Abstract

One of our goals when building the University of Michigan Digital Library (UMDL) was to provide an architecture for a digital library that can continually reconfigure itself as users, contents, and services come and go. This has been achieved by the development of a multi-agent infrastructure with agents that buy and sell services from each other using our commerce and communication protocols. We describe the protocols, services and agents that embody the UMDL Service Market Society (SMS).

1 Introduction

A library serves a community of users by making available information content and services that are valued by that community. A traditional, physical library is thus not simply a building that houses information, but rather a complex configuration of information goods and services that have been carefully selected and organized around the needs of a user community.

In a digital library, the content and services are electronically available, and user communities are no longer geographically defined. Realizing a digital library therefore includes difficulties in digitizing contents, computerizing services, and networking users together. But even if these difficulties are overcome, the result can well be an overwhelming tangle of possible information sources without the structure and selectivity that renders a library navigable. In other words, if the administration of a traditional library is challenging, the administration of a digital library can border on the impossible due to the magnitude of content and services available, the rate of change in what is available, the size of a user population that is not bounded by physical proximity, and the evolving nature of that population.

One answer to this challenge is to rely on traditional methods of putting administrators at the center of the endeavor, to attract, register, and track a user community, to seek and include the content that will benefit the community, and to provide the most valuable services for tasks such as organizing, searching, abstracting, and disseminating the content. An alternative approach, however, is to move as much of the administration into the digital infrastructure as possible. The goal is to provide mechanisms by which a digital library can continually reconfigure itself as users, contents, and services come and go. These mechanisms should encourage: Flexibility: They should be able to embody a wide variety of policies to realize different flavors of libraries (public, corporate, university, personal, . . . ) Extensibility: Providers and consumers of information goods and services should have incentives to join the library and abilities to find their counterparts. Scalability: As the plethora of users, goods, and services grows, the underlying, computerized administration of the library should not bog down.

Toward this end, the University of Michigan Digital Library (UMDL) is structured as a collection of agents that can buy and sell services from each other using our commerce and communications infrastructure. While one of the emphases of the UMDL is to provide a working testbed to improve secondary education [1], a second emphasis is on the definition and design of the infrastructure, and the kinds of agents that exist in it, that allow decentralized (scalable) ongoing configuration of an extensible set of users and services. We refer to the services/protocols offered by this infrastructure as the Service Market Society (SMS).

2 The Service Market Society

The UMDL SMS implements a market-based multi-agent system where agents buy and sell services from each other. Agents can be added to or removed from the system at any time. Instead of having to rely solely on internally designed agents, UMDL can attract outside agents to provide new services. These agents in turn are motivated by the long-term profit they might accrue by participating in the system.

The raw resources of a digital library consist of collections of information, where a collection might be a database of journal articles or it might be a collection of related web pages. Collection Interface agents, (CIAs), provide access and search services for these collections. Various middlemen, or mediator agents, transform the raw information resources into finished products or services which the end-user desires. Users, or library patrons, each have an individual User Interface Agent, (UIA), which interacts with UMDL agents on their behalf to acquire these services.

Figure 1 shows a simplified scenario, with less agent instances than we normally have. In this scenario, users want to find sources of information for various topics (e.g. history,
CORBA objects, see [1] for details. A final agent, the Price Monitoring Agent (PMA) monitors the price of query planning services and spawns/kills QPAs as necessary. The price in this auction reflects the load on the QPAs. One way to reduce the load is to replicate QPAs. When the load is reduced, the price should come down. Our experiments show that the PMA, given reasonable bounds for the prices and activity of the agents, was able to keep the price within the given price bounds.

The agents are free to return services of differing qualities or to disagree on the exact quality of a given service. Therefore, agents might also need to be able to assess the quality and value of a service received or the exact price to charge, in order to maximize their expected value/profit. This is achieved by giving agents the ability to learn and make strategic bids. Our experimental results with learning agents show that the UMDL SMS benefits from the existence of agents with the capability of keeping deeper models and of looking out for their best interests. Agents are encouraged to model others because this can bring them higher profit. However, there is also a computational cost associated with modeling, along with decreasing returns as other agents also start to build models. This means that the SMS will likely evolve to a point where some agents build models, some of the time. This is a great scenario because it gives us a very robust system (i.e., one that can not be sabotaged by deviant agents), while using few resources for this purpose and distributing these resources among the agents.

In summary, the UMDL SMS is flexible enough to encompass a wide variety of pricing/use policies while still maintaining robustness. Its design also supports the extensibility of the UMDL via the addition of new agents, without slowing down the system.

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References