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# Migratory Continuous Media Applications

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In future computing environments, users can use their computing environments even if they move out of their offices or homes, and they expect the environments can be used in any places. In this case, it is convenient that their applications will be moved with him according to his location. For example, their intelligent agents that monitor their behaviors should give advice to them whenever they need helps. The users expect the agents to be executed in computers that exist near them. Traditionally, the scenario can be realized by carrying computers for respective users, and agents can be executed on the computers.

The approach requires that the computers may execute heavy computation, and always connects to networks for acquiring information from servers. This means that users should carry powerful computers with them. The alternative approach is that the agents run on the computers near their users. In future, computers will be embedded in various objects that are placed everywhere, and we want to use these computers for executing applications for helping our work. In the environments, applications will be moved computers that are embedded in objects existing near their users according to their locations. The applications are called as *migratory applications*

However, since computers may have dramatically different hardware and software configurations, these applications cannot be moved without taking into account the configuration of the new computer. Therefore, migratory applications should be aware of environments that the applications are executed, and should be adapted to respective computing environments that the applications are moved. Also, these applications may need to process various types of media data such as video and audio for monitoring surrounding environments of the users of the applications, or showing video and audio information that is interested by the users in a timely fashion. Therefore, environment-aware migratory continuous media applications are one of the most important classes of applications in future computing environments.

In this paper, we present system supports for building environment-aware migratory continuous media applications. Currently, we have a few experiments about migratory applications in large scaled heterogeneous distributed environments. We need a lot of experiments how applications adapt to respective computing environments, and how applications are moved between computers connected with low bandwidth networks if the movement of the applications has timing constraints. The work described in this paper is one of case studies showing what is required for supporting migratory applications. The experiences with building the system supports clarify the problems and requirements for realizing migratory applications in large scaled heterogeneous distributed environments.

For building environment-aware migratory continuous media applications, the following three issues should be taken into account.

- How do applications recognize computing environments in which the applications run, and notify their changes to the applications ?
- How do continuous media applications should be adapted to respective computing environments ?
- How are applications migrated to other computers in the middle of their execution ?

Our system supports consist of three components as shown in Figure??, which solve the above respective issues, and they make it possible to build environment-aware migratory continuous media application in a systematic fashion.

The first component that answers the first issue is the environment server that monitors computing environment, and it notifies the changes in the environments to applications. The environment server provides primitives for accessing information about computing environments. Traditionally, respective information about computing environments requires to be accessed by different primitives. This makes the structure of environment-aware applications unclear. On the other hand, the uniform interface provided by the environment server enables us to build environment-aware applications in a systematic fashion.

The second component that answers the second issue is the continuous media toolkit that enables us to build continuous media applications in a highly configurable way. By using the toolkit, continuous media applications are constructed by composing several modules. The approach has two advantages. The first advantage is that the toolkit enables us to build continuous media applications with a little programming. The second approach is that the toolkit enables applications to change the configurations according to respective computing environments. The advantage makes it possible to build environment-aware continuous media applications.

The third component that answers the third issue is the migration manager. The migration manager that makes continuous media application migratory have two functions. The first function is that it manages the reconstruction of an application on a computer that the application will be moved. The second function is that it saves the states of applications, and restores the states in applications that are reconstructed on a new computer. In our approach, the amount of states of applications can be changed by taking

into account the tradeoff between the time for migrating applications and the bandwidth of a network connected between two computers.

The above three components are currently implemented on Real-Time Mach. The environment server is implemented as a server, and the continuous media toolkit and the migration manager are implemented as libraries that are linked with applications.

Various new types of applications can be available in future computing environments such as mobile computing environments and ubiquitous computing environments. The applications may change our daily life dramatically since computers can be embedded in our daily necessities such as televisions, microwaves, cameras, and air conditioners. In these environments, computing environments can be changed dramatically, and applications may be migrated among computers that have drastically different hardware configurations. Therefore, these applications should be adapted to various computing environments that may have dramatically different characteristics for their efficient executions, and the adaptation requires that the applications can access information about computing environments through a uniform interface.

In this paper, we propose an *environment server* that is important as a basic infrastructure for building adaptive applications for future computing environments. The environment server manages various information about computing environments in an integrated fashion, and applications can access these information through its well defined interface. This makes it possible to build adaptive applications with a systematic framework.

In this paper, we propose system supports for building migratory continuous media applications. In future computing environments, various objects in home and office will embed computers, and various applications will be moved between these computers according to the location of these users. For example, a computer that executes an application may be changed according to the location of the user of the application for monitoring his behavior. However, since computers may have dramatically different hardware and software configurations, applications cannot be moved without taking into account the configuration of the new computer. Therefore, migratory applications should be aware of environments that the applications are executed, and should be adapted to respective computing environments that the applications are moved.

The paper focuses on system supports for building migratory continuous media applications that are one of the most important classes of migratory applications. Our system supports consist of three components. The first component is an environment server that monitors computing environments that applications run, and it notifies the changes of environments to the applications. The second component is a continuous media toolkit that enables us to build environment-aware migratory applications easily. The toolkit enables us to build continuous media applications in a highly configurable way. The third component is a migration manager that makes application migratory. We also show an example of migratory applications, and describe some experiences with building the applications.