a set $\boldsymbol{A} = \{a: a \in \boldsymbol{A}\}$ of inhabitants. Each inhabitant a is equipped with a ubiquitous computer with the knowledge of the individual's preference $P_a(e)$ for each alternative environment e. An intelligent coordinator communicates with the ubiquitous computers of inhabitants through an interface, in order to choose one of alternative environments such that the value of a certain aggregate function $W(e) = f(\{P_a(e): a \in \boldsymbol{A}\})$, is maximized. For example, consider preferences of three people for two alternative environments $\{e_1, e_2\}$ as shown in Fig. 1(b). When we use average for the aggregation, alternative e_1 will be chosen since it gives 8/3 while alternative e_2 gives 7/3.

This framework is applicable to various shared environments that can be found around us. For example, a school bus is an environment shared by many passengers. There exist many adjustable parameters such as temperature, brightness, and music volume, each with multiple levels resulting in possibly hundreds of alternative environments. It is obvious that individual passengers will have different preferences for each alternative and hence the school bus needs to provide the best one taking into account the preferences of passengers.

2.1. Aggregate functions in literature

Due to the lack of common consensus, the designers of intelligent shared environments have offered various aggregate functions. Table 1 shows a brief summary of the functions found in literature. Average function averages individual



(a)

Preference \ Alternative (e)	e_1	e_2
$P_1(e)$	1	2
$P_2(e)$	3	3
$P_3(e)$	4	2
Aggregate value, $W(e)$	**8/3**	**7/3**

1: really hate, 4: really like

(b)

Fig. 1. Architecture of intelligent shared environments.