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Mobile Agents: Control Algorithms

Bearbeitet von
Joachim Baumann

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THE ROAD NOT TAKEN
Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;
Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them really about the same,
And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.
I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I -
I took the one less traveled by,
And that has made all the difference.

Robert Frost

Preface

A comparatively new paradigm in the area of distributed systems is the mobile agent paradigm. Mobile agents promise to deal very efficiently and elegantly with dynamic, heterogeneous, and open environments as e.g. the Internet.

A mobile agent is an active entity that can act on behalf of its user, following a given task. The agent can autonomously migrate through the network during its execution. While it computes, it is able to observe its environment and to adapt dynamically to changes. It can continue its computations asynchronously even if the user that has started it, is (temporarily) not connected to the network. By moving the agent to the host on which data resides, communication latency and bandwidth consumption may be reduced in many cases.

Applications for mobile agents are widespread and encompass not only applications in electronic commerce environments and applications to search and filter global information spaces, but can also be found in the areas of network management, monitoring, information dissemination, or parallel processing. These are only some of the application areas on which many different authors agree. In all of these applications mechanisms are needed that provide the user with the ability to control mobile agents.

In this book several control mechanisms for mobile agents are presented, i.e. mechanisms for locating and for terminating mobile agents, and mechanisms for orphan detection in a mobile agent system.

First, control mechanisms are discussed that have been specifically designed for mobile agent systems, taking into account the peculiarities of the mobile agent paradigm. The energy concept is presented, which supports orphan detection for mobile agents. In this concept every agent gets some energy. Every action the agent takes, every service that is used, costs energy. When the energy is used up, the agent is terminated. Then the path concept will be discussed, a variant of which is used in the area of distributed systems to track mobile objects. Every agent leaves a path in the system, i.e. on migration, information is left behind about the agent's target place. This path can be followed to find the agent, and/or to terminate it. The third concept presented is the shadow concept. This concept supports locating and terminating of mobile agents and furthermore, provides orphan detection for mobile agent systems. This concept combines the energy and the path concept in a way that leaves the agents most of their autonomy, has low communication costs, and provides excellent fault tolerance (i.e. a high availability). An agent leaves a trail in the system, but in contrast to the trail in the path concept, this trail is cut short in regular intervals. To allow for simple termination of agents, a delegate of the application is left in the system, the shadow. As long as the shadow exists, all dependent agents are allowed to continue their work. The agents are no longer depending on the availability of the application. Thus no permanent connection between agents and application is needed, an application can e.g. run only intermittently to check for results. Furthermore, we discuss for each of these concepts fault tolerance and message complexity.

In the area of distributed algorithms, mechanisms have been developed to solve similar problems (i.e. termination detection and distributed garbage collection). Using a transformation, an algorithm of one class can be changed into an algorithm of the other class and vice versa. In fact, new algorithms were discovered this way.

A similar transformation providing the conversion of either of these classes into control algorithms for mobile agents should allow access to a large number of algorithms for controlling mobile agents. But the failure model of the area of distributed algorithms and that of the area of mobile agents are radically different, ruling out the direct use of these mechanisms.

Instead we will use transformed garbage collection algorithms to show the following: all the principles of the transformed algorithms can be found in the control mechanisms developed explicitly for mobile agents. Furthermore, if a new, radically different algorithm is developed either in the area of termination detection or in the area of distributed garbage collection, it can be transformed at once and its principles can be exploited for developing new control mechanisms.

Finally, the control mechanisms are compared with mechanisms presented in the literature regarding reliability, message complexity, interference with the agent autonomy, and usability for applications.

This book is an extended version of my PhD thesis, and a large number of people helped in creating both the thesis and the book; without them it would not have been possible to realize them. First of all I have to thank Prof. Kurt Rothermel and Prof. Friedemann Mattern for their help. Both were ever willing to motivate me anew, and to point me to new directions of importance for my work.

I would like to thank many colleagues at the IVPR for suggestions and advice. Most of all I have to thank my colleagues and friends of the Mole project for their constant help. The discussions with Fritz Hohl, Markus Straßer, and Markus Schwehm were very important for this work, as were their comments regarding this document. Furthermore, I have to sing their praise regarding their fine and never-failing sense of humour, and for the ability to point out the good in every situation.

And I have to thank all those students who, in implementing the Mole system and the protocols, were crucial for my work to succeed. Especially important to me are those of the students who became more than part-time colleagues. These friends are: Bernhard Beck, Jens Höfflinger, Michael Paulus, and Matthias Zepf. I have to thank Felix Gärtner from the University of Darmstadt for his helpful comments regarding fault tolerance.

Then there is my family: I have to thank all of them, my mother for teaching me the important things in life, and for believing in me, my parents-in-law for readily welcoming me in their family, for their good-natured humour, and their always ready willingness to feed me (there is nothing better than their Fleischkäsrouladen[1] and Spätzle[2]), and my wife, Annette, for her support and for cheering me up.

Finally I have to thank Prof. John Argyris, for starting it all.

I do not regret that I took this road.

Jun 2000 Joachim Baumann

1. You take thin slices of Fleischkäse (a meat loaf made of ham and pork or veal) and roll it, filling the roll with cheese, small cucumbers and mustard. Then you put it in the oven for half an hour, together with a sauce of tomatoes and sliced onions.
2. Spätzle are swabian noodles, infinitely better than all the italian cuisine has to offer (at least in my opinion).