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Workflow Application Architectures: Classification and Characteristics of Workflow-based Information Systems

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ABSTRACT

Workflow management systems have come a long way from the first office automation prototypes of the late 1970s. Today, workflow systems are deployed in a variety of situations, ranging from the coordination of document-centric processes in office environments to the automation of application data flow in enterprise application integration scenarios. The variety of applications as well as the diversity of the workflow systems available easily leads to confusion, when the most suitable system for a specific setting has to be identified.

In this paper we present a classification for workflow application architectures. Based on the specifics of the process to be supported, we develop a framework that helps designers and users of workflow applications identify the system type suitable for their specific application. The coordination features and integration requirements of workflow applications serve as guidelines throughout this approach.

Within the organizational dimension, we distinguish between workflow applications at the inter- and intra-organizational level. Within the process dimension we differentiate between workflow-driven software processes, workflow-supported organizational processes, and hybrid processes that combine features of the other two.

FROM OFFICE AUTOMATION TO PROCESS COORDINATION

From Process Thought to Workflow Support

The structuring of organizations along their processes has been a common theme since the 1930s. Authors like NORDSIECK and HENNING in Germany, as well as CHAPPLE and SAYLES in the United States were among the first to point out the potential benefits of a well-managed workflow (see e. g. [3, 11, 17]). Despite these early efforts, a functional separation of tasks, and the resulting functional or divisional structures dominated the corporate practice until the 1980s, when changing market conditions and increasing competition led companies to investigate the efficiency of their process

structures. Following the Total Quality Management movement of the 1980s, numerous process-related management practices emerged in the 1990s, most notably Process Improvement [10], Business Process Innovation [4], and Business Process Redesign [7-9]. Each of these approaches noted the enabling role of information technology for the restructuring of organizations. Consequently, enterprises that engaged in these activities sought adequate information system support for the management of their processes. Workflow management technology is designed to support this exact problem.

Despite claims that the development of workflow applications is tightly interwoven with the business process reengineering movements of the early 1990s (see e. g. [6]), the origins of workflow technology can be traced back to the late 1970s. One of the first concepts of an information system to support organizational processes was described by ZISMAN in his account of the SCOOP system, an office automation system that used Petri-nets to represent business processes [21]. Research in office automation, which flourished between 1975 and 1985, laid the groundwork for the development of industrial workflow applications through the analysis of technology support for administrative processes [5, 13]. While the research interest in office automation vanished by the middle of the 1980s [19], two developments spun off that were targeted beyond the boundaries of traditional office automation: Groupware and workflow management. While research in groupware focuses on the support of unstructured, collaborative activities, research in workflow management focuses on the coordination of activities along a common process model, without the automation of the activities themselves.

Workflow Management Systems as Coordination Tools

From a conceptual perspective, the purpose of a workflow management system is the coordination of all entities involved in the execution of a (business or software) process. Coordination can be defined as the management of dependencies between activities [14], and workflow management systems address two kinds of coordination problems: Data dependencies between activities (i.e.: one activity relies on the results of one or more other activities), which are managed through control and data flows, and shared resources (i.e.: one resource such as a workflow participant can only perform one task at a time), which are managed through scheduling and staff resolution mechanisms. Through the automation of these coordination functions, workflow management systems support several efficiency goals of the enterprise (see ***table 1***).

Efficiency Goal	*Description*	*WfMS Support*
Process efficiency	Optimization of process criteria such as processing time (to be minimized) or faithfulness to deadlines (to be maximized)	Coordination of activities through control flow, deadlines etc.
Resource efficiency	Efficient use of the resources (human resources as well as application systems) available for the execution of processes.	Staff resolution and reminder in case of escalations
Market efficiency	The proper positioning of the enterprise in its relation to market partners. This includes a reliable prediction of delivery times, transparent communication with suppliers and customers and optimized procurement and distribution processes.	Well defined process interfaces for web services (defined external behavior), predictable internal behavior through standardized processes
Delegation efficiency	Adequate use of the competencies of superior (greater scope of vision along the process) and subordinate (detailed knowledge about single activities) organizational units.	Coordination of staff assignment, role concepts
Motivation efficiency	Motivation of staff to act in a way congruent to the business goals of the enterprise.	Guidance to perform activities along a workflow model, monitoring of progress and explanation of previous activities

Table 1: Efficiency goals and workflow support (modified from [1])

It is apparent that the benefits of workflow applications increase with the number of coordination tasks that can be automated through the system. The number of coordination tasks varies with the granularity of the components controlled through the workflow system as well as with the type of the process controlled through the workflow system.

Figure 1 shows a classification scheme for workflow applications based on specific attributes relating to their implementation. The participants of a workflow application can be humans, machine resources (e. g. if production processes are automated) or software components (e. g. if workflow is used for application integration purposes). The structure of the processes automated can be predefined or flexible (ranging from production workflow to ad-hoc workflow applications). The scope of the processes automated can be restricted to a single application in case of an embedded workflow system, or extend beyond the boundaries of a single organization in

case of a B2B application. The granularity of data objects handled within the workflow can be either coarse (if documents or entire objects are passed along the process) or fine (if single attributes are passed between activities). Finally, the granularity of applications invoked within the workflow can be either coarse (e. g. if web services are used in a B2B implementation) or fine (e. g. if single method calls on application components are used).

Attribute	Possible Values		
Participants	Humans	Machines (Hardware)	Software
Process Structure	Ad-hoc Process and Activities	Pre-defined Activites, Ad-hoc Process	Pre-defined Process
Process Scope	Between organizations (B2B)	Within an organization	Within an application
Data Granularity	Documents, Objects	Attributes	
Application Granularity	Process-level (e. g. web services)	Application-level (e. g. programs)	Function-level (e. g. method calls)

Figure 1: Classification of workflow attributes

Using the participant attribute, we can distinguish three major process types, which can be supported through workflow technology:

Organizational processes are business processes with a high degree of human involvement. They typically occur in office environments and consist of a number of human participants working autonomously on activities using applications that may or may not be invoked by the workflow system. The overall process structure is typically coarse and well defined (if the process is well understood, the separation of activities may lead to a finer granularity). A typical workflow application within this category is the routing of document images along a workflow model.

Software processes are automated processes within application systems. Within this category, workflow systems are used to “glue” disparate application system components together and to automate the exchange of data between software components, in case they don’t share the same database. Often, the human element in software processes is restricted to the initiation of the process and the presentation of the results.

Hybrid processes combine the characteristics of organizational and software processes. In this case, the workflow system can work as

an intermediary between the human participants and a (functionally oriented) application system, guiding the work of participants within single activities.

In the following section we take a closer look at the functions and benefits of workflow systems for the three process types described above.

WORKFLOW SUPPORT CLASSIFIED BY PROCESS TYPE

Workflow for the Coordination of Organizational Processes (Workflow at the Meta Level)

Workflow management systems of the first and second generation have traditionally been applied in administrative settings, supplying office workers with the information necessary to perform clerical tasks, routing the results along the process model to the next participant, and supervising the overall process through the handling of deadlines and escalations.

An important component of workflow management systems for organizational processes is the notification of participants about pending activities. This is done through the concept of a work list, through which all qualified participants can access pending work items and select those they wish to work on.[1] The result is a "pull" model of work assignment, where the workflow system has control over priority and presentment of work items, but the user has the ultimate control about the fact, when s/he performs a particular activity.

Due to this concept, it is difficult for the workflow system to predict processing times of activities and/or processes, because the idle time between the presentment of a work item and the activation through a user can only be estimated (if summarized audit trail information is used, the precision of these estimates may increase, compare e. g. [16, 22]). An important feature of workflow systems for organizational processes is therefore the capability to handle exceptions such as activities exceeding deadlines by notifying the responsible party. If this party is not a frequent user of the workflow system (typically the involvement decreases along the hierarchy of the enterprise), the notification has to be transmitted using a medium used by the recipient (e. g. e-mail or pager).

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[1] Typically the presentation of work items is integrated into existing messaging applications or user desktops. This is addressed by the WfMC WAPI specification [20]. Under certain conditions it may be desirable to eliminate the user choice of the next work item. For a brokerage application with a high throughput requirement, an American financial institution decided to implement a "next work item" button, which delivered the next work item to the user. The prioritization was done by the workflow system, eliminating "cherry picking" among the participants.

The autonomy of workflow participants is high in organizational processes, and their consent to the use of workflow technology is crucial for the success of a workflow project in this setting. As a consequence, applications are often invoked in a "black-box" fashion, leaving the detailed use of their functionality to the users in order not to micro-manage them. This means that the workflow system has little control over the applications and the data processed therein. Because the use of the applications within the workflow may create changes to data that is used outside of the workflow, these side-effects need to be taken care of in case a workflow needs to be undone. A truly transactional processing of organizational processes thus requires additional effort in terms of compensation activities in case of failure. It is advisable to design the workflow model in such a way that the human participants have the means to perform local trouble-shooting, in case of an error, and not leave this to the workflow system.

Despite these limitations, workflow applications for organizational processes provide a number of benefits. These mainly lie within the controlled assignment of work and the traceability of processes through monitoring and controlling functions.

Workflow for the Coordination of Software Processes (Workflow at the Micro Level)[2]

The emergence of framework-based application system architectures, such as J2EE or .NET leads to an increasing specialization and fragmentation of application system components. While the modular development of applications enables the re-use of components, a software "glue" is necessary, to tie the disparate application components together to form a coherent, enterprise-level application system.

Within this scenario, workflow technology is used to connect application components along a structured process flow. The processes are defined at a fine level of granularity and the workflow component may act in a transactional fashion, controlling the data transfer to and from components and performing data conversions if necessary. Especially in multi-tiered architectures, that combine a web front-end with an application server at the middle tier and database and/or legacy systems at the back-end, the workflow system can be used to implement concepts such as straight-through processing or access to the same functionality through different clients.

The granularity of the process and the application components typically is fine, and the workflow system is located at the center of a hub-and-spoke architecture. A typical application is the integration of back-end data into an application located at the middle-tier of a

[2] The term "micro workflow" has been borrowed from MANOLESCU, compare [15].

three-tier architecture, such as the nightly update of a CRM application with customer records from a legacy system. Performance considerations play a bigger role in this scenario, since the performance of the workflow component determines the performance of the overall application to a large extent. Idle times are nonexistent, because the workflow component invokes other programs or object methods that are executed right away, resulting in a push-distribution of work items.

The benefits of workflow technology at the micro level lie within the reuse of application components in different processes, the integration of front- and back-end systems along controlled processes and the changeability of applications in case the enterprise processes change.

Workflow for the Coordination of Hybrid Processes (Workflow at the Macro Level)

Companies wishing to streamline their business processes are often faced with an existing information technology infrastructure that has been developed to support the "traditional" functional way of work. Since a new development of existing functionality is costly, companies often strive to retrofit existing applications into new process structures. This can be achieved by creating a lightweight user interface that is controlled by an intermediary workflow component, which in turn invokes the relevant functions of the legacy system without the involvement of the user. The workflow system can perform integrity checks on the data entered by the workflow participant, before it is passed on to the back end system. At this level, the workflow system serves as a guide (or "wizard") for the user through a process-oriented application system.

Figure 2 summarizes the key characteristics of workflow applications for the three different process types.

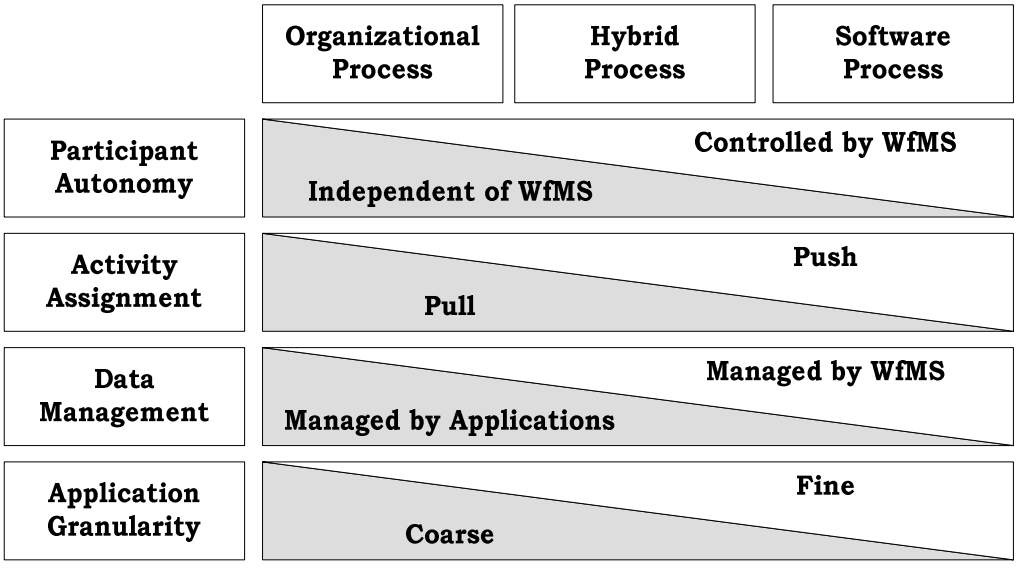

Figure 2: Process Characteristics and Workflow Support

WORKFLOW SUPPORT FOR INTER-ORGANIZATIONAL PROCESSES

The need for companies to expand the automated enactment of their business processes beyond the boundaries of their own organization is driven by the resulting savings in transmission time, gains in data quality and improved monitoring capabilities about processes at the sites of business partners. The current movement toward electronic data interchange is fueled by the relatively inexpensive exchange of business data over the Internet using data encoded in the eXtensible Markup Language (XML), which fosters the development of vendor-independent frameworks that aim to standardize data schemas for common business documents, such as purchase orders, delivery notes, invoices, etc. For a thorough discussion of the role of XML in workflow environments refer to the article by HOLLINGSWORTH [12]. Workflow management systems support inter-organizational processes mainly on the software process level. It should be noted, however, that a number of organizational processes occur at the B2B-level, which may be supported by workflow technology as well.

Software Processes in B2B Settings

For processes across enterprise borders, the significance of automated workflow support at the software process level is high, since many of the interactions between companies are quite standardized (for example the exchange of a purchase order between customer and supplier and the resulting exchange of the purchase order acknowledgement in the other direction, see e. g. [2]). Workflow technology can be used to supervise the correct sequence of documents exchanged, monitor timeouts and supervise the maximum number of retries, in case a message is lost. At the operational level, the workflow system can serve as a gateway to the internal processes of the enterprise. If a standardized message format is used in conjunction with a standardized command set (such as the one defined by Wf-XML), B2B processes can be fully automated, decreasing cycle times and increasing data integrity.

Organizational Processes in B2B Settings

Notwithstanding the benefits of automated B2B processes, the human element in inter-organizational exchanges can also be supported by workflow technology. Since the conversion of data between the internal format of the application of company A, the intermediate format (for example an ebXML document) and the internal format of the application of company B is complex, errors may occur, especially if the overall process has an “optimistic” design, assuming that each company does not modify either its applications or its data formats. The impact of erroneous process instances on the overall economic result should not be underestimated. According to STOHR, each problematic B2B transactions cost 300 percent more than regular transactions (compare [18]). With an increasing automation of transactions, this figure is likely to increase. One possible

approach therefore is the handling of erroneous transactions through pre-defined workflows. Within this scenario, the responsible users from both parties are informed about the error and are provided with a structured process to resolve the problem.

INTEGRATION REQUIREMENTS OF WORKFLOW APPLICATIONS

The design of a workflow application creates integration requirements, which can be differentiated into internal and external integration requirements. Internal integration requirements concern those systems a workflow application needs to connect to in order to ensure the functionality of the core workflow system. External integration requirements exist with regard to systems that either invoke the workflow system from the outside (embedded usage) or systems that are invoked by the workflow application.

Internal Integration Requirements

As stated above, a workflow application coordinates participants, data and applications. Consequently, all these elements need to be integrated to ensure the functionality of the workflow systems.

- **Resource integration** is required by the workflow system to keep track of the participants available for work assignment. Since many companies maintain resource information in X.500 directories or similar applications, a fully integrated workflow application would use this information rather than replicate resource data internally.
- **Data integration** is required to make workflow relevant data accessible to the workflow system. This can be achieved by connecting the system to databases using standard connections such as ODBC/JDBC. If the workflow system acts as an enterprise application integration hub, conversion of data types and field values may be necessary.
- **Application integration** describes the ability of the workflow system to invoke external application systems during the enactment of a process. For organizational processes, applications are often called in their entirety (e. g. a word processing application), while for software processes the granularity of application invocation is at the method or function level.

In addition to these three integration requirements, the use of existing security infrastructures is another important feature of workflow applications.

- **Security integration** relates to the use of existing authentication and authorization mechanisms through the workflow system, such as single-sign-on and public key infrastructures.

External Integration Requirements

The external integration of a workflow system relates to the fact, that a workflow system is, after all, an application system in itself. External applications may require calling the services of the workflow engine from the outside, invoking processes, querying the status of work items or handling resource assignments through external scheduling mechanisms. On the other hand, the workflow system may be required to present work to outside parties, which are not participating in the workflow application.

- **External invocation of the workflow engine** is used for example in B2B process integration. The workflow engine can exhibit itself as a service to outside parties, allowing them to invoke a process and pass initial data to the process instance. Examples for the external invocation are e-mail (mail daemon triggers the workflow), the web (a web server triggers the workflow) or other applications, which embed the workflow system (a function within an application results in the start of a workflow).
- **Presentment of information to outside parties** is necessary, if the workflow system has to notify external participants about the status of "their" workflow instance or if system load information is passed on to external system management tools. Also, the use of audit trail information through external applications falls into this category.

Figure 3 summarizes the internal and external integration requirements of workflow applications.

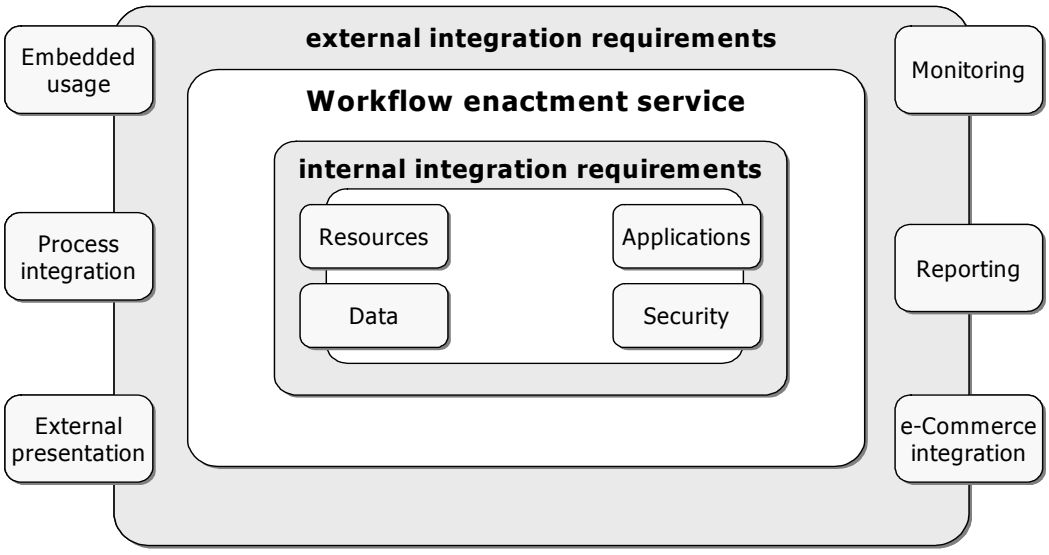

Figure 3: Internal and External Integration Requirements

CONCLUSIONS

Workflow management systems can be deployed in various scenarios, ranging from human-centered organizational processes to autonomous software processes, both confined to or extending beyond the boundaries of an enterprise. Each of these scenarios utilizes the coordination functions provided by the workflow system in different ways and requires integration to a different set of systems. Understanding the differences between these applications and their requirements is an important step for potential users of workflow technology.

Even though the concept of automated workflow management can be traced back for more than 25 years, there are still numerous open research issues, ranging from the organizational impact of workflow technology to integration issues in inter-organizational settings. For the future we expect the coexistence of various types of workflow systems within one organization. Their seamless integration is one of the great challenges of workflow research.

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