Position paper: Transportable information agents

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An *information agent* manages a portion of a user's information space. The electronic resources in this information space are often distributed across a network and can contain tremendous quantities of data. *Transportable agents* provide efficient access to such resources. A transportable agent is a named program that can migrate from machine to machine in a heterogeneous network. The program chooses when and where to migrate. It can suspend its execution at an arbitrary point, transport to another machine and resume execution on the new machine. By migrating to the network location of a resource, an agent can access the resource efficiently even if the resource provides only low-level primitives for working with its contents. The agent executes local to the resource so no intermediate data is brought across the network. Transportable agents also allow the rapid development of distributed applications since application- or even user-specific code can be sent to remote sites *dynamically*. None of the code needs to be pre-installed. This combination of efficiency and a short development cycle makes transportable agents a powerful tool for implementing information agents.

The goal of the agent project at Dartmouth is to develop a software architecture that allows the rapid implementation of efficient information agents. The lowest level of the architecture and the current focus of the project is a transportable-agent system. Existing transportable-agent systems include Telescript^{TM} from General Magic and Tacoma from the University of Cornell and the University of Tromsø [4, 5]. Existing systems, however, suffer from a range of weaknesses. Tacoma, for example, requires the programmer to explicitly capture state information and provides no security mechanisms. Telescript requires powerful or special-purpose hardware, is not open to researchers and limits the programmer to a specific language. Due to the weaknesses of existing systems, we are developing a transportable-agent system called Agent Tcl. Agent Tcl will run on standard Unix platforms, support multiple languages and transport mechanisms, provide transparent migration and communication, and provide effective security and fault tolerance in the uncertain world of the Internet. We believe that five open research issues must be addressed to realize Agent Tcl.

- *Nonvolatile store.* An agent should be able to backup its internal state to nonvolatile store so that it can be restarted in the event of node failure. The backup must be performed incrementally and only at "key" points so that the agent remains as efficient as possible.
- *Namespace.* An agent should have a unique name within the space of all agents. The name should be location-independent so that agents can refer to each other without knowledge of current network locations. This requires an efficient, transparent routing scheme for agent communications.
- *Security.* There are two levels of security. The first level involves the standard point-to-point issues of authenticating the sender of an agent and preventing the agent from performing malicious actions. The

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second level involves all of the security holes that appear when an agent migrates through a *sequence* of machines. For example, if an agent migrates from its home machine to machine A and then to machine B, machine B must be able to authenticate the *original* sender of the agent and verify that machine A did not modify the agent in a malicious way.

- *Privacy.* An agent might carry sensitive information about its owner in order to make effective decisions. This information must be hidden from other agents and from malicious machines. The latter appears impossible so some information must always remain at the home site.
- *Network awareness.* An agent should be able to determine the current state of the network and then use this information to select a migration strategy that takes it through the required resources as quickly as possible while maintaining application constraints.

Other services, such as scheduling, planning, resource discovery and additional fault tolerance, are not required in every agent and do not belong in the system itself. These services should be implemented as *agents* so that obtaining a service requires nothing more than communicating with the appropriate agent.

The current implementation of Agent Tcl supports only a single language (Tcl) and a single transport mechanism (TCP/IP) and does not address the issues above. However it has allowed the rapid development of several information-management applications including the monitoring of remote events and the retrieval of distributed medical records. Initial experiments indicate that these applications are at least as efficient as their client/server analogs even though there is no application-specific code at the remote sites. This lends credence to the the transportable-agent paradigm and suggests that transportable agents will be a powerful tool for implementing complex information agents.

Project members

The agent project is supported under ONR grant N00014-95-1-1204 as part of the Navy's effort to develop Tactical Picture Agents that filter and organize incoming tactical information for real-time presentation to Navy commanders. The principal investigators are Professor David Kotz and Professor Daniela Rus from the Department of Computer Science and Professor George Cybenko from the Thayer School of Engineering. The lead programmer is Robert S. Gray who is a third-year Ph.D. candidate and the author of this paper. Application developers include Ting Cai, Saurab Nog, Dawn Lawrie, Aditya Bhasin, Kurt Kohen, Yunxin Wu. Jason Kochel, Jospeh Edelman, Robert Leathern and Jake Wegmann. Additional students have worked on pieces of the system as part of a class project.

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