The Paradigm of Mobile Software Agent in Tourism Applications

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Abstract

The vast diffusion of handheld mobile devices in the mass market is changing the way in which information is accessed and the individuals' online presence and behaviour. The advancement in technology built in smart-phones and tablets has enabled the development of personal ubiquitous features within a new set of context-aware applications and services hosted directly on the devices. The anticipated increase in popular use of mobile web will create opportunities for a new generation of tourism applications, but there will be additional challenges and problems in meeting bandwidth requirements, and network and energy management on battery powered mobile devices. Many researchers believe that the mobile software agent paradigm could facilitate attractive solutions to deal with such challenges. Considering the author's former research experience as a creator of a mobile software agents system, this paper introduces the core concepts of software agents and presents an account of the studies and technologies that have emerged during the last years. The aim is to provide a research note and indications to inspire future development of tourism applications considering agents and mobile agent systems.

Keywords: mobile software agents; multi agent systems; mobile web; context aware; activity recognition; augmented reality.

1 Introduction

The software agent approach started in the field of artificial intelligence and is considered one of the most innovative technologies for the development of distributed software systems (Jennings et al., 1998; Vinaia & Sircar 2003; Bellifemine et al., 2007; Beydoun et al., 2013). Since the second part of the '90's several agent-based applications have been presented, and some software products moved from the research community to the industrial community (Bellifemine et al., 2007). The recent diffusion of smartphones and tablets has renewed the attention to the software agents for the development of smarter, more flexible, autonomous, and efficient applications in the mobile web.

In the tourism domain, a number of Web-based tourism-related agents have already been established, to overcome the problem of the vast amount of information available on accommodation, transportation, restaurants and sightseeing (Maw & Naing, 2008). Multi-agent tourism systems can assist users to retrieve and integrate tourism information on the Web and facilitate more personalized interaction with the users by acquiring information that meets the users' needs (Kirsch et al., 2006). Mobile agents paradigm is not employed much in today's applications, but has a relevant role to play in the development of the next generation of tourism software. This agent-based computing technology allows software migration between

interconnected sites, and offers interesting solutions in meeting bandwidth requirements, and network and energy management issues on battery powered mobile devices.

This research note aims to introduce the core concepts of software agent and mobile agent paradigm for inspiring future development of tourism applications in areas such as advanced distributed systems, mobile services, context-aware, e-market places, information retrieval and augmented reality.

2 The concept of Software Agent

One of the earliest and probably the most accepted definition of software agent is the one provided by Wooldridge and Jennings in 1995: "an autonomous, self-contained, reactive, proactive, computer system, typically with central locus of control that is able to communicate with other agents via some Agent Communication Language" (p 115). An agent is a goal-oriented computer programme that reacts to its environment and runs without continuous direct supervision to perform some function for an end user or another programme. The concept of agent can be also extended from a single process to a computer system, to one which present attributes and characteristics related to:

- intelligence,
- self-adaptation,
- mobility,
- cooperation/communication with other agents,
- interaction with human users,
- meta-information processing,
- knowledge representation.

Franklin and Graesser (1997) describe a taxonomy for autonomous agents and consider a number of definitions available in the literature for distributed computing and artificial intelligence. After a decade of continuous development, scholars consider the agent-orientation approach as a computing paradigm that combines concepts from artificial intelligence, distributed computing, expert systems, and extend the object orientation paradigm (Vinaia & Sircar, 2003). Many agent-based systems and agent platforms have been developed and researchers have explored key concepts of agent-based computing as well as issues related to agent management and the definition of message exchange interaction protocols. There is still a deficiency in open and closed standards for protocols and application programming interfaces, however, numerous efforts are emerging from various organizations and companies (Wang and Wang). The Foundation for Intelligent Physical Agents – FIPA is an example of attempting to draft specification for an Agent Communication Language and an ontology of services (FIPA, 1998). Within the mobile computing arena attention has been renewed on agent technology and its possible commercial applications.
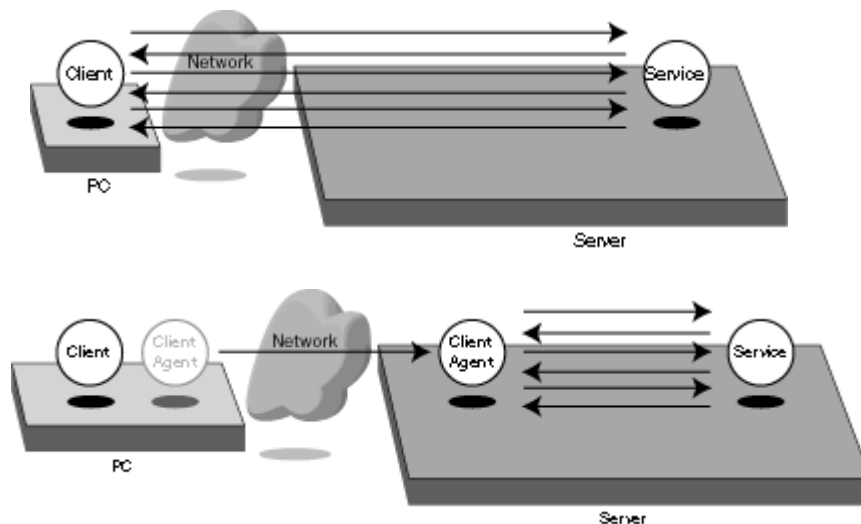
3 Mobile Agent Paradigm

A mobile agent is a composition of software and data that is able to autonomously "migrate" between different interconnected computers and continues its execution

after the migration (Magedanz & Eckardt, 1996; Mattern et al., 1997; Pham & Karmouch, 1998; Morellato, 2000)

In computer science code mobility is adopting different possible paradigms, such as "remote evaluation", "code on demand", and "mobile agent". Within the mobile agent paradigm, a software agent is able to interrupt its execution, relocate itself to a different computer, and continue its execution in the new destination. The execution context for a mobile agent can be provided by adopting specific programming languages or by installing an agent platform on the interconnected computers. Therefore the mobile agent concept encompasses the areas of artificial intelligence, networking, and operating systems (Vogler et al., 1998; Vinaia & Sircar, 2003).

Mobile agents are advantageous in that they consume fewer network resources than traditional code, because the agent moves the computation to the data, rather than the data to the computation. Figure 1 shows the different network usage for the communication overhead between a traditional client/server application and a mobile agent application. Considering the complex information retrieval from a data warehouse, the application in Figure 1.a uses the network for each query whilst the application in Figure 1.b migrates to the server and interacts locally.

Error! No text of specified style in document.**1.** Client/Server paradigm (a).
Mobile Software Agents paradigm (b)

Mobile agents have advantages particularly in situations where the connectivity to the network is limited or subjected to bandwidth and latency problems. This is the scenario of modern mobile web where smart phones and tablets allow ubiquitous and discontinued access to the Internet by using WiFi, 3G and 4G standard. A mobile agent can be "injected" on the Net to conduct targeted Internet searches, retrieve information in large data warehouses, check and prioritize incoming e-mails, fill out e-forms, synchronize social networking profiles, monitor remote devices, assemble

customized news reports, find good deals in electronic commerce, and many other complex applications in financial, educational and even health care domains (Jennings, 2001; Wang and Wang, 2001; Chen and Liu, 2010).

3.1 How to implement mobile agents

The agent mobility involves the migration of a process where two different types of migration are possible. (1) "*Strong migration,*" if the entire state of the process is freeze and transfer. This type of migration is very hard to implement because all internal registries need to be transferred and there is a hardware dependency. (2) "*Weak migration,*" if the state of the process is codified and reactivated by specific routines specifically designed.

The agent migration requires transferring code and data. Data transfer is a well-known topic, whilst the code transfer requires a further comment. Figure 2 summarizes the three possible approaches for code transfer: *binary code transfer, source code transfer, and virtual binary code transfer*.
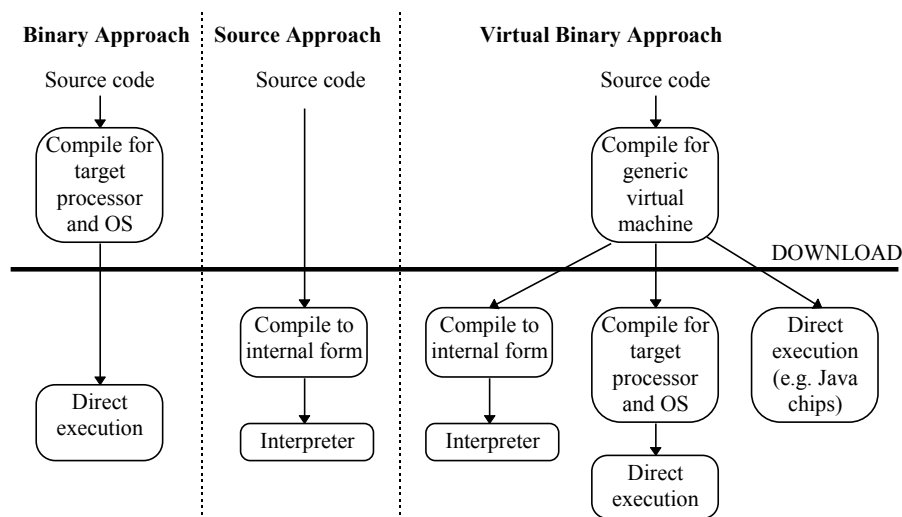
Fig.2. Code transfer approaches

Without entering into specific software engineering details, which are beyond the purpose of this research note, it is important, to highlight that virtual binary transfer is facilitated by Java technology. Considering that a Java Virtual Machine is commonly part of modern mobile devices, the author suggests the implementation of a weak migration of mobile agents based on a virtual binary code transfer. The solution identified by the author has been already implemented in 2000 when the author designed and developed a platform for the management and the execution of mobile software agents as part of a European research project (Morellato 2000). The Agent Platform has been developed using Java, whilst the mobile agents have been implemented using a script language with introspective features for realizing the weak

migration. A run-time code introspection is the key for allowing the capture of agent's context during its execution and to freeze the state before transfering the execution.

On modern smartphones and tablets a similar framework can be implemented for mobile agents. Usually mobile devices are already equipped with a Java Virtual Machine and so a dedicated agent platform could be installed as a simple 'App'.

3.2 Mobile Agent technologies

In the last decade, many studies on the mobile agents have emerged in different domains. Electronic commerce and Internet application based on auctions, transaction processing and automated distributive resource allocation seem to present the best scenario to employ mobile agent technologies (Vogler et al., 1998; Yokoo & Fujita, 2001; Bellifemine et al., 2007). However, remote monitoring, cellular telecommunications, location aware computing and context-aware applications have the highest potential-growth within the adoption of mobile agents (O'Hare & O'Grady, 2003). The following is a brief list of some of the existing technologies:

- **Aglets** is the project developed by IBM Tokyo Research Lab on the electronic commerce by implementing weak migration of agents.
- **TACOMA** (Tromso and Cornell Mobile Agent) implements the weak migration with a briefcase for TCL interpreter.
- **JADE** is an FIPA- compliant software framework that facilitates development of interoperable multi-agent systems under an Open Source License.
- **JACK** is a commercial software development framework based on Java for the realization of Beliefs, Desires and Intention – BDI agent-based systems.
- **Cougaar** is a Java-based agent architecture in the domain of US military logistics planning and execution.
- **MOBIFLEX** is an architecture based on JADE which combines mobile agents and web services for the design of a platform for integrating Healthcare Information Systems.
- **SCEM** is also implemented with JADE and is a multi-agent system created to take into account the distributed nature of the supply chain and to facilitate autonomous and corrective control actions.
- **MATS** is a multi-agent tourism system which aims to provide relevant and updated information according to the users' interests.

4 Mobile Agent in Tourism

A decade ago, Vinaja and Sircar (2003) anticipated the diffusion of agent-based technologies: "Agent orientation is no longer an emerging technology, but rather a powerful approach that is pervasive in systems and applications in almost every single area" (p. 20). Several security and agent communication matters have still important challenges to face and each agent platform or agent-based framework has to solve issues related to authorization, stability, remote manageability, tracking, network coordination and systems access legacy (Wang & Wang, 2001).

Software applications in tourism can benefit from mobile agents. Ubiquitous and smart content delivery is probably the area where researchers are experimenting more their theories and applications by targeting tourists. Electronic guides, aids for

visitors to museums, arts' galleries, and exhibitions have been developed to support users in indoor environments. More recently, numerous prototype systems have also been created to enrich tourist experiences in outdoor environments and tourism destinations. **TravelMate** is a system with a multi-modal user interface developed for San Francisco. **GUIDE** is a context sensitive tourist guide for the city of Lancaster. The **Personal Travel Assistant** uses agents to plan travel itineraries on behalf of its users. **Gulliver's Genie** is a context sensitive travel guide. A multi agent system with multimedia database augmented with geographic information system. (O'Hare & O'Grady, 2003). Bearzotti et al. (2012) present an updated collection of agent systems and prototypes based on mobile agents for the management of the supply chain and the support of intra-organizational activities. Other examples of pioneering context-aware research projects are undertaken under the umbrella of Smart-Cities.

Today the modern mobile devices have enough computing power to make the execution of distributed applications directly possible for users' smart-phones and information can be processed and rendered on the devices. Mobile software agents paradigm could be adopted for a new generation of tourism applications where users can personalize and delegate software agents to retrieve information or negotiate deals starting from their devices. The integration of context-aware features with information acquired locally or on the Internet can enhance augmented reality services with a less network usage. Users would need to access the Net to retrieve their mobile agents for the required information instead of waiting online for information processing.

The Agent Oriented Software Engineering as already been recognized as effective paradigm to manage complexity of software systems and discontinued ubiquitous connections. The challenge for a public affirmation of technologies based on mobile agents relies in addressing security and privacy issues in a meaningful way. Ethical and legal dimensions are extremely important in the deployment of systems able to determine visitor's position and preferences. A failure to prevent potential technological abuse could deter the development of this technology.

References

Bearzotti L.A., Salomone E., Chiotti, O.J. (2012). An autonomous multi-agent approach to supply chain event management. *International Journal Production Economics* 135. 468–478.

Bellifemine, F. Caire, G., Poggi , A., Rimassa, G. (2007). JADE: A software framework for developing multi-agent applications. Lessons learned. *Information and Software Technology* 50, 10–21.

Beydoun G.,Low G.,Bogg, P.(2013).Suitability assessment framework of agent-based software architectures. *Information and Software Technology* 55. 673–689.

Camacho D., Borrajo, D., Molina, J.M. (2001). Intelligent travel planning: A multiagent planning system to solve web problems in the e-tourism domain. *Autonomous Agents and Multi-Agent Systems* 4. 387–392.

Chen, B., Liu, W. (2010). Mobile Agent Computing Paradigm for Building a Flexible Structural Health Monitoring Sensor Network. *Computer-Aided Civil and Infrastructure Engineering* 25. 504–516.

FIPA (1998). Foundation for Intelligent Physical Agent Specification.Part1,Agent Management. Part2, Agent Comunication Language. <http://www.fipa.org>.

Franklin, S.,Graesser, A. (1997). Is it an Agent, or just a Program?: Ataxonomy for

Autonomous Agents, Istitute for Intelligent System University of Memphis

Jennings, N.R., Sycara, K., Wooldridge, M. (1998). A Roadmap of Agent Research and Development. Autonomous Agents and Multi-Agent Systems 7-38.

Jennings, N.R. (2001) An Agent-based approach for building complex software systems. *Communication of the ACM* 44(4). 35-41.

Kirsch, S.M., Gnasa, M., Cremers, A.B. (2006). Beyond the Web: Retrieval in social information spaces. Advances in Information Retrieval, Proceedings of the 28th European Conference on ECIR (vol. 3936/2006, pp. 84-95), London.

Kreller,B.,Carrega,D., Shankar,J., Salmon,P., Bottger,S., Kassing,T.(1998). A Mobile Aware City Guide Application. *Proceedings of ACTS Mobile Communications Summit*, Rhodes, Greece. 60–65.

Magedanz, T.; Eckardt, T., (1996). Mobile software agents: a new paradigm for telecommunications management. *Network Operations and Management Symposium*, IEEE , vol.2. 360,369.

Mattern, F., Rothermel, K., Schneider, F. B., Welch, B. (1997) Mobile Software-Agents. Workshop at Schloss Dagstuhl Oct 13-17.

Maw, S.Y., Naing, M., (2008). Multi-Agent Tourism System (MATS) *Social Information Retrieval Systems:Emerging Technologies and Applications for Searching the Web Effectively*. Information science reference. 289-310.

Morellato M. (2000). Una piattaforma di sviluppo di agenti software mobile per l'integrazione di Internet e la Domotica. Univerista' degli studi di Milano.

O'Hare, G.M.P. ,O'Grady, M.J. (2003). Gulliver's Genie: a multi-agent system for ubiquitous and intelligent content delivery. Computer Communications 26. 1177–1187.

Pham V.A., Karmouch A. (1998). Mobile Software Agents: An Overview IEEE Communications Magazine. 26-37.

Schmidt, A., Beigl, M., Gellersen, H-W. (1998). There is more to Context than Location. *Proceedings of the International Workshop on Interactive Applications of Mobile Computing (IMC98)*, Rostock, Germany.

Vinaja R., Sircar S. (2003). Software Agent Orientation: A New Paradigm. W: C.V. Brown, H. Topi: IS Management Handbook. Auerbach, London, 1-20.

Vogler, H., Moschgath, M., Kunkelman, T. (1998). Enhancing Mobile Agents with Electronic COmmerce Capabilities. *In Klusch, M, and Weib, G. Cooperative Information agents II, Proceedings of the Second International Workshop.* Eds Springer-Verlag. 148-159.

Wang, D., Wang, J. (2001). Towards the Distributed Processing of Mobile Software Agents. ACM SIGAPP Applied Computing Review, 9(2), 2-5.

Wickramasinghe, L.K., Amarasiri, A., Alahakoon, L. D. (2004). A Hybrid Intelligent Multiagent system for e-business. Computational Intelligence, 20(4) 603-623.

Wooldridge, M., Jennings, N.R., 1995. Intelligent agents: theory and practice. *Knowledge Engineering Review* 10, 115–152.

Yokoo, M., Fujita, S. (2001). Trends of Internet Auctions and Agent-mediated Web Commerce. New Generation Computing, 19. 369-388.