Proactive Scheduling for Situated Displays

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1. Introduction

This work builds upon a vision of situated displays as public, shared, networked, and pro-active devices that are embodied into their environment and reflect the information and the interactions associated with that environment and the people on it. Such situated displays should enable new and more engaging user experiences by sensing their environment, giving users a more active role in the system behaviour, and providing people with brief encounters with information that is relevant for their specific situation. A scheduling function that determines what is displayed and when is a central feature for any multi-purpose display system, and the idea that a situated display should be adaptive implies that such scheduling decisions are made dynamically, taking into account the recent and current state of the system and its environment. Therefore, instead of setting a detailed timeline that defines exactly what is going to be presented and when, the behaviour of a situated display should be defined in terms of a long-term scheduling policy that that defines rules for how the scheduling process should adapt to the varying circumstances of its operating environment. Even though it is impossible to determine exactly what would be the most relevant content to be presented in a particular context to a particular group of people, we can significantly improve the utility of what is displayed by introducing even small and simple adaptation mechanisms.

However, even though this concept of maximising utility seems an intuitively natural one, the formalisation of the notion of utility, and consequently the realisation of specific scheduling criteria, is clearly much harder. Firstly, there can be many different and conflicting conceptions of utility associated with the various stakeholders, i.e. display manager, people in the environment or an advertiser. Secondly, the impact of context variables in utility is far from being obvious and intuitive. Finally, there is usually very little information about the people that are sharing the environment of a situated displays and their specific interest. This type of smart behaviour also raises several research challenges related with pro-activity, adaptation, context-awareness and machine learning that form the core of this work.

2. Problem definition

We can define the objective of this work as a scheduling problem in which a potentially very large and diverse set of jobs is competing for display time, with our goal being the maximisation of the overall utility of the system.

We define the concept of presentation job, or simply job, as an atomic schedulable unit of presentation. A certain number of jobs are associated with a display but only one can be selected at any particular time.

We define the concept of behaviour as a high-level definition of the system in the form of basic layout definitions and the identification of the presentation jobs that are going to be associated with the display. We assume that either the display has a single presentation region or jobs are pre-allocated to any sub-regions that may exist. For each job, a number of constraints, triggers, and context sensitivity rules can be defined, together with attributes that determine the expected frequency of their selection and possibly the circumstances in which the respective content would be more useful. More than a detailed scheduled, a behaviour should be seen as a sort of genetic code that determines the nature of the system, but not exactly what it will do. In the end, the behaviour exhibited by the system will also depend on the influence of the environment in which the system is operating.

The environment will provide a number of stimulus that will affect the system behaviour. When considering which dimensions to include in the definition of that environment, we have identified the following dimensions.

Dimension	**Overview**
Environment Context	Context refers to the overall state of the environment where the situated display is integrated. This may include the time, nearby people or current weather. The display may be equipped with sensors and be able to acquisition various types of context information. Changes in context can then be transmitted over the system components and be reflected on jobs utility function and context constraints.
Identification	Identification corresponds to the ability to identify the presence of unique entities, e.g. the presence of a specific Bluetooth device, the recognition of a specific tag, the reception of an SMS from a particular number. Entities may or not have associated profiles.
Job Relevance	Job relevance is a self-measure of relevance provided by the job and its calculation must reflect the nature of the job and its information. For example, the relevance of an RSS feed may rise/when it is updated and then slowly decrease as it approaches its expiry time.
User Hints	User hints are user interactions that can be used infer interest in some type of application. A user hint is not traceable to any specific activity and therefore cannot be interpreted as a measure of success for any activity. Examples may include a content request, the submission of new data for publication.

Finally, certain presentation jobs may solicit user actions. We refer to those user reactions as actionables. They differ from user hints in that they can be traceable to a specific job and thus used as feedback about the success of that job. Examples of actionables may include an SMS that responds to a specific solicitation, the collection of a specific voucher that was displayed, the download, e.g. by IR or Bluetooth of some information being advertised, or a mechanism for explicit user feedback in which users are able to classify the relevance of what is being shown. Actionables are particularly important because they represent the only type of feedback about the performance of the system.

3. Scheduling Model

We will now describe our model for approaching the previously describe scheduling problem. It is important that the objective function represents as close as possible, the appropriateness and usefulness of each job considering the context of presentation and potential users. To describe the expected utility obtained by scheduling a job we use Multi-Attribute Utility Theory (MAUT).

According to MAUT, the overall expected utility *EU(job)* of a job *job* is defined as a weighted addition of its evaluation with respect to its relevant value dimensions.

$$EU(job) = \sum_{i=1}^{n} w_i \times d_i(job) \qquad \text{Equation 1}$$

Where d_i is the evaluation of the job on the *i-th* dimension, and w_i the weight determining the impact of the *i-th* value dimension on the overall evaluation, with

$\sum_{i=1}^{n} w_i = 1$. The vector of weights w_i can be seen as the genetic code of a scheduling process, since it is going to determine how the scheduler if affected by the surrounding environment.

Considering the above equation, the scheduling process will essentially select the job with the highest utility at the time of selection. The inclusion of dimensions associated with previous presentation frequency can be used to avoid the successive selection of single job. To support our approach we use a model as shown on figure 1.

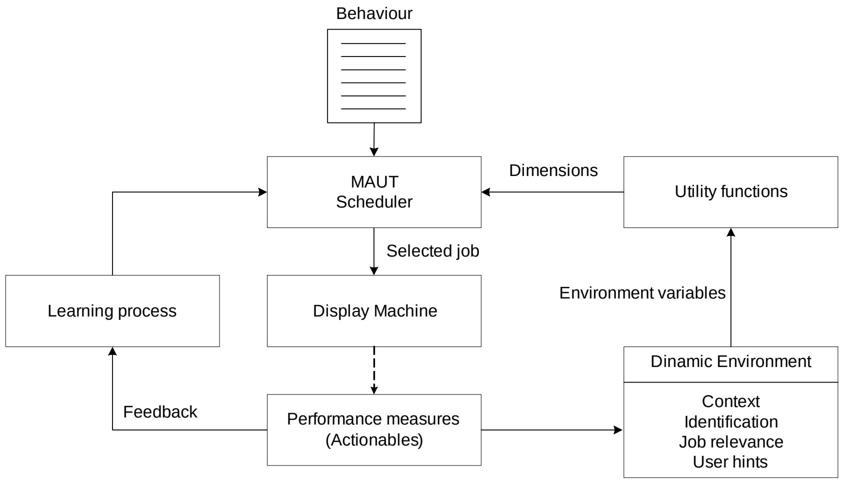

Figure 1 – A model for maximizing utility of situated display system

The MAUT Scheduler is responsible for scheduling the next job. If there are no explicit user interactions, the scheduler selects the job with the highest utility at the ready state. When an user interaction occurs or a job originate an extra request for presentation, the scheduler must analyze this that in some cases may led to pre-emption of the job actually scheduled.

Utility functions calculate the value of each dimension by mapping between a particular environment variables and the way how that variable affects the utility of the system.

The Learning Process can build on performance measures to improve the system behaviour over time. The main goal of this stage is to include the users' reactions to the scheduled jobs on the utility of the next jobs to be schedule. Typically some common patterns can occur derived by users' requests or users' feedback to past schedules. This information allows scheduler to learn with past users' behaviours and habits and can be used to influence the utility of the next schedulings. In this model we are only considering actionables as the input for the learning process, since they are the only event that can be linked to a particular scheduling decision. This may result in an adaptation of the initial weights associated with the various dimensions, in order to increase the importance of the dimensions that correlate more with successful selections.

4. Conclusion

We present an approach to improve the usefulness of situated displays systems. Our approach is based on expected utility obtained by presenting each job. We use MAUT to specify job utility and we use a context-aware scheduling to select the most relevant job. Next we intend to evaluate our system in way to improve our model and compare our results with different approaches.