A TMO Based Real-Time Model: Supporting u-GIS Informative Construction Technology Innovation

Myoungjin Kim¹, Hanku Lee¹,*, Muwook Pyeon², Yangdam Eo³,
Dongkeun Lee¹, Wonsa Lee¹

¹Mobile Computing Laboratory at Konkuk University, Seoul, Korea
²Research Center for u-GIS Informative Construction Technology Innovation at Konkuk University, Seoul, Korea
³Department of Advanced Fusion Technology at Konkuk University, Seoul, Korea

¹, ², ³{tough105, hlee, neptune, eoandrew, dklee2, wlee}@konkuk.ac.kr

Abstract

In the real world it is very difficult to implement real-time models in uncontrolled distributed environments and to support well-defined interfaces from real-time systems to external systems. An ongoing project for ubiquitous computing environments, u-GIS based Informative Construction Technology Innovation project needs a system to handle and control various data (sensor data, visual data, equipment status data, etc.) generated from remotely distributed construction sites in real time. The main purpose of this paper is to study how to support real-time applications, to design TMO-based distributed real-time processing techniques for real industrial applications, and to develop a TMO-based real-time model with less strict real-time constraints in ubiquitous environments. We propose an easy-to-use TMO-based real-time model with less strict real-time constraints for u-GIS based Informative Construction Technology Innovation project.

1. Introduction

Until year 2011, Ministry of Land, Transport and Maritime Affairs (MLTM) of the Korean government puts US $ 43 million (including US $ 14 million from industry) into “u-GIS Informative Construction Technology Innovation” that is one of the five core projects for “Korean Land Spatialization.” u-GIS Informative Construction Technology Innovation project (so called the u-GIS project), subdivided into three sub-projects, was launched by the Research Center for u-GIS Informative Construction Technology Innovation (http://www.ubigis.co.kr), so called the u-GIS center, at Konkuk University, Seoul, Korea, on September 11, 2007. 56 member organizations (373 researchers overall), including 41 industry partners, 14 universities, and 1 research institute, such as Korea Telecom (KT), Korea Electronics Technology Institute (KETI), LS Industrial Systems, Samsung SDS, etc., has been participating in the project.

To successfully develop the u-GIS project, it is very critical to reliability handle a huge amount of location and shape information created by construction equipments, sensors, and computing devices in “real-time.” With the fast development of ubiquitous and grid computing environments, we can access geographically distributed remote instruments, equipments, databases, human resources, high-performance computers, etc., as if accessing local resources from a long distance away. Though this accessibility is very stable and secure, it brings us another side: How can a huge amount of data created by construction equipments, sensors, and computing devices be well-synchronized in ubiquitous environments?
environments? With conventional programming methods it is very hard to implement real-time models in uncontrolled distributed environments, to design interactions between real-time systems and external systems, and to support well-defined interfaces from real-time systems to external systems.

Our ongoing u-GIS project needs a system to handle and control various data (sensor data, visual data, equipment status data, etc.) generated from remotely distributed construction sites in real time. The main purpose of this paper is to study how to support real-time applications, to design TMO-based distributed real-time processing techniques for real industrial applications, and to develop a TMO-based real-time model with less strict real-time constraints in ubiquitous environments. We propose an easy-to-use TMO-based real-time model with less strict real-time constraints for u-GIS based Informative Construction Technology Innovation project.

In the next section, we discuss related works such as TMO, Distributed Object-oriented Freeway Simulator (DOFS), and Real-time CORBA. In section 3, we introduce the u-GIS project in detail. We propose a TMO-based real-time model and mention design and implementation issues caused by using TMO in section 4. Section 5 concludes.

2. Related Works

The Time-Triggered Message-Triggered Object (TMO) was established in early 1990’s with a concrete syntactic structure and execution semantics for economical reliable design and implementation of RT systems [2, 3, 4, 5]. TMO is a high-level real-time computing object. It is built in standard C++ and APIs called TMO Support Library (TMOSL). Its member functions are executed within specified time windows. TMO is also a high-level distributed computing object. TMOs interact among themselves via remote method calls. Remote method calls are made in forms that are essentially the same as those of calling conventional object methods.

TMO contains two types of methods, time-triggered methods (SpM), which are clearly separated from the conventional service methods (SvM). The SpM executions are triggered upon reaching of the RT clock at specific values determined at the design time whereas the SvM executions are triggered by service request messages from clients. Moreover, actions to be taken at real times which can be determined at the design time can appear only in SpM’s. As in other RT object models, the TMO incorporates deadlines and it does in the most general form. Basically, for output actions and methods completions of a TMO, the designer guarantees and advertises execution time-window bounded by start times and completion times. Real-time Multicast and Memory Replication Channel (RMMC) is an alternative to the remote method invocation for facilitating interactions among TMOs. Use of RMMCs tends to lead to better efficiency than the use of traditional remote method invocations does in many applications, especially in the area of distributed multimedia applications which involve frequent delivery of the same data to more than two participants distributed among multiple nodes.

Distributed Object-oriented Freeway Simulator (DOFS) [6] is a freeway automobile traffic simulator conducting with the goal of validating the potential of the TMO structuring scheme supported by the recently implemented TMOSM. DOFS is intended to support serious studies of advanced freeway management systems by providing high-resolution high-accuracy easily expandable freeway simulation. The system can help the Driver avoiding the traffic road and supply real-time traffic information. The TMO scheme brings major improvement in the RT system design and implementation efficiency.

The Real-time CORBA (RT-CORBA) [7] is an optional set of extensions to CORBA to be used as a component of a real-time system. It is designed for applications with hard real-time requirements, such as avionics mission computing, as well as those stringent soft real-time requirements, such as telecommunication call processing. Moreover, to allow applications to control the underlying communication protocols and end-system resources, the Real-time CORBA specification defines standard interfaces that can be used to select and configure certain protocol properties.

3. u-GIS Project

u-GIS Informative Construction Technology Innovation project (so called the u-GIS project), subdivided into three sub-projects, was launched by the Research Center for u-GIS Informative Construction Technology Innovation (http://www.ubigis.co.kr), so called the u-GIS center, at Konkuk University, Seoul, Korea, on September 11, 2007. 56 member organizations (373 researchers overall), including 41 industry partners, 14 universities, and 1 research institute, such as Korea Telecom (KT), Korea Electronics Technology Institute (KETI), LS Industrial Systems, Samsung SDS, etc., has been participating in the project.

The u-GIS project is categorized into three sub-projects: (1) Renewal of Geo-spatial DB with
Construction Drawings, (2) R&D on Construction of Indoor Space DB with Application of Construction Drawings, and (3) R&D on Object Interlocking of Construction Drawings and Indoor Space. The u-GIS center not only manages the whole project but also focuses on developing the third sub-project. The objectives of the third sub-project are to develop: (1) techniques for spotting and tracking objects in construction sites and synchronizing with construction drawings, (2) techniques to extract shape information such as videogrammetry, and (3) techniques for telemetering displacements such as strains, distortions, cracks, etc. The main reason the third sub-project is necessary is that, on large scale construction sites, it has been much important to develop technologies to gain/provide location and shape information from/to construction-related objects such as structures, workers, equipments, and building material in “real time.” The ultimate goal of the project is to establish real-world infrastructures of a future high-tech city by Construction Technology (CT)-IT fusion.

4. The Proposed TMO-Based Real-Time Model

4.1. Architecture

With the fast development of the Internet and ubiquitous computing environments, it is no longer necessary for remote instruments, computing resources, and human resources (i.e. engineers and researchers) to be located in the same place and at the same time. Moreover, to support the u-GIS project, it should be possible for engineers and researchers to access remote instruments and computing resources from a long distance away. However, we need to support real-time controls and the timing characteristics on these geographically distributed and real-time applications without pain during the development.

In general classic real time systems have been designed with respect to time-restriction for single processors. Implementing and debugging of real-time controls and timing characteristics cause pain during the development of distributed real-time applications with conventional real-time methods. Thus it is difficult to adapt the classic real time systems into distributed environments such as ubiquitous systems.

In this paper we propose a TMO based real-time system to handle and control various data (sensor data, visual data, equipment status data, etc.) generated from remotely distributed construction sites in real time.

Figure 1 depicts the architecture of the proposed TMO-based real-time model. One of the main issues for the proposed model is to apply the easy-to-use TMO to real-time applications that are usually hard to design and implement with conventional programming methods. The proposed model is divided to 3 domains: RD (remote domain), ICSD (Information Convergence Server domain), and CSD (Control System domain).

4.2. RD (Remote Domain)

The remote domain (RD) is to collect remote data and to monitor remote instruments. RD consists of the Time Sever TMO (TST) and Working TMOs (WTs). TST gives the timing characteristics to WTs. The video, audio, and sensor data with the timing characteristics are transferred via sockets (TCP/IP) to Information Convergence Server Domain (ICSD).

WTs are synchronized by time characteristics supplied by TST. The time characteristics supplied by TST are more suitable to the proposed model than those supplied by the Internet or GPS time services since TST is closely located to other WTs and this locality avoids the network latency that makes it hard to synchronize real-time applications.

4.3. ICSD (Information Convergence Server Domain)

The Information Convergence Server Domain (ICSD) is to manage information convergence sever in order to help data communication between RD and CSD (Control System Domain). In real time ICSD manages
data communication between RD and CSD (Control System Domain) via TCP/IP-based client / server model. Moreover, it periodically handles collected data (with time characteristics from RD) and control-messages (from CSD) to be safely and precisely transferred.

ICSD should keep waking up, be started prior to other domains, and wait for collected data (with time characteristics from RD) and control-messages (from CSD). When collected data from RD is arrived, ICSD immediately transmits the data to CSD. Also, when control-messages from CSD are arrived, it immediately transmits the messages to the specific WT where the messages are heading in RD.

Servers in ICSD can storage a large amount of data from the remote domain and can provide the secure management of data from the remote domain to the interfaces.

4.4. CSD (Control System Domain)

Using CSD, remote engineers can monitor and control the entire system in real time. CSD is to provide user interfaces to check the status of the whole system, to monitor sensors and equipments in RD, and to manage control-messages to control remote instruments in real time.

4.5. Implementation

In this section we describe several implementations issues caused by using TMO APIs for RD and ICSD in detail.

Figure 2 represents the basic structure of the TMO-based Real-Time Application Framework, the core of the proposed Model. The real-time application framework is implemented using the TMO toolkit. [2]

ICSD consists of 3 TMOs: Monitoring_TMO, Sensor_Request_TMO, and Command_TMO. Monitoring_TMO requests Capture_SvM to capture and transmit visual data. Sensor_Request_TMO requests Sensor_SvM to transmit collected sensor data. Command_TMO transmits control messages to Motion_SvM.

RD consists of 4 TMOs: Time_Server_TMO (TST), Capture_TMO, Device_TMO, and Sensor_TMO. All TMOs can be easily and securely synchronized via time provided by TST. Capture_TMO captures visual data that will be requested by Monitoring_TMO. Device_TMO get control messages from Command_TMO in ICSD and transmit the messages to equipments such as robot arms and surveillance cameras. Sensor_TMO collects sensor data and transmits the data to Sensor_Request_TMO.

For time synchronization, when the framework is started up, Time_Set_SpM in TST transmits its system time to each Time_Set_SvM of WTs in RD via the socket channel. Then all TMOs in RD are completely synchronized. From now on all data requested from ICSD to RD are transmitted with timestamp completely synchronized.

To get data from WTs in RD, a Request_SpM in ICSD requests the designated SvM in WT to transmit the proper data back to itself via the SvM Gate (‘G’ in Figure 2) supported by TMOSM. For example, Capture_TMO captures visual data via Capture_SvM.

To control remotely distributed equipments such as robot arms and surveillance cameras in real time, Command_SpM in Command_TMO of ICSD with short periodicity transmits control messages to Motion_SvM in Device_TMO of RD via the SvM Gate. The transmitted control messages are used to control the equipments.

Figure 3 represents an example of a TMO based real-time system based on our proposed framework. The system can be used as a remote monitoring system and a remote control system which controls equipment. Using the system, a remote supervisor can monitor construction sites, control construction instruments, and conference with local engineers from a long distance away. In detail, first, a remote supervisor monitors the current status of construction sites from a long distance away through surveillance cameras. Second, he/she can monitor the current position of
5. Conclusion and Future Works

To successfully develop the u-GIS Informative Construction Technology Innovation project, it is very critical to reliably handle a huge amount of location and shape information created by construction equipments, sensors, and computing devices in “real-time.” With the fast development of ubiquitous and grid computing environments, we can access geographically distributed remote instruments, equipments, databases, human resources, high-performance computers, etc, as if accessing local resources from a long distance away.

We proposed an easy-to-use TMO-based real-time model with less strict real-time constraints in ubiquitous environments. Using the proposed model, we designed and developed a TMO-based real-time system for real industrial applications able to be used in construction sites.

The proposed model is very promising since it provides a sound TMO-based real-time application framework, cost-effectively resolving the problems caused by conventional programming methods during the development. However, the experimental research and development with the proposed model is at an early stage. Moreover, much more research efforts are needed to develop more stable TMO-based real-time application framework.

6. References


construction resources such as workers, materials, equipments, etc. in real time. Finally, he/she can control remote distributed construction equipments in the distributed construction site by using a remote controller.

It is easy to implement and debug TMO nodes. Implementing and debugging of real-time controls and the timing characteristics cause pain during the development of distributed real-time applications with conventional real-time methods. But all we need to do is to use TMO communication APIs supported by the TMO tool kit.

It is easy to modify and expand the proposed TMO-based model. We often need to scale up or down the whole system in the time dimension. Many modifications could be needed with conventional real-time methods. But all we need to do is to change the scale of the real-time clock of TMO for the proposed TMO-based model.

Thus, we urge TMO-based real-time applications are suitable to systems with less strict real-time constraints such as construction equipments, space probing equipments, tsunami-detecting equipments, etc, since those equipments product relatively small amount of data in the period of SpM and are not a time-critical decision model.

4.6. Advantages of the Proposed Model

Figure 3. A TMO Based Real-Time System