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A reputation-based model for mobile agent migration for information search and retrieval

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ABSTRACT

Mobile agent technology has been used in various applications including e-commerce, information processing, distributed network management, and database access. Information search and retrieval can be conducted by mobile agents in a decentralized system. As compared with the client/server model, the mobile agent approach has an advantage of saving network bandwidth and offering flexibility in information search and retrieval. In this paper, we present a model for mobile agents to select the most reputable information host to search and retrieve information. We use opinion-based belief structure to represent, aggregate and calculate the reputation of an information host. Since reputation is a multi-faced concept, our approach first allows the users to rank each information host's quality of service based on a set of evaluation categories. Then, a comprehensive, final reputation of the host is obtained by aggregating those specific category reputations. To recognize the subjective nature of a reputation, the transferable belief model is used to represent and rank the category reputation. Experiments are conducted using the Aglets technology to illustrate mobile agent migration.

1. Introduction

Retrieval of useful information has become challenging as the amount of the information available on various sources continues to grow (Akuma, Iqbal, Jayne, & Doctor, 2016). As an example, when searching for information on the Web, there is a considerable delay using search engines, the quality of the results is in general poor, it is difficult to access the appropriate information, and the overall costs for complete satisfaction of the users' needs are considerably high (Gehmeyr, Muller, & Schappert, 2006). In general, it requires significant amount of time and resources to acquire relevant and accurate information (Iqbal, Grzywaczewski, & Chang, 2016). Therefore, systems and tools are needed to efficiently identify, collect and retrieve information that users need. Mobile agent technology has been proposed as an approach to search and retrieve information in a decentralized information system.

Mobile agents are software programs that can migrate to multiple locations in a network of distributed machines or on the Internet. As they travel, those mobile programs perform designated work on behalf of the users, such as collecting information, processing information, and delivering results back to their origins. Programmed with a level of intelligence, mobile agents act on one's behalf with features of autonomy, learning ability, and mobility (Singh, Gulati, & Niranjan, 2012). When a mobile agent is created in a user host, it is released and moves to a specific destination. When it reaches the destination, it is installed to an agent execution environment and starts its executable parts. After accomplishing its designated tasks, a mobile agent delivers the results back to the sending host. Then, it may move to the next host for further tasks or dispose itself once its mission is fully fulfilled. In addition to mobility, mobile agents are social and goal-oriented. They can cooperate with each other to complete complicated tasks in a group environment.

Mobile agent technology has been applied in various fields. In E-commerce, mobile agents are deployed to various retailer sites to help the customers in finding the best products, for example. A summary report is returned where a customer can see the prices for those products on different retailer sites and consequently picks a choice which is then directly sent to the chosen retailer. Mobile agent approach significantly eases the burden for the customers to find the best price and helps to compare prices and other product features based on collaborative filtering (Naik, Tarihal, Swami, Purandare, & Adike, 2013). A mobile agent may even act as a seller, buyer, or trader of goods and other items on half of a user (Funfrocken & Mattern, 1999). Mobile agents also play an important role in developing personalized mobile services (Lee, 2007). Furthermore, mobile agents have been applied to network monitoring and diagnosis, manufacturing and

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scientific computing. For example, mobile agents can be deployed to manage a large heterogeneous network in such functional areas of network management as performance, configuration, accounting, and fault management (Kona & Xu, 2002). In terms of performance management, mobile agents can be programed to gather statistic about network traffic and schemes to condense and present data. Using mobile agents to manage network has several advantages as compared with the traditional management techniques including the flexibility of analyzing the managed nodes locally (Kona & Xu, 2002).

One major application of mobile agents is information search and retrieval. In a decentralized system, mobile agents travel to remote sources of information and work locally in searching and retrieving information of interest. Instead of moving large amount of data to the querying host, a mobile agent searches indexes and processes the queried data on the information provider site. The processed results can later be shipped back to the origin. Mobile agent can continue the information retrieval work even when the network links to the querying host go down (Naik et al., 2013). Examples include information retrieval from electronic calendars for multiparty event scheduling (Glitho, 2002), search engines on yellow page to locate the servers that may contain a piece of information of direct interest to the hosting user (Brewington et al., 1999, Chap. 15), information search to aid in personalizing weather forecasts (Johansen, 1998), retrieving information needed to make a medical diagnosis (Smith & Paranjape, 1999), and providing medical and fetal monitoring services to patients in an eHealth information system (Germanakos, Mourlas, & Samaras, 2005; Su & Chu, 2014; Bagga & Hans, 2015). Mobile agents have also been used to access distributed database (Papastavrou, Samaras, & Pitoura, 2000).

Mobile agent technology for information search and retrieval is especially useful in a decentralized, open system such as a peer-to-peer (P2P) system. In our discussion, an open system includes any distributed systems with a set of independent participants sharing resources. Those systems are self-organized by participants based on mutual interests. They typically do not have a single administrative authority and members join and leave at any time. Resources are shared in a controlled and accountable manner and decisions to offer and consume resources are made by each participant. P2P system is a decentralized system for sharing data among users in an open community. In such a system, data are managed by individual peers and information retrieval mechanisms such as distributed hash table are provided for a participant to find out interested data from peers (Cudre-Mauroux, Budura, Hauswirth, & Aberer, 2008). Using mobile agents in a decentralized system saves a user considerable effort and energy in managing and conducting information search and retrieval. By moving executable programs between machines, agent-based computing introduces an important new paradigm for the implementation of distributed applications in an open and dynamically changing environment (Funfrocken & Mattern, 1999).

The mobile agent approach saves network bandwidth (Singh et al., 2012). Mobile agents continue roaming and working on behalf of users even when the user machines are disconnected (Glitho et al., 2002). After mobile agents are submitted, they proceed autonomously and independently. The connection between the client and the server is disconnected. Later when the mobile agent finishes its job at the server, it will reconnect to the client with the result (Singh et al., 2012). Such no requirement for constant network connection saves network bandwidth in a wireless environment where network connection is limited or communication delays are common (Fukuta, Mizutani, Ozono, & Shintani, 2003). As intelligent entities, mobile agents act towards their goals and can be equipped with planning algorithms to determine when and where to migrate and which migration path to choose given different network conditions.

In this research, we study mobile agent migration planning in a decentralized, open system. In such a system, different information sources have different levels of quality in terms of information and services they provide. There may also be issues on security, privacy or even fraud on the information and the information services available on those information provider sites. Our approach is to facilitate a mobile agent to select the most reputable information host to migrate to search and retrieve high quality information. We propose to use a reputation-based approach for such information host migration selection based on the consensus of the users towards the quality of information offered by the information host and the information services provided by the host. Intuitively, an information host with a high reputation tends to be more likely to provide quality information and offer a secure and efficient execution environment for a mobile agent to search and retrieve information. Computational reputation has been studied in the research community (Boukerche & Ren, 2008; Mui, Mohtashemi, & Halberstadt, 2002; Noorian & Ulieru, 2010; Pinyol & Sabater-Mir, 2013; to cite a few). In open and decentralized systems, reputation and trust have been used as a mechanism for individuals to choose the best source of resources, the most trustworthy peer to cooperate, and the most appropriate environment to execute.

Our proposed approach is based on the opinions of users in a decentralized system to assess a given information host's ability and reliability to provide quality information and information services. More specifically, the users rate the quality of information and information services provided by each information host from several aspects based on those users' previous interactions with the information host. The assessments provided by users are regarded as first-hand evidence in evaluating and ranking each information host. Since user's evaluations represent their opinions towards the quality of information and services provided by an information host, we use an opinion-based belief structure (belief, disbelief, and uncertainty) to represent, aggregate and finally calculate each information host's reputation based on users' feedbacks. Reputation is a multi-faced concept. Our approach first allows the users to rank each information host's quality of information and service on a set of specified evaluation categories. Then, a comprehensive, final reputation of the information host is obtained by aggregating those individual category reputations. To recognize the subjective nature of a reputation, the transferable belief model is used to represent and rank the category reputation. To illustrate mobile agent migration, we have developed a prototyping system based on the Aglets mobile agent development platform. Although the simulation was conducted based on a small group of mobile agents, it shows the feasibility of mobile agent technology in facilitating information search and retrieval in a decentralized system.

This work is based on our previous research on service migration for moving target defense (Zuo, 2016) and mobile agent-based service migration (Zuo & Liu, 2015). The rest of the paper is organized as follows. Section 2 presents the background of theories and concepts related to this research. Section 3 discusses the proposed reputation-based mobile agent migration model. Experiment to demonstrate mobile agent migration is shown in Section 4. Section 5 offers discussions of the proposed research work. Section 6 concludes this paper.

2. Background

In this section, we briefly introduce the theories and concepts related to our research. There are two streams of research work as discussed next: opinion-based reputation and transferable belief model.

2.1. Opinion-based reputation

A belief structure (Josang, 1999; Josang, Guo, Pini, Santini, & Xu, 2013) is defined to express an opinion of a subject towards a binary proposition. In addition to a confirmation or a negation that a user has about the proposition, an uncertainty is added as part of the opinion. Due to imperfect knowledge, it is impossible for a user to know for sure whether a given proposition is true or false. So users can only have an