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Reinforcement learning for dynamic multimedia adaptation

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Abstract

In this paper we present an integration of several user and resource-related factors for the design of dynamic adaptation techniques. Our first contribution is an original reinforcement-learning approach to develop better adaptation agents. Integrated with the content, these agents improve gradually, by taking into account both user's behaviour and the usage context. Our second contribution is to apply this generic approach to solve an ubiquitous streaming problem. Mobile users experience large latencies while accessing streaming media. We propose to adapt the streaming by prefetching and to model this decision problem by using a Markov decision process. We discuss this formal framework and make explicit reference to its relationship with reinforcement learning. We support the benefits of our approach by presenting results from simulations and experiments.

Keywords: Multimedia adaptation; Reinforcement learning; Markov decision process; Ubiquitous streaming; Prefetching policies

1. Introduction

The ubiquitous access to multimedia services is facing an increasing amount of heterogeneity in devices, networks, content and users' preferences. Enabling transparent use of multimedia content (anytime, anywhere and anyway) therefore requires the intermediate help of adaptation techniques. These techniques usually adapt the multimedia

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content or the delivery mechanisms according to terminals' capabilities, networks' conditions and user' preferences. Far from previous Internet or TV paradigms, the emerging use cases are further complicated by the dynamic nature of ubiquitous communication and interactive services. Hence the aforementioned adaptation techniques must be dynamically designed to deal with the variability of each usage context or environment.

The description or modelling of such a "usage context" is a major issue of the current research in adaptation within several research communities. Sometimes limited to content transcoding in the past, the resource-based adaptation now integrates the user profiles and preferences in their framework (e.g. the usage environment description of MPEG-21 DIA, Timmerer and Hellwagner, 2005). In addition, the user-modelling based personalization provides adaptation not only to user-models but also to the properties of available devices and network conditions.

All these adaptation mechanisms integrate widened usage contexts which are characterized by great unpredictability in the ubiquitous multimedia field. Two unpredictability sources can be illustrated. By nature, a nomadic user of a multimedia service with a limited terminal and varying bandwidth will experience an unpredictable execution environment. This unpredictability doubles if the service becomes interactive with random access to online content. Both types of uncertainty, those coming from the user as well as those from the available resources require dynamic adaptation techniques but it is no longer clear that they must be treated independently with separate mechanisms: "resizing an image for a user who will not scroll down to see it" is not relevant. Confronting all these numerous uncertainty sources on one hand, and the multitude of possible adaptation mechanisms, on the other hand, we are considering the question of how to dynamically choose among or compose these mechanisms.

We try to answer this question in an original manner by proposing a closed-loop recipe:

- observe the user's behaviour rather than presuming it;
- define performance criteria (possibly linked to available resources);
- learn adaptation strategies that maximize these criteria;
- enrich multimedia content with adaptation agents that are updated as and when the content is used (then we get back to the first point).

In this sense, we argue the case for an intelligent integration of several user-based or resource-based factors to design dynamic adaptation techniques. The key idea of our approach is to map this closed-loop proposal in the reinforcement learning (RL) framework. Reinforcement learning is a very successful computational intelligence method investigated or simply used in several fields (AI, robotics, networking etc.).

In the following sections of this paper we first review the related research (Section 2). Then we introduce our first contribution in the third section: an original approach to dynamic adaptation by RL. Three illustrative adaptation problems are briefly discussed. In Section 4 we make the link between RL and Markov decision processes (MDPs). Among the three problems considered in Section 3, the adaptive streaming problem is detailed in Section 5. We show in this paper that this problem can be modelled in a very elegant way by using a MDP. We then bring a second contribution by deriving optimal and adaptive prefetching policies (Section 6). Some experiments validate these ideas before concluding and listing possible avenues for further work.