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## **The METEOR System for Managing Mission-Critical Enterprise-wide Workflow Applications**

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The Large Scale Distributed Information Systems Lab (LSDIS) at the University of Georgia (UGA) performs research and develops technology to support *enterprise integration* and *enable Infocosm* (an information society enriched by information any where, any time and in many forms). In this article, we discuss our METEOR system, which is a result of a large research project leading to several industry partnerships and a technology that can be licensed and may be commercialized.

Workflow management systems are used to re-engineer, streamline, automate, and track organizational processes. Many workflow products adequately support relatively simple processes involving document and forms processing, imaging, ad-hoc processes with synchronous and asynchronous processes, etc. In fact, the workflow product and service market was estimated to be about \$2 Billion in 1996, and over 200 products claim to support workflow in one form or the other. However, while the current technology and products can reasonably address the requirements of the simpler 70 to 80% of all the processes, they fall short in meeting the requirements of other 20 to 30% processes that are complex, large-scale, and mission-critical organizational processes that also represent very high value to the business. Such processes span multiple organizations (e.g., child immunization tracking discussed in this article), run over long periods of time, require more support for dynamic situations (e.g., clinical pathway process), or require a highly scalable system to support large instances of workflows (e.g., supporting automated process in a genetics. Many of the workflow applications that support real-world processes also need to be integrated with (or reuse) existing (legacy) information systems, need to run over distributed, autonomous and heterogeneous computing environments, require support for transactional features (especially recovery) and error handling, and need varying degree of security (including authorization, role based access privileges, data privacy, and communication security). Emerging and maturing infrastructure technologies for communication and distributed object management (e.g., CORBA/IIOP, DCOM/ActiveX, Java, Notes, and Web) are making it feasible to develop standards-based large scale, distributed application systems. These are however exploited in a very limited way in the current generation of the technology and products.

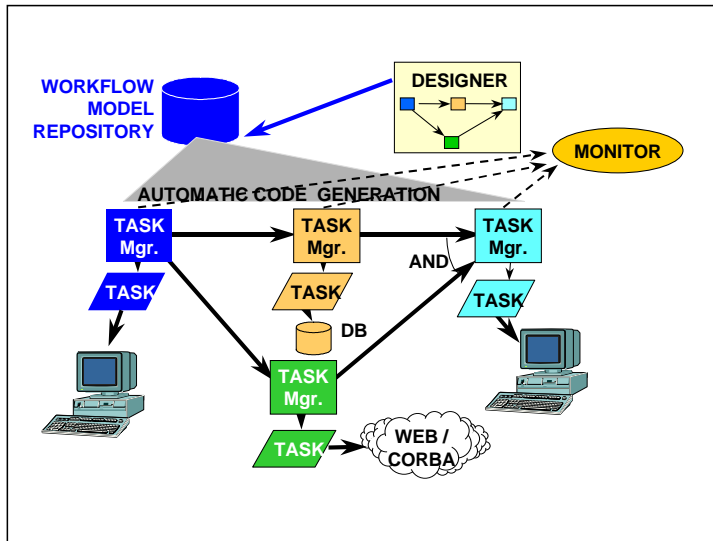
Workflow management techniques developed in the METEOR (Managing End-To-End Operations) project at the LSDIS meet the requirements of more complex, mission critical, and higher value processes mentioned above. The 3.5 years project is funded under the National Institute of Standards and Technology supported Advanced Technology Program as part of a cooperative agreement with the Healthcare Open Systems and Trials consortium. Nearly half of its \$1,400,000 budget is funded by NIST, with the rest as matching funds, coming from the University of Georgia and private industry donations to the LSDIS-UGA. An important aspect of this project is that the technology and system development effort at UGA-LSDIS has occurred in close collaboration with its industry partners. A key partner has been the Connecticut Healthcare Research and Education Foundation (CHREF) which serves its approximately 110 healthcare members in Connecticut. The collaboration involves a detailed study of healthcare workflow application requirements, prototyping of significant healthcare workflow applications with a follow-on trial, and evaluation of METEOR's technology at the partner's location resulting in technology improvement leading to a commercializable technology.

### **METEOR Architecture and Technology**

A Workflow Management System (WFMS) is a set of tools providing support for process definition, workflow enactment, and administration and monitoring of workflow processes. Key capabilities of the METEOR WFMS include a comprehensive toolkit for building workflows (map/data/task design) and supporting high-level process modeling, detailed workflow specification, and automatic code generation for its workflow enactment systems - WEBWork and ORBWork. Figure 1 shows the METEOR architecture. A good workflow system is ultimately used to increase the productivity and quality of products of an organization, and these aspects of organizational success critically depend on human participation and their acceptance of any computerized system they have to deal with. This

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fact has lead us to keep the ease-of-use of all participants including workflow application developers and end users in mind when designing all aspects of METEOR. Next we describe the key components of METEOR.



### State-wide Immunization Tracking Application

Let us briefly review a comprehensive workflow application developed using the METEOR WFMS. With managed healthcare coming of age, monitoring and tracking the performance of the different players involved, compulsory performance reporting, immunization tracking, child birth reporting, etc. have become important. In fact, the first item listed under Quality of Care in the Health Plan Employer Data and Information Set is Childhood Immunization Rate. Healthcare resources have to be used efficiently to lower costs while improving the quality of care provided and processes in the managed healthcare industry need to be computerized and automated.

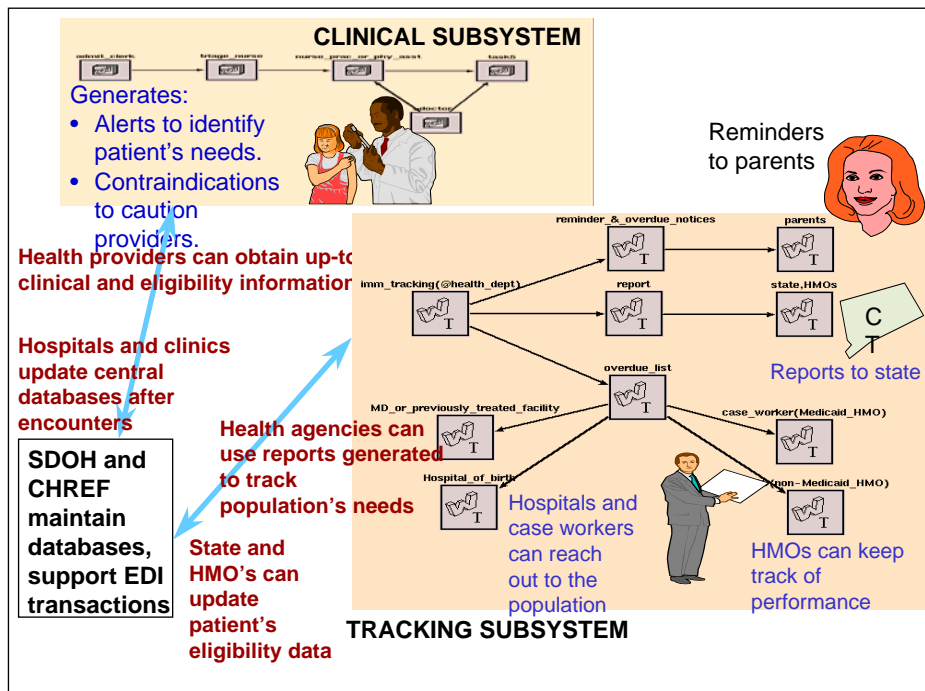
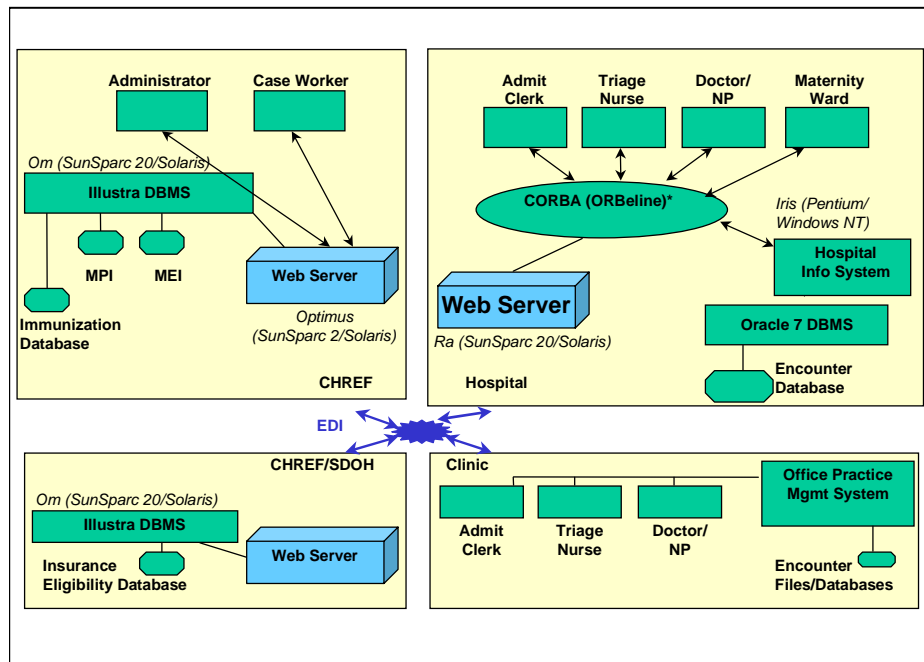


Figure 2 shows a schematic and the scope of the immunization tracking application. This includes on-line interactions for the workflow application between CHREF (as the central location), healthcare providers (Hospitals, Clinics, Home

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Healthcare Providers) and user organizations ( SDOH, Schools, Department of Social Services-DSS). Some of the important requirements for this application, as determined by CHREF, and supported to a very good extent by the testbed implementation , include:

- Support for a distributed client/server based architecture in a heterogeneous computing environment. At the level of any user of the system, this distribution should be transparent.
- Support for inter- and intra-enterprise wide coordination of tasks.
- Provision of a standard user-friendly interface to all users of the system.
- Support for a variety of tasks: transactional and non-transactional, user and application.
- Capability of using existing DBMS infrastructure across organizations.
- Low cost of system for the providers and user organizations.
- Ease of modification (re-design), scalability, extensibility and fast design-to-implementation.
- Use of standards, including EDI for interactions between autonomous organizations where possible.
- Security authorization for users and secure communication (required as patient data is typically confidential).



Based on these requirements, we have created a system testbed on which the application is implemented (see Figure 3). This includes heterogeneous server systems (Solaris and NT) spread across CHREF and LSDIS-UGA, use of heterogeneous communication infrastructure, multiple Web servers, CORBA, and five databases. It involves 13 tasks (e.g., tasks for the admit clerk, triage nurse, eligibility check, etc.), heterogeneous computers in Georgia and Connecticut (Web and DBMS servers on Sparc20/Solaris2.4, Sparc5/Solaris2.4, and Pentium133/WindowsNT as well as several PC/Windows95 clients), five databases on two DBMSs (Illustra, ORACLE) and files, etc.

### Benefits, Status, and Plans

Let us now review some of the key features and benefits of the METEOR technology. The cost bearing on the end-user is very low as all interactions with the WFMS are done through a web-browser. The graphical workflow designer eases the workflow definition process. The METEOR approach enables rapid design-to-development via automatic code generation. The workflow model and enactment system support a variety of activities - user and application (automated) tasks, thereby making it feasible for use in real-world organizational processes. The workflow engines support heterogeneous, distributed computing environment with standards based computing infrastructure (Web and/or CORBA). This allows workflow process and data to be distributed within and across enterprises. Reliability is an inherent part of the WFMS infrastructure. The WFMS includes support for error handling and recovery by exploiting transaction management technology. A well-defined hierarchical error-model is used for capturing and defining logical

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errors, and a recovery framework provides support for detection and recovery of workflow system components in the event of failure.

Components of the METEOR system are already being used for early application development at CHREF, South Carolina Research Authority, and NIST. Boeing and Microelectronics Computer Corp. are about to start the same. Serious evaluators and users of the METEOR technology can request a CD with multimedia tutorials, manuals, research papers, etc. as well as receive hands on training. A startup company, Infocosm, Inc., can provide additional consulting and support that is outside the scope of the LSDIS's project. Furthermore, the technology can be licensed for use in a various forms, and it is our intention to provide multiple nonexclusive licenses. Its commercialization with additional venture funds is a distinct possibility.

Besides the METEOR project, the LSDIS-UGA has several projects that range from fundamental research, applied research, and fully functional commercial grade applications. The **CaTCH** (Collaborative TeleConsulting for Healthcare) project is innovating collaboration and collaboration technologies by integrating videoconferencing, application/data sharing, multimedia (patient) records, parallel access over the Web of multiple heterogeneous (healthcare) repositories, scheduling/workflow, and other technologies in one easy to use system. A trial involving echocardiology related consultation with participation of physicians from the Medical College of Georgia is being developed. The **InfoHarness** project addresses the issues of integrated access of heterogeneous media (text, images, structured databases, and in future video) in intranet and Internet environments, without restructuring, reformatting, and relocating existing data. Bellcore, LSDIS's collaborator in the InfoHarness project already has a commercial product called AdaptX Harness based on the InfoHarness system. **CAPA** (Course Approval Process Automation) is a fully operational 35 step Web-enabled workflow application that was completed in record four months period including testing. It may be used by any one of UGA's 3500 faculty members and has already been used to process approx. 6000 new university courses (or corresponding workflow instances).

While the LSDIS competes for the same federal research funds as any other academic research lab or center, its unique strengths include its partnerships with industry on practically all of its projects, substantial sponsorships of its activities by industry, and its proven success in technology transfer. Boeing and MCC are LSDIS's industry sponsors, and Hewlett-Packard is its affiliate. Donations exceeding \$250,000 in value over last 15 months, primarily in terms of software products, have also been provided by Informix (for which the LSDIS is the proud first recipient of the Informix Universal Server under its grant program), Iona, Persistence, Visigenic, Virage, I-Kinetics, PictureTel, etc.

I welcome the reader to visit us on the Web at URL <http://lsdis.cs.uga.edu> where numerous publications, on-line demonstrations (including an audio guided tour of the immunization tracking applications discussed above), presentations, tutorials, and other resources are available. Of course, the readers are also welcome to contact me directly.

### **Acknowledgment**

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Attachment: Workflow Marketplace [see print or PDF version]