Workflow Management Systems and Agents - Do they Fit Together?

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Abstract. Workflow management systems are an emerging category of information systems, currently under dynamic evolution. On the other hand software agents is a distinct research area and an also emerging paradigm for information systems design and development. In this paper, I outline the major points of a doctoral thesis that will focus on the intersection of these two fields. I try to clarify the thesis specific objectives and describe the motivation underneath. The general methodology as well as some initial findings are also described.

1 Introduction

Workflow Management Systems emerged in the Information Systems landscape as a promising office information systems technology at the 70s. During the 80s, they have evolved into enactment machines of operational models. Their critical feature of that time was that they were too rigid to support the integration of human activities. This essential requirement advantaged the development of systems that could support collaborative work. Singh and Huhns [1] support that “Workflows have been with us from the dawn of time” and sectionalize the systems into five generations: Starting from the “manual” ones which were a side-effect of bureaucracy; they continue with the “closed” ones that focused mainly on data processing and on the automation of the existing manual activities. The third generation concerned the “database-centric” systems. It was then when data and process appeared to decouple themselves. The next generation refers to the current situation. This generation’s systems provide the separation of control from the application. Finally, Singh and Hunhs predict that the next generation will incorporate agent-based systems.
Abott and Sarin [2] provided a different taxonomy of the WFMS. They name as “first generation” systems the systems that were “application-specific”. Those systems were tightly related to specific functions (e.g. document management) and they were closed and proprietary. During the second generation, the workflow logic is separated from the application one; while the integration of third-party tools becomes available. Current situation is mapped on the third generation. Contemporary WFMS provide access to other applications through APIs and they integrate third-party tools as well. They adopt standards-based architectures and they become far more user-friendly. Abott and Sarin’s prediction for the next generation describes a ubiquitous environment; interchange of data and control is the focal event. Sheth and his

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colleagues [3] illustrated the evolution of the WF runtime system architectures. Starting from centralized / one-engine early systems, the architectures evolved to more distributed ones; including web-orientation and mobile-agents enhancements. As depicted in [3] the evolution will continue by supporting organic processes. In [4] a very explanatory figure demonstrating the history of automation and workflow systems is provided.

My thesis is trying to keep a pace with the technological advancement of WFMS and strives to make a contribution towards more open and ubiquitous workflow architectures. The specific objectives and the research problem I am focusing on are described in the next section, while in section three I briefly discuss existing work, research trends and motivation. In the last section, I present the work made so far and discuss the next steps and how I am planning to achieve them.

2 Objectives of the Research

2.1 General Objectives

Different types of theses have been identified in the literature (Table 1). My thesis is dedicated in providing a unifying framework and providing a new tool for verification purposes.

Table 1. Types of Ph. D. Theses.

Opens up new area	Produces an ambitious system
Provides unifying framework	Provides empirical data
Resolves long-standing question	Derives superior algorithms
Thoroughly explores an area	Develops new methodology
Contradicts existing knowledge	Develops a new tool
Experimentally validates theory	Produces a negative result

More specifically, my thesis is situated in the intersection of two fields: Workflow Management Systems and Software Agents. It tries to unify these fields by examining their interactions. Although both software agents and workflow management are established areas of research, few works focus on their intersection. The overall objective of the thesis is to identify the agent contribution potentials in WFMS and to provide efficient solutions in those niches.

2.2 Research Problem

Following the general objectives defined in the previous paragraph, agent contribution potentials to WFMS are identified and classified. For the classification criteria we adopt the concept and the standards of WfMC [5]. The reference model that WfMC provides is broadly accepted in an area where a bold confusion of standards exists. Adopting a popular reference model will hopefully make the thesis contribution more identifiable and easier disseminated.

The first challenge is to propose a functional decomposition along the reference model of WfMC. Then, for each function, existing approaches should be categorized. Every function is a distinct operational utility of WFMS (e.g. scheduling, task assignment, resource allocation, etc.), thus established methodologies from operational research could be exploited to provide efficient solutions. The major endeavor is then to adjust OR methodologies into an agent-oriented workflow management system architecture.

3 Research Agenda – State of the Art

3.1 Trends and Standards

The term "workflow" is overloaded to the point where it is hard to distinguish what a WFMS is meant to achieve. This happens mainly, because there is a variety of scenarios where workflow technology is applied: diverging from Human WF to document management; Business Rule-Driven WF; ISO certification claim; process controlling; composite WF for Service Oriented Architectures; groupware; grid computing; enterprise application integration, just to name a few.

Due to its interdisciplinary nature, workflow research cuts a generous swath across many fields. Storh et al. [6] classify the active research efforts into 3 categories: Technical issues; Management and organizational issues; and market, economic and social issues. Li et al. [7] discern two trends in current workflow research community. One trend embraces the Web services paradigm and strives to develop WS-related architectures and methodologies (choreography, orchestration, Process definition exchange, service discovery, message exchange, coordination). The other focuses on overcoming the limitations of traditional workflow management concerning adaptability and flexibility.

3.2 Requirements and Limitations of Existing WFMS

WFMS are currently an active field of enterprise information systems, thus some functional requirements that could put added value are identifiable: WFMS should find a way to manage the dynamic nature of business processes. As business processes become more volatile; and as they start crossing the organization's boundaries, their interactions need a rather sophisticated supervisor. Within business processes, many tasks are interrelated; responsibilities and data are distributed [8, 9]. This natural concurrency demands efficient techniques for task assignment; resource allocation and scheduling. Moreover, in the case of multiple service providers, the WFMS should be able to semantically discover the appropriate service providers; negotiate with them and finally allocate them the work. Failures and exceptions must be tackled adaptively and efficiently.

Contemporary WFMS must be able to operate in a pervasive computing environment. They should be able to integrate external applications; other WFMS; heterogeneous devices and legacy systems. Operating in the web appears a sine qua non requirement; while supporting the users with friendly and customizable interface would promote their application. Scalability; security and reliability still remain critical requirements.

Considering the above requirements, many researchers have exposed the limitations of existing systems [9-17]. WFMS lack of adaptability: most of them require an a priori representation of a business process and all potential deviations from that process [13]. They can not response in a reactive way to exceptions that may occur during the execution of a process instance. They are unable to cope with dynamic changes in resource levels and task availability, as they tend to lack the necessary facilities to redistribute work items automatically as and when required [11]. They suffer from disadvantages such as not supporting the dynamic incorporation/modification of process models; poor adaptability of process models at runtime and they are incapable of integrating distributed process models [18]. The static workflow definition and its passive interpretation do not allow WFMS to demonstrate flexible behavior and to deal with real-life situation such as fast changing customer requirements and enterprise goal shifts [15, 19].

WFMS lack of resources management facilities [11, 13, 16]. They focus on the administration[20] of processes and they pay less or even hardly any attention to the problems such as the resource allocation and the resource restriction [20]. Resources conflict is seldom monitored as WFMS tend to manage independently resources in an organization. This kind of conflicts may become even more critical in the case of cross-organizational workflows. In addition, tasks are associated with users (actors) rather than roles [10]. Role management is a feature that still does not exist in many systems.

Authors of [13, 21-24] noticed very early that semantics is a feature that can lift up workflow functionality and that existing systems lack of them. Through the use of semantics the decisions will be further automated; negotiation among actors will be enabled; optimization of processes and learning features will be disposable; and compensation activities will have a formal basis to lie on. Unfortunately, the use of semantics is still in infantile level of integration in existing WFMS. They have a weak support of correctness and reliability [25]; inadequate exception handling [11, 12];and limited or non-existing optimization features.

Existing WFMSs tend to be centralized while their runtime systems are based on the client-server model [26]. Relying on one central control does not allow systems to support reliable and consistent process execution with acceptable failure resiliency, performance, and scalability. WFMSs operate in splendid isolation and they represent islands of automation that provide inflexible tactical solutions [14]. They lack of heterogeneity [13] and they have poor support of interoperability [25]. Although WfMC strives to establish generic interfaces and to enable interoperability, when WFMSs need to exchange data they use distinct APIs calls [16]. This fact limits significantly their extensibility [9].

3.3 Why Use Agents?

Agents are not the panacea for all the WFMS problems and limitations. Yet, they constitute an attractive metaphor that advances WF development.

In [27], Lange and Oshima promote the use of mobile agents in the distributed systems field by demonstrating seven arguments. In the same paper, they present a few application areas where the agents' paradigm could flourish (workflow is indeed included). Mobility infuses agents with the ability of migration. This potential allows one to decentralize a WFMS [28] and exploit the benefits of both distributed WFMS [25, 29, 30] and of the agents paradigm in distributed systems [27].

By their nature, agents support heterogeneity. By using an abstract communication and coordination level, they can be incorporated into the varying hardware and operating systems architectures that dwell in a business process [28]. This enhanced coordination ability allow agents to act as configuration facilitators [31, 32] and advances them as a promising technology for application integration [33].

Agents modular nature can provide highly reusable workflow architectures [34] which not only are an alternative technology to existing workflow systems but most importantly, they also offer an alternative vision of how organizations can be structured and managed [13].

Agents (being autonomous) can relief WF engines from some computation. Consequently the engines' workloads shall be reduced favoring significantly WFMS scalability [35]. They enable the recovery process as they are stateful entities, contributing significantly to the fault tolerance of the system. The encapsulation of state also supports the asynchronous execution of a business process, a popular case when human participants are involved [28]. As a more general contribution, we may notice that the agent paradigm supports the vision of human substitution: the inherent autonomy of software agents can fulfil activities on behalf of human with an expected quality of service.

Another core feature of agents, reactivity, provide them with an intrinsic capability to adapt to dynamic changes in the environment [34]. Actions do not need to be rigidly prescribed as agents can anticipate their environment and timely as well as efficiently respond to the changes that occur [9, 36]. Besides reactivity, pro-activeness can boost agents' intelligence. Agents can adopt feedback mechanisms to guide themselves during future actions [9]. They can implement intelligent decision-making techniques such as negotiation [8]; semantics [16, 37, 38]; planning [18, 39]. Moreover, agents would be able to perform optimization tasks as routing and scheduling [35, 40]; task assignment [41]; resource allocation [10]. In [20], Qiu et al. advocate that problems such as resource collision and low efficiency of resource utilization can not be readily addressed unless agents join the system.

Of course, designing an agent-based system is far more complicated than relying on a traditional WFMS. One shall always balance the trade-off between design and development complexity and efficiency and effectiveness. Let us provide a list of cases when the agent paradigm appears to be an eminently suitable technology for workflow management:

- Process definitions can not describe entirely the problem solution [8] or can not predict all possible paths of the process execution.
- Interactions among tasks and/or participants are fairly sophisticated [8]

- Applications that are modular; decentralized; and changeable [42]
- The environment demands asynchronous communication [43]
- The environment is radically heterogeneous
- The applications call for extensive human participants integration [28]

4 Expected Outcome

As mentioned in section 2.2 the initial phase of the thesis is to identify the functions of a WFMS where agents could contribute. These functions are categorized according to the WfMC's reference model and presented in Table 2. Although the proposed classification schema needs justification, it would be out of the scope of this paper, hence omitted.

In the ideal situation the ultimate product will be an agent-oriented workflow management system that will demonstrate how agents can add value to every function mentioned. In a more realistic scenario, it is possible to design an operable agent-oriented architecture that would exploit the advantages of agents and overcome some of the limitations mention in section 0.

In [44], we present a first proof of this vision: an agent-based workflow architecture exploits an efficient algorithm for dispatching tasks. A robust mathematical reasoning model is employed and it allows agents to optimally distribute the workload. We have reasons to believe that this reasoning model could be expanded in order to address more workflow basic functions (resource allocation; scheduling). We plan to base the system's development on this reasoning model so that the system will be as much autonomous as possible. Hopefully, a consistent reasoning model will guide both the administration of the business processes and agents coordination. In addition, we plan to "agentify" heterogeneous devices (e.g. PDAs) so that they could be integrated into the unifying agent architecture of the system. Finally, business process modelling standards will be adopted, in order to facilitate the system's interoperability.

Concluding this paper, agent paradigm seems to have a large potential in the workflow area. Still, their integration into WFMS is not straightforward. In fact, if there has to be a trade-off between workflow functionality and exploiting the agents' technology, then probably the latter argument will not be favoured. So, this thesis should provide a unifying framework that will demonstrate that agents not only they do not limit workflow functionality, but indeed, they enhance workflow operations.

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Table 2. Functions of WFMS where agents could contribute.

Interface 1: Process Definition Tools	Analyze; model; compose; describe; and document a BP
	Process Definition Write / Edit
	Definition Retrieval
Interface 2: Workflow Client Applications	Worklist Handling
	Process Control
	Data Handling
	User Interface
Interface 3: Invoked Applications	Worklist Handling
	Process Control
	Data Handling
	Service Discovery
Interface 4: Workflow Interoperability	Common Interpretation of Process Definition
	Control Information Interchange
	Data Interchange
Interface 5: Administration & Monitoring Tools	User / Role Management
	Audit Management
	Resource control
	Process Monitoring
Workflow Enactment Service	Runtime Control Environment
	Definition Interpretation
	Execution of Tasks
	Scheduling
	Data Functions
	Task Assignment
	Resource Allocation

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