Agent Enhanced Workflow

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In agent-enhanced workflow, a community of intelligent, distributed, and autonomous software agents is used to improve the management of business processes under the control of a workflow management system. These improvements are achieved by allowing the software agents to negotiate with each other to establish contracts that govern the distribution of work across a number of processing centres. Furthermore, the agents collaborate to perform real-time exception handling, and to co-ordinate the redistribution of work items to meet changing circumstances.

1. Introduction

Agent-enhanced workflow is a technique whereby intelligent, distributed, autonomous software agents are used to improve the management of business processes under the control of a workflow management system. It represents a first step towards agent-based process management, a paradigm in which intelligent software agents manage the provisioning, execution and exception handling of end to end business processes [1]. The authors believe that agent-enhanced workflow represents a viable means of exploiting agent technology for process management in the short term, whereas agent-based process management remains the ultimate goal.

The workflow ideal can be described as

> *"the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action according to a set of procedural rules"* [2].

A workflow management system is a commercial implementation of this ideal, and is frequently deployed in situations with clearly defined and well understood business process, where high volumes of work items requiring rapid turnaround are handled.

One of the key weaknesses of the current generation of workflow management systems is their inability 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. This currently requires human intervention, and is a highly skilled, time consuming and thus expensive process.

In agent-enhanced workflow, software agents are used both o negotiate the distribution of work items and to collaborate to perform real-time exception handling. Similarly these software agents can be used to manage overall resource levels, bringing individual resources on and off-line as required, to accommodate peaks and troughs in the incoming workload.

The remainder of this paper is as follows: Section 2 describes a typical workflow management problem, a Correspondence Handling Centre (CHC), and outlines the main shortcomings with current workflow solutions to this problem. Although the CHC business process is used in this paper, agent-enhanced workflow is also applicable to domains such as call centres and supply chain management. In principle, any business model (from an internal market to a virtual enterprise) that requires mediation or negotiation in order to balance the distribution of work could potentially benefit from agent-enhanced workflow. In Section 3, we describe an implemented agent-enhanced workflow solution to the CHC problem. Section 4 discusses other related work, and Section 5 concludes the paper.

2. The Correspondence Handling Centre Domain

The problem described here is that of an enterprise receiving a stream of correspondence from its customers concerning its service offerings. These requests are fed into the enterprise's correspondence handling centre, a logical entity which may

incorporate one or more processing facilities that are operated by third-parties (i.e. out-sourced).

The correspondence-handling centre is composed of a number of disparate Work Processing Centres (WPCs) and a Central Administration (CA) as shown in Figure 1.

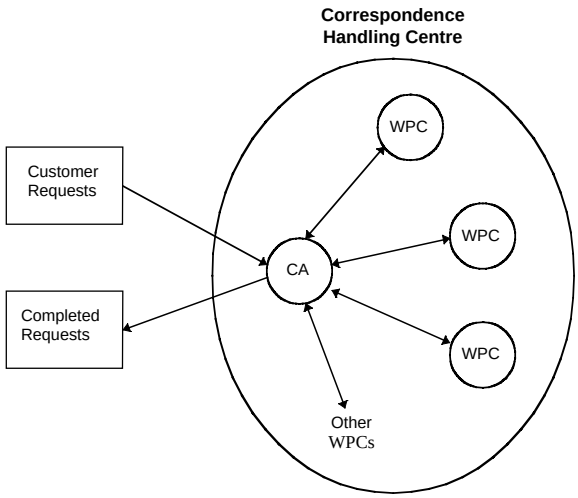

Figure 1: Correspondence Handling Centre context

A correspondence-handling centre may handle all or part of the correspondence received by the enterprise it serves. This correspondence is of many types, ranging from requests to quote for new business, through complaints about existing goods or services, to requests to modify or remove/cease goods or services already provided.

The business process used in our scenario is shown in Figure 2 and is based on a simplification of the process in a typical correspondence-handling centre. It includes six specific categories of activity – reception, classification, distribution, processing, inspection, and dispatch. Of the six activities, only 'processing' is performed by the WPCs, the rest are the concern of the CA.

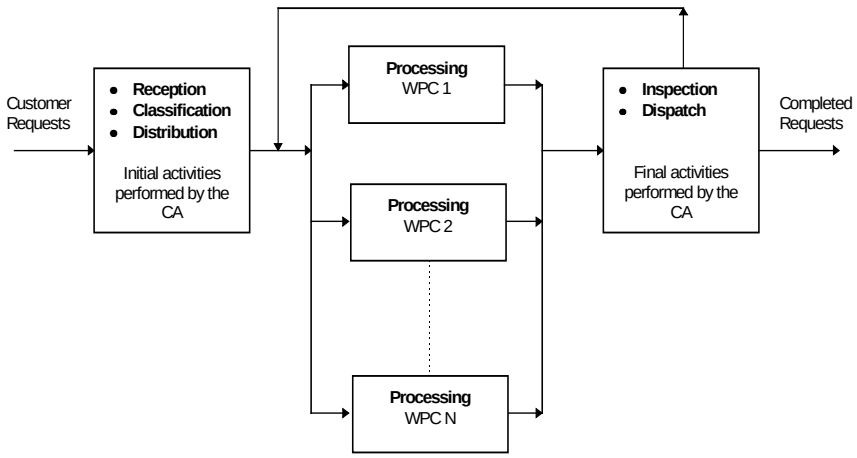

Figure 2: Simplified correspondence-handling centre business process

2.1 Limitations of Current Workflow Management Technology

Workflow management systems are employed in many industries to automate business processes such as the correspondence-handling problem. However, current workflow systems suffer from a number of shortcomings, including[1]

- the inability to cope with dynamic changes in resource levels and task availability;
- a lack of resource management facilities;
- inadequate exception handling, especially during the processing of decomposed items;
- a limited ability to predict changes, due to external events, in both the volume and composition of work entering the business process;
- the inability to improve dynamically both the business process and how it is managed;
- a limited or non-existent ability to manage the decomposition and re-combination of complex items.

These shortcomings manifest themselves as a mismatch between the actual capacity of work a work-processing centre can undertake and the work offered to it at a given time. This in turn leads to sub-optimal throughput, necessitating wasteful over-provisioning of resources and/or backlogs of work.

3. The Agent Enhanced Workflow Solution

As Figure 3 shows, agent-enhanced workflow for the correspondence-handling centre problem is realised via the addition of a software agent layer above an existing workflow management system. The correspondence-handling centre consists of a workflow management system which is used to automate the business process shown in Figure 2, and a collection of tasks and resources that are respectively enacted and consumed by that business process. In our scenario there are two types of software agents - the Central Administration Agent (CA agent) and the Work Processing Centre Agent (WPC agent). The CA agent is responsible for managing the activities of the central administration and the WPC agents are responsible for managing the activities of the work-processing centres.

The basic premise of agent-enhanced workflow is that the agent layer manages the overall distribution of work by establishing contracts that are used to regulate the flow of work items, within the workflow management system, between the CA and individual WPCs.

The two classes of exception that are handled automatically by the agent layer are referred to in this paper as external and internal deltas. An ‘external delta’ is a significant positive or negative change in the amount and/or composition of work received from the outside world. An ‘internal delta’ is similarly a significant positive or negative change in the amount and/or composition of work that a WPC can currently process, despite having agreed a contract with the CA agent previously. It is important to note that any change to existing contracts requires the consent of both the CA agent and the WPC agent concerned.

[1] The major challenges relating to scalability, adaptability (i.e. dynamic workflow), and support for collaboration are detailed in [16].

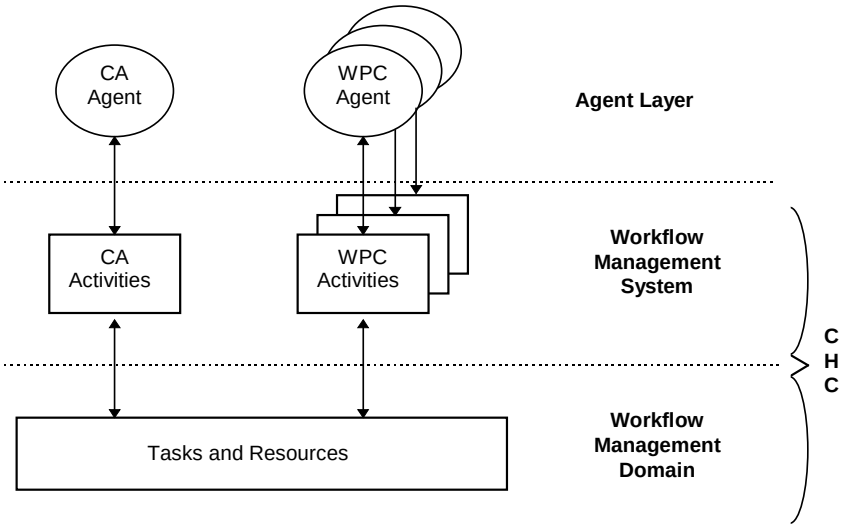

Figure 3: High Level System Architecture

3.1 Structure of the Software Agents

Both the CA and WPC agents implement a simplified version of the Agent Based Process Management System reference model [1] architecture, which includes communication, environment and collaboration modules.

The communication module enables the agent to communicate with other software agents, the underlying workflow management system and end users. In addition, it provide a mechanism for intra-agent communication.

The environment module contains information of each agent's operational characteristics such as their business objectives. The co-ordination module contains the algorithms and strategies that are used while negotiating for contracts.

3.2 Collaboration between the Agents

The co-ordination strategy used by the software agents in our CHC scenario is an extended form of the standard contract net protocol [3,4]. In contract net, at the start of a bidding process, a manager announces a contract to all potential contractors. The contractors return bids for the contract. Next, the manager evaluates the return bids, selects a winning bid, and awards the entire contract to the contractor that returned the winning bid.

In contract net terms, the CA agent assumes the role of the manager, divides the problem (work distribution) into sub-problems (distributing work items), searches for contractors to carry out tasks and monitors the overall solution by maintaining local copies of all its contracts. The WPC agents assume the role of contractors who carry out sub-tasks of processing work items. The CA agent starts with a large volume of work, possibly more than the capacity of any one contractor. In the bidding process, as shown in Figure 4, it progressively excludes *successful* bidders of portions of the total work. This results in a distribution of work across a number of contractors, rather than a 'winner takes all' scenario.

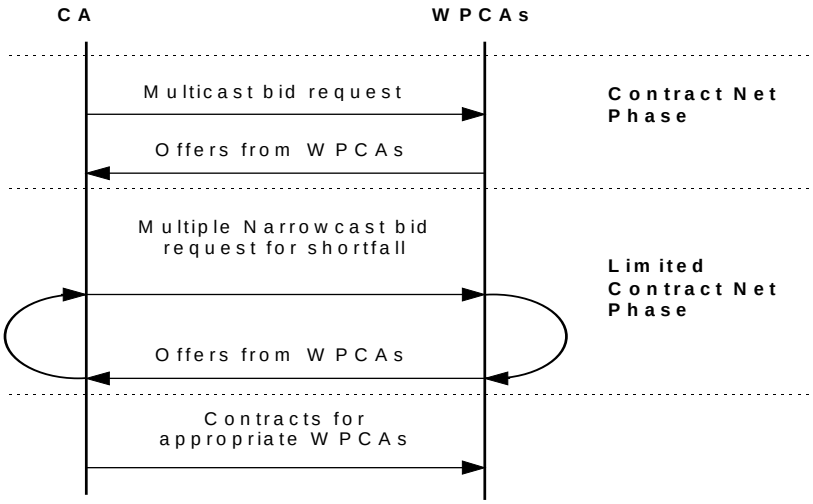

Figure 4: Software agent negotiation protocol

3.3 Agent Enhanced Workflow Demonstrator

We implemented a demonstrator system of the agent-enhanced workflow solution to the CHC problem, which consisted of a layer of software agents, a commercial workflow management system and a CHC domain simulator. The workflow management system implements the CHC business process of Figure 2; the CHC domain simulator drives work through the workflow management system in accordance with the current version of the distribution plan.

A three-tier architecture was adopted, with a Frontware layer of information and control GUIs, a Middleware layer comprising the distribution mechanism, and a Backware layer made up of the functional engines of the various components.

3.3.1 Technologies Used in Agent Enhanced Workflow Demonstrator

Backware: In order to allow platform independence, the software agents were implemented in Java using the JDK1.1 development kit. The correspondence-handling centre domain simulator was written in C, and runs on a UNIX platform. The workflow management system was a commercially available third-party product.

Middleware: This was based upon a commercially available, CORBA 2-compliant, distributed computing platform, and came in two different flavours: Java-to-Java for inter- and intra-agent, and agent to Frontware communication; Java-to-C++ (known as the 'Sworb') for agent to workflow management system and agent to correspondence-handling centre domain simulator communication.

Frontware: The software agents used GUIs implemented in Java to provide administration and reporting tools for the end user. The CHC domain simulator ran in the background, and printed status messages to standard output. It had no GUI of its own as it was under the control of the software agents and enacted the latest version of the distribution plan that the agents have created.

Figure 5 illustrates the physical distribution of the demonstrator system components.

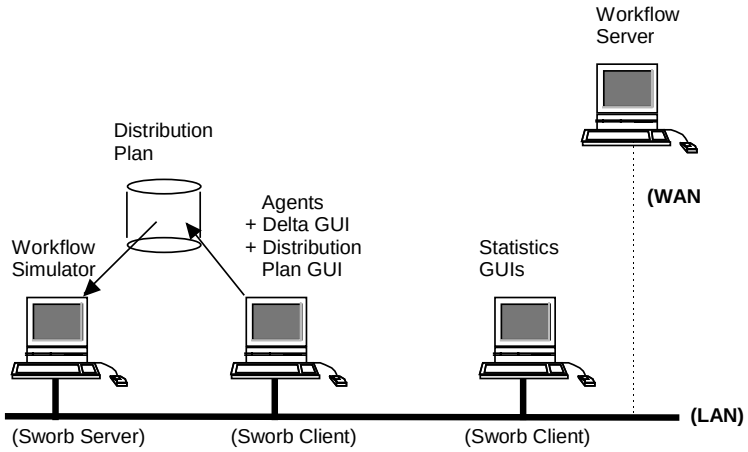

Figure 5: Physical Distribution of Demonstrator System Components

3.3.2 Demonstration Scenario

In the demonstration scenario, three WPC agents were used (WPC1, WPC2 and WPC3), along with three work item categories, designated A, B and C. Figure 6 shows one steady state condition at the correspondence-handling centre: 'Existing Contracts' shows the distribution of work by category across the WPCs; 'Unallocated Work' shows that the CA agent has been unable to place some category A and B work; 'Unavailable Work' shows that WPC3 has not been provided with all of the category C work which it had successfully bid for.

Existing Contracts

Work category	WPC1	WPC2	WPC3
A	10	20	10
B	20	10	20
C	30	20	10

Unallocated Work

Work category	Excess rate
A	10
B	20
C	0

Unavailable Work

Work category	Deficit rate	Owed To
A	0	-
B	0	-
C	20	WPC3

Figure 6: Steady State Conditions

To drive the demonstrator, an external delta is generated by the user and sent to the CA agent (see Figure 7). Upon receipt of this external delta, the CA agent attempts to match its contents against details of unavailable work. Matching items are removed from the delta and added to the distribution plan. The CA agent then adds any

previously unallocated batches to the modified delta, and constructs an initial bid request (**Error! Reference source not found.**), which it sends to the WPC agents. This bid request contains details for each category of work that the CA agent is trying to distribute, including required start and end times, work rate (i.e. items per unit time) and quality thresholds.

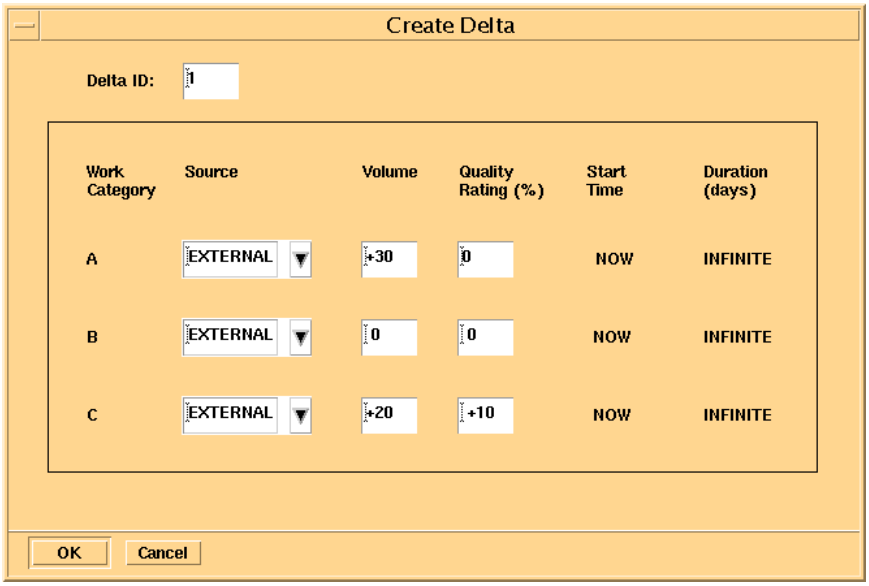

Figure 7: Simulating an External Delta

Work Item category	Rate Change	Quality Change	Start Time	Duration
A	+40	0	NOW	INFINITE
B	+20	0	NOW	INFINITE
C	0	0	NOW	INFINITE

Figure 8: Initial Bid Request

Each WPC agent determines its response to the bid request, and sends a bid response to the CA agent. (A WPC agent can decline to respond if it cannot process any additional work in the time period specified in the original bid request).

As well as bidding for *some* or *all* of the offered work, a WPC agent can make an overbid, i.e. bid for more work than was actually offered by the CA agent. If accepted, the CA agent records the details of the overbid (as 'Unavailable Work'), with a view to offsetting it against the contents of subsequent deltas.

The CA agent either waits for replies from all of the WPC agents to arrive, or for some pre-determined time-out period to expire. Received bids are ranked in ascending cost factor[2] order.

The lowest 'cost' bid is used as the basis for the next round of negotiation. If this bid accounts for all the offered work, then this branch of the negotiation is terminated. Otherwise, the CA agent generates a new bid request message to cover the difference between the quantity (per unit time) of each work category covered by the bid response with the lowest cost factor, and the requested rate for each work category

[2] Further details on how this ranking is performed are given in [6].

contained in the original bid request. The new bid request is narrowcast to the remainder WPC agents – i.e. the WPC agent that supplied the lowest cost bid is excluded from the list of recipients. The process continues until either all of the work has been accounted for, or there are no more WPC agents to solicit bids from. Any outstanding work is recorded for distribution at a later time.

Once the lowest cost (as opposed to ideal) solution has been found, the CA agent records the details of the new contracts and forwards the updated distribution plan to the end user for confirmation, prior to dispatch to the Workflow Management System for implementation. Figure 9 shows the end user view of the distribution plan.

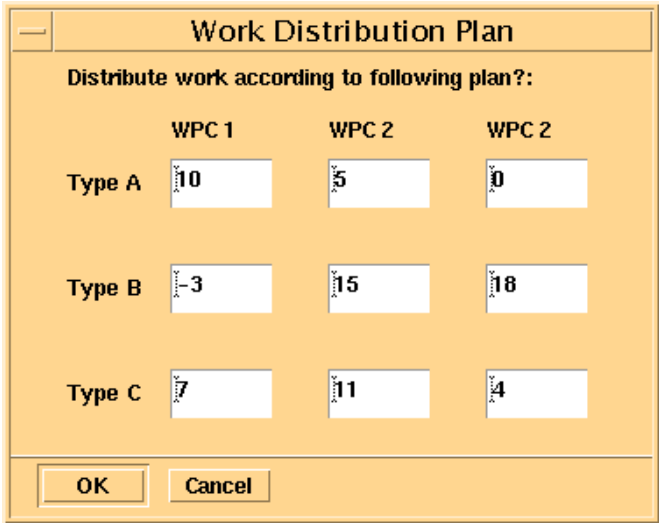

Figure 9: Work Distribution Plan

3.3.3 Handling an Internal Delta

When a WPC agent is alerted that its WPC's ability to process work has been reduced for any reason (e.g. 'flu' epidemic, local public holiday) it generates an internal delta. This contains details of the categories and rates of work that the underlying WPC wishes to return unprocessed to the CA, along with the details of the period for which this shedding of work is requested.

Upon receipt of an internal delta by the CA, it is converted to the equivalent of an external delta, by the simple expedient of reversing the signs of the work rate values. The negotiation protocol is then very similar to that for an external delta, the one difference being that the initial bid request message is not sent to all WPC agents as before. This time the CA agent begins with a narrowcast - the initial bid request is sent to all WPC agents except the one that raised the internal delta. The process continues until the lowest cost, available solution has been found, details are updated and end user confirmation is sought, as before.

4. Related Work

There is a growing amount of interest in the use of intelligent software agents for business process management. Recent research includes the following:

- competitive work distribution, make/buy decisions [6], extended contract net and a co-operation model for resource scheduling [7];
- self interested agents using real-time negotiation with bounded costly computational resources [8];
- learning based on past performance [9];

- workflow architectures such as 'intercorporate linkage' and 'intracorporate integration' [10], and web-based architecture for distributed workflow [11].

Although such work has combined to make the vision of agent-based process management (as defined by the ADEPT project [1]) seem increasingly realisable, in reality there are still a number of issue to resolve. Not least amongst the challenges is the need for the widespread adoption of standards for agent communication, in-service agent management and agent software integration.

A number of white papers, and even some early product offerings, espouse the notion of 'agent-oriented' business process management solutions, for example business processes and mobile agents [12], Plexus agents [13], Agentis/SPOC [14]. It would appear that 'agent-oriented' in this context refers to agents that are vendor specific implementations, intended to be tightly coupled to a particular product offering.

Some early investigations into the combination of agents with a leading groupware product are described in [15]. Although groupware applications address a different market segment to workflow-based solutions, such work is of increasing interest, as the gap between groupware and workflow is steadily diminishing.

5. Conclusions

This paper has described how a layer of intelligent collaborating software agents was developed and used to enhance a commercial Workflow Management System, in order to address some of the shortcomings of Workflow. The addition of the software agent layer means that the Workflow Management System is able to react to changes in the working environment automatically. In the Correspondence Handling Centre domain, this includes both changes to the internal resource levels of the Work Processing Centres, and to the rate and mix of work presented to the Correspondence Handling Centre as a whole.

Agent Enhanced Workflow technology builds on previous work in the field [1], and is intended to show how software agents could be used to provide an 'early win', prior to the full scale commercialisation of Agent Based Process Management. Agent Enhanced Workflow could help automate the management of business processes to a much greater degree than has been possible before. The potential benefits include a reduced need for human intervention (which impacts the overall cost of managing the business process), and improved response times when handling exceptions (leading to increased customer satisfaction).

6. Acknowledgements

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