F. Dignum and G.-J. Houben. Integrating Information Systems: Linking Global Business Goals to Local Database Applications. In *Transactions of the Society for Design and Process Science*, Vol.3, Nr.1, March 1999, pages 43-53.

Integrating Information Systems: Linking Global Business Goals To Local Database Applications

F. Dignum and G.J. Houben

Faculty of Mathematics & Computing Science
Eindhoven University of Technology
P.O. Box 513, 5600 MB Eindhoven, the Netherlands
phone: +31 40 2472733
fax: +31 40 2463992
email: {dignum,houben}@win.tue.nl

Abstract

This paper describes a new approach to design modern information systems that offer an integrated access to the data and knowledge that is available in local applications. By integrating the local data management activities into one transparent information distribution process, modern organizations can offer better support for its workers in the execution and coordination of their work activities.

The new generation of information systems is characterized by systems that are decentralized, autonomous and heterogeneous. Observing practical applications we can see the deficiencies of the currently available approaches to model such information systems. They do not acknowledge the pivotal role that (informal) communicating workers play in the context of an entire organization. The interaction between the members of social, informal groups of employees make that (in many of today's information-intensive enterprises) the local structured procedures can be effectively and flexibly integrated into global work processes supporting the business goals.

Traditional design techniques concentrate on either the structured local procedures (and its local database applications), the structured global process (and its global business goals), or the informal (less structured) communication between individuals. We suggest to combine an activity-based model (suited to describe the structured parts of the processes) with a goal- or conversation-based model to tie the different elements together.

Using an agent architecture we show that it is possible to implement this integrated approach. The different types of cooperating agents support the individual workers by assessing the goal of the activity, the applicability of the standard procedure, and the availability of alternative knowledge and information in order to supply the necessary information.

A characteristic property of the approach is the focus on the processlike management of data. Treating the collection of documents as any other warehouse results in an information system that supports more than just the retrieval of documents. By truly supporting the global business processes the information system is less vulnerable in handling exceptions and inconsistencies and much more targeted at the global business goals.

1 Introduction

Modern business applications of information systems show a trend towards the development of systems that are decentralized, autonomous and heterogeneous [KUW]. The new generation of information systems is characterized by the combination and integration of local information systems (mostly databases), each with their own intended purpose and goal. Often we see that the goals of these local information systems are independent and that the integrated information system reuses the information from the local systems for new purposes and new goals. Related to this reuse of information is the fact that these local systems often are implemented differently, resulting in the use of heterogeneous information in the integrated information systems. All these aspects make that these new integrated information systems require new design approaches.

Another issue that has its consequences on the need for new design methods, is the role of local work activities within the global organizational processes. More and more we can see that the global work processes are perceived as highly structured processes. The success of workflow management and work activity coordination results from the approach to view the coordination process as *the* means to have a grip on the business. While this business process can indeed be considered to be highly structured, the activities that make up the business process are not as structured at all. It is true that the local activities, as they are performed by the individual office workers, usually are the application of standard structured procedures (involving standard database applications). However, the connection between the high-level structured business process and the local procedures and applications is realized by an intermediate level. In our perspective this level or layer of work is implemented by the communication that takes place between the individual workers: they act as the linking pins. They decide within the high-level structured business process how they perform the local activities: by assessing the local procedure and its associated application they choose to use or adapt that procedure in such a way that the intended goal is reached. It means that they should assess the functionality of the local (database) applications while using it to achieve higher level goals. This implies different requirements for the new generation of integrated information systems.

In the remainder of this paper we present a new integrated approach. In section 2 we discuss modern applications involving integrated information systems, we describe the requirements for such systems and we conclude that existing approaches do not suffice. In section 3 we concentrate on the global processes and we look at the process aspects that are relevant for integrated information systems. Section 4 addresses the role of the local users and the relevant aspects that should be acknowledged in a new approach. In section 5 we look at the integration and we combine all relevant aspects. Section 6 describes the new modeling approach and it illustrates the approach using small parts of a banking application. In section 7 we discuss the implementation approach, which means that we show the agent architecture that is used to implement the model. Finally, section 8 contains the conclusion and comments on future work.

2 Integrated information systems

In the introduction we have argued that the new generation of information systems has new requirements. The trend in information systems shows a shift towards the integrated support of both structured and unstructured processes, both formal and informal communication, and both predefined and ad-hoc work activity coordination.

A decade ago the most important of the electronically available information sources in companies were individual (relational) databases. At that time all information relevant to the processes of the company would be modeled in these databases that each would serve a specific purpose. Besides these large databases there also existed some small knowledge based systems that provided information for a small amount of specialized processes that needed more complex information. This situation, however, has changed drastically over the past few years. Many more forms of storage, dissemination and processing of electronic information have become available and are widely used in practice. Moreover, we have seen a linking of these individual databases and knowledge bases into large bodies of data that are used for multiple purposes: "everybody wants access to everything". This trend towards integrated information systems is illustrated by the attention for concepts like hypertext systems, Intranets, document management systems (e.g. Saros,

Documentum), groupware products (e.g. Notes, Exchange), and workflow management systems (e.g. Staffware, Cosa).

While the software tools may be using traditional database technology, the users perceive that the tools enable them to use new ways of communication. For the users the data and information is stored and accessed in a completely different way as before: often users have less notice of the technical issues involved in retrieving and maintaining the data, since the technical issues are often transparent. Therefore, the traditional perspective of data and information processing does not cover the essential aspects of modern integrated information systems. It is not sufficient anymore to look only at a uniform language to represent information in the traditional database and knowledge base formats, but one should look at ways to access many different types of information intelligently. The key aspects are the integration of information from different sources, and the differences in disclosure principles for information accessed through different tools.

This different perspective does not only relate to the retrieval of documents, but also to the management of the data. The linking of data and documents in different system into one large body of data implies that also the responsibilities involved in maintaining that body have changed. In the traditional local applications it usually was well defined who had the responsibility of maintaining the database, including tasks like import, updates and internal structuring: "every database had its own warehouse chief". The new integrated systems imply a large amount of transparency with respect to the retrieval of data. However, the distribution of responsibilities with respect to the maintenance of the integrated collection of data becomes far more complex. Few systems have solved this problem in a satisfactory way.

This current interest in new requirements for information systems can not only be seen in industry, where the attention for issues like workflow management, groupware, or document management shows how modern organizations feel a need to structure their work processes in a robust and flexible way. The need to be able to react quickly to changed circumstances implies that internal and external communication and information distribution must be designed to support these changes.

At the same time the academic world shows a gained interest in the same issues. It has seen that models and methods that have long proven their value, can be applied to these areas as well. The application of logistical principles to administrative settings is a nice example. One of the most prominent aspects is the use of classical process models to represent the work and document processes that build the heart of the computer applications. In this perspective the flow of work is seen as a sequence of tasks that are executed by automated systems or people in order to carry out a business process. These processes are built by linking together diverse activities and specifying the flow of data and control among them. The success of this workflow paradigm is based on its ability to support modeling, simulation, automated execution, and monitoring of processes in an environment that is distributed, heterogeneous, and only partially automated: we can therefore speak of workflow and/or process automation.

Another view originates from the fact that we see more and more applications of workflow technologies in information-intensive domains. This leads to a growing application of these technologies to organizational information, communication, and cooperation processes. Specifically, the coordination of human activities and computerized applications attracts more and more attention, as this coordination builds the heart of the workflow management. So, a number of researchers have studied the modeling of groups, organizations and their processes, and have tried to understand them. By defining the computer support for collaboration and negotiation, a number of approaches suggest to integrate multiple computer-based tools and technologies into group interaction: take for instance the CSCW approach. The relevance of this view is supported by the successful implementation of groupware applications in small- and large-scale industrial settings. The success of a product like Notes shows that there is a large need for a specific kind of support of office workers. We mention the integrated use of Notes with typical workflow products or ERP-packages: this increasing use of Notes as an addition to these applications that support the structured processes, supports the argument that there is a need to cover the less-structured communication within the combined computer-support.

We feel that the target for those involved in developing (office) information systems is to combine all aspects involved in information systems that implement the structured logistical processes, while supporting the unstructured communication and the existing local database

applications. As both researchers and practitioners we want to suggest useful tools for this activity, since formal tools are needed for serious program development. Many of today's workflow and work activity specification languages use process-based information system models. This class of tools appears to be limited: there is less attention for the support of the typical local activities encountered in an office environment with existing applications. In order to achieve a higher quality of products (or services) and a higher customer satisfaction, a new approach is therefore needed.

In the next two sections we discuss the two aspects involved in the integration: in section 3 we discuss the global processes and the deficiencies of current process approaches, while in section 4 we focus on the local users and their role in integrated information systems. In both sections we show that an approach which is only based on one of the aspects does not suffice. In section 5 we combine the results to obtain an integrated approach.

3 Global processes

An approach that in the last years tries to support local workers in their grip on the global processes that play a role in the integrated information systems, is the use of process models. Concepts like workflow management, document management or product data management, start from a view on the information that focuses more on the process, and less on the data. Considering workflow management, we see that the information processing in an organization is perceived as a logistical process. In this process the data or information is simply considered as material that must be distributed among the right users. Moreover, the humans involved are seen only as resources. This paradigm is generally valid if the work processes are highly structured, and produce end-products in high volumes.

While the design of an optimal logistical process contributes heavily to the performance of the information processing, this approach alone does not quite acknowledge the problem of using information from different sources. The information used in the workflow originates in different databases and knowledge bases, but also comes from the less formal knowledge of the workers involved. This knowledge of the workers also includes information on the applicability of a predefined process (procedure) to a specific case. In ad hoc or less structured situations knowledge workers need to customize the procedure to the actual needs of the specific case (see for example [KUW]). This type of knowledge and insight is not acknowledged in workflow applications.

Additionally, the integrated system involves an integrated collection of data or documents. This integrated collection needs a different management process. Just as a large integrated warehouse needs other control mechanisms as can be used to control the small individual warehouses, a different collection management process should be applied. The management process for the integrated data collection becomes more complex, while it should maintain the transparency for the different kinds of usage (e.g. retrieval). While the global business processes get more attention in the different process perspectives, the data collection management processes appear to get less attention: it is often left to the technical implementations to solve the associated problems.

An important aspect of the role that processes play in an integrated information system is related to the relationship between process and data. In current approaches the decisions taken within processes are mainly based on process properties: sometimes data properties are involved, but in those cases it is often explicitly defined beforehand. In modern integrated information systems the retrieval of relevant data (documents) to support the execution of a task must be facilitated more flexibly by the information system. This means that, instead of explicitly specifying which data is needed for a given task, the process determines the context in which the retrieval of the data is executed: the process determines a set of rules that guide the information system in the retrieval process. It can imply that data is retrieved dependent on the task that is executed and on the process to which this task belongs.

4 Local users

The local users of the information systems figure as the key actors in the processes of an organization. When they perform their activities, they process data and information retrieved from information systems, often local database applications. Traditionally, the approach has been that the architecture of the information system reflects the data processing aspects of some business process: the designer

of an information system has designed the system with a prescribed usage in mind. Therefore, the user is actually guided by the information system itself.

Nowadays much more unstructured information can be stored through hypertext, document information systems, and other kinds of integrated bodies of data. These systems are used as general knowledge repositories and are not focused on one process. This flexibility also has its consequences on the actual information processing. In a large number of organizations local knowledge workers need mechanisms to deduce which type of information can be used to perform a business activity. More than before, the knowledge worker must decide on the data to be used, the sources where the data can be retrieved, the format in which the data is retrieved, and the general quality of the information produced: all due to the fact that more data is available in the larger body of data. Because information is stored in many different ways, an assessment of its quality is necessary to determine its value for a business activity.

The quality of information is determined by a number of properties. First and foremost the functionality is important. People or applications producing or offering information must know how (with which semantics) the information is used. Other important quality aspects include time (validity, availability), costs, and resources involved in the production (both humans and information). In the end the overall quality is related to the effectiveness and the efficiency for the activity at hand.

Essentially, the users lack knowledge. They lack knowledge about the quality of information available within the organization: in order to be able to use a truly integrated information system, users must posses knowledge (meta-information) about the business information; without knowing what the information is worth, they cannot produce an optimal product or service. At the same time they lack knowledge of the activities and processes in which they use the information. In the traditional dedicated information systems the users/system interaction reflects the intended processes. In most of the modern practical cases the processes have a goal of their own, not reflected in the specific information systems: in the abstract integrated information systems it is left to the local knowledge worker how to use the specific local information systems in order to fulfill the (global) process goals.

We claim that a modeling approach is necessary that also considers the internal communication processes in their right perspective. We feel that the people in the office should be seen as actors, not as resources. People working together in an office do not simply play the role explicitly specified in the control processes. Only in some highly structured processes people can be considered as resources. In most situations the processes leave room for people to use their informal communication processes in order to cooperate. For the knowledge workers of today the communication processes have a significant impact on the effectiveness and efficiency of their work. From the point of view of global information systems builders the information sharing processes need to be considered: not just those that are directly part of the formal control process, but also those that are part of the informal operations of the office ("office memory"). The local document and information management processes should therefore be included in the analysis of the processes to be supported by the information system: this data and information handling is the basis for the cooperative data management.

5 Integration

In the previous sections we have argued that there are new requirements for designing and developing information systems. We have also demonstrated the limitations of the focus on just the global process, and we have argued that a focus on the local users should be added.

The integration of all relevant aspects can be tackled bottom up from the local information system applications: the databases and knowledge bases. There are a number of difficulties in the bottom up use of information. Especially, it is rather difficult to assess the quality of the information used, with respect to the activities on hand: "what does this information contribute to the product or service that I am producing?".

The top down approach suggested by the workflow management paradigm, is not always the route to follow. It does not acknowledge that the use of local information requires knowledge (meta-information) on the effectiveness and efficiency of using that information.

We feel that a combined approach is necessary (in line with conclusions from [AS] and [Sea]), combining proven techniques and tools. Specifically in cases where the processes are less structured, may be even ad hoc, and where the quality of the information is an issue, we argue that an adequate support of the local worker is necessary. They should have the knowledge to assess the combination of procedure and information that is available and relate that to the goal of the activities to be performed. By this we mean that the human actors have the means to decide how an activity is actually performed. They can use their professional knowledge of the available data (application) and of the prescribed procedure to suggest the ideal process: besides using their own knowledge, they should be able to consult their coworkers and managers in order to use the common knowledge of the group in which they participate. The target is to use existing organizational practices.

In order to build good integrated information systems the relationship between the (group) communication process and the local information system applications should be seen in the right perspective. If for instance one designs a workflow management support system one must distinguish between the workflow management concept, the communication processes among the relevant people and the actual information system applications.
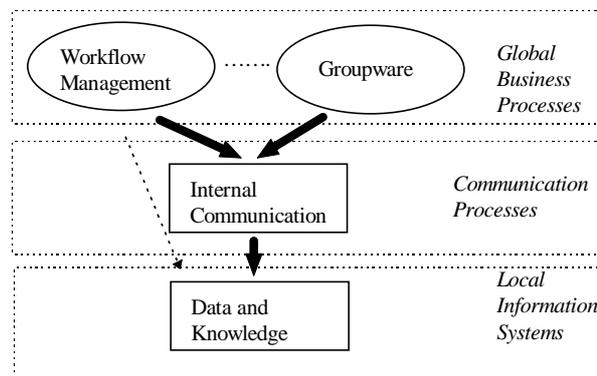
In general the workflow management process implies communication processes which imply the requirements for the local information system applications. While there can sometimes be a direct link between workflow management and information systems, in most situations the link is an indirect one.

The same holds for the design of a groupware system: the communication processes build an intermediary between the groupware concept and the information systems. The information system builder must look at the communication processes and make sure that the information systems support them. It is trivial that the combined nature of the general office setting (integrating for example workflow management, groupware and document management) can benefit from an approach that acknowledges the role of the communication processes.

By basing the integrated information systems on the communication processes more flexibility is guaranteed: both in the original design of the processes and in their implementation in the information systems. In the development of the implementation the flexibility of the communication processes should play a prominent role.

6 Modeling approach

This section presents the highlights of our approach. We illustrate the approach using parts of a practical application within a banking organization.

We combine elements from an activity-based approach with the core of a goal-based approach. As is shown in [Sea] these two types of modeling approaches exist to design information system applications with different perspectives. For the more structured aspects of the relevant processes we use the activity-based approach, specifically we use Petri-nets. Specially for the description of workflow management processes Petri-nets have proven to be effectively applicable. Therefore, we suggest to use Petri-nets for those parts of the global business processes and the local work activities that are structured enough to benefit from the Petri-net approach.

For the effective expression of the internal communication processes and the less structured aspects of the work processes we suggest to use an goal-based approach. It takes the persons as

central entities in the workflow and models the workflow through commitments (and conversations) between the persons involved. The approach that we use is based on Action Workflow [MWFF]. In that approach each task can be modeled through the following cycle:
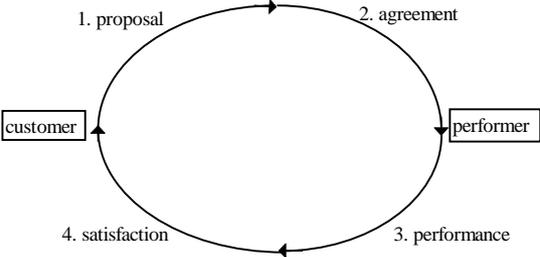

The cycle shows the different phases in the communication about the execution of some action. First, a proposal is made towards the (designated) performer. After agreeing with the "customer" the performer actually performs the work: this is indicated by the third arc in this cycle. Upon completion the satisfaction of the customer is checked.

To illustrate the use of these two approaches we consider small parts of a banking application.

The usual way to start considering a process is to view the structured sequence of activities at the top level. At the top level of our banking application example the bank and one of its clients communicate regarding a business credit application, e.g. for developing a new product: a bank employee receives the credit application, evaluates it (with the help of an expert in the business area), negotiates the terms with the client, asks for approval from the head-office and finally implements the credit. The following Petri-net represents this structured process.
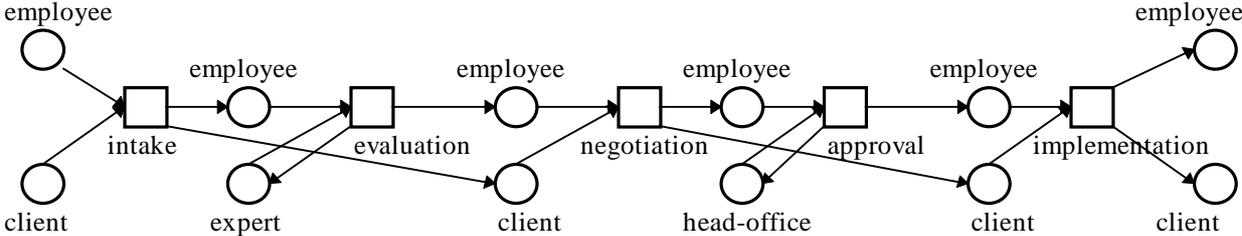
It is clear that the different activities can involve standard-procedures and local information system applications. In general the bank has procedures available that the employees can use whenever that is necessary. One example of such a procedure is the procedure for the evaluation: this procedure can be modeled by the following Petri-net (which can be seen as the net to be substituted for the evaluation-transition).
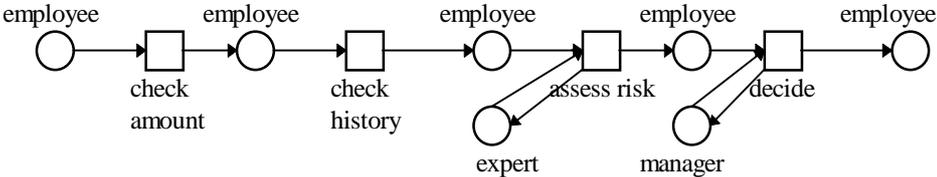
In between these two abstraction levels there is the level at which the office workers assess the situation in order to decide how an activity should be performed: using the standard-procedure or using a customized approach. In terms of the above example this means that for the execution of the evaluation-activity (in the context of the process modeled by the first Petri-net), it is determined whether the standard-procedure (and its associated application) modeled by the second Petri-net is followed or not.
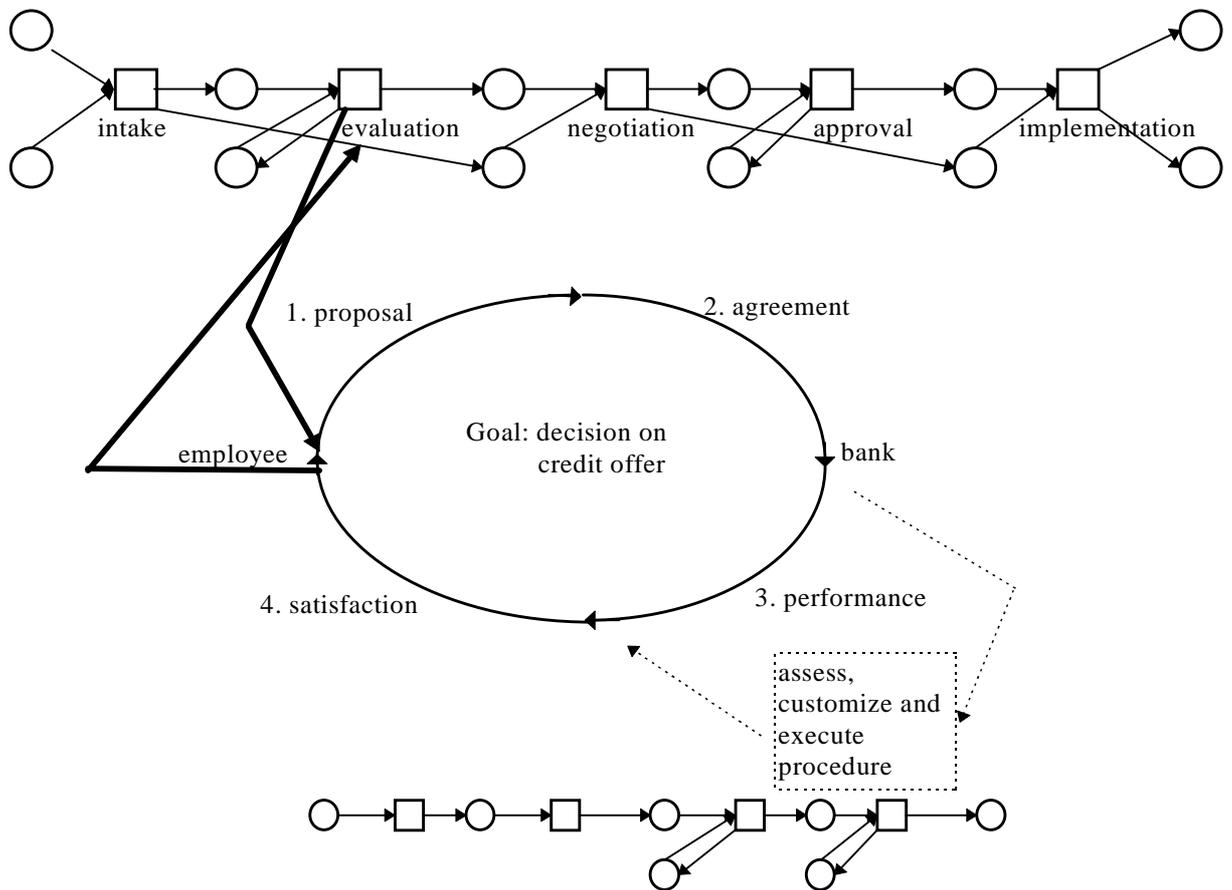
In such a situation, first the goal of the procedure is determined. This can be done using the goal-based communication model (Action Workflow). In this case the goal of the evaluation is to come to a decision on whether an offer for a credit should be given or not. After the goal is established, the employee has to evaluate the available information and assess the present situation. Is it really necessary to involve an expert in this case? Maybe not if the client has a very good business history and has successfully developed many similar products before. Also the manager might be involved earlier or not at all. In case the credit is on the borderline of acceptance according to the intuition of the employee it might be wise to involve the manager right away in the evaluation. If the amount of the credit is very low and the history of the client is good, the manager might not have to be involved in this case at all. Depending on these factors the employee decides to use the standard procedure for this task or use alternatives (possibly communicating about this with coworkers).

We have found it vital that the organization does not commit itself to simply applying the procedure (substituting the lower level Petri-net within the higher level Petri-net) without assessing the goal to be achieved. We feel that the organization and its employees as its key actors should be evaluating the applicability of the procedure (and its associated applications) in regards of the goal at hand. This means that, in terms of the goal-based model, the third arc (performance) for the evaluation-activity implies the assessment of the applicability of the procedure and its possible customization and application. The execution of the evaluation is an interaction between employee and the bank, where the main issue is that the defined goal is achieved: it is less important whether the procedure is applied.

In the context of our example the bank employee should assess whether the evaluation needs to be conducted according to the procedure. It is vital in the bank's philosophy that the employee does not just asses the financial issues involved: the bank wants to find out the business initiative behind the financial question. It wants to include its opinion on this business initiative in its decision on the financial arrangements. If this can be done in another but effective way, the bank supports this. The employee can choose to ask his manager to cooperate and to help evaluating in a different way: specially, in cases that occur less frequently or which are not foreseen in the procedure, the usage of the common experience can be more helpful than the exact following of the procedure. If the

employee (with the help of coworkers, e.g. the branch manager) finds that the procedure is not applicable, they can together achieve the goal, which is to evaluate.

One can observe that our modeling approach combines two characteristic elements.

First, we put the local users in the center of attention. They are seen as the one party that can tie the process and the underlying information (data, documents) together. Only in certain special cases the relationship between process and information can be defined explicitly during a design phase. In most of the practical situations an organization needs to use the knowledge and expertise of its human users to effectively support both the process level and the information (data) level.

Secondly, the modeling approach is characterized by exploiting the goal-based approach in giving the users the possibility of assessing the procedures. By using an assessment of the effectiveness of a given procedure for the case at hand, the users can use the information and the underlying information system more effectively and more flexibly.

While this is often not reflected in the actual workflow, the integrated information system should support both the workflow process (in for example a workflow management system) and the availability of relevant information or documents in a document management system. Our integrated modeling approach makes the entire process more robust and less vulnerable for errors or unforeseen events. The bottom line is that the communicating experienced workers can more effectively deal with special circumstances as following the standard procedure would do.

7 Implementation approach

The exact connection between the modeling approaches can be implemented using an architecture of cooperating agents. We use the cooperative information agent as described in [VD]. Basically we use three classes of agents:

1. process agents: they carry the knowledge about the global or local business processes
2. user agents: they carry the knowledge about the experience and preferences of the different users (both as participant in the processes, and as user of the automated information system giving access to all relevant data)
3. data agents: they carry the knowledge about the properties of the data or document
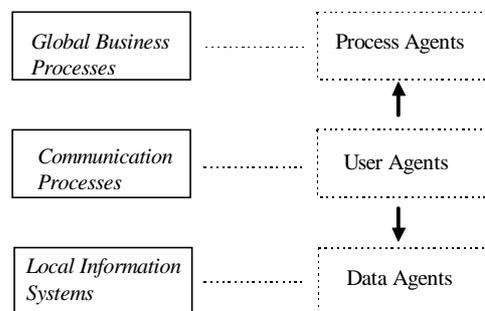
The process agents are mainly concerned with the management of the work processes. They make sure that the right tasks are identified and they command, suggest or stimulate the employees (users) to execute these tasks. Therefore, they must know of the processes, their tasks and the role that the different employees can play in those tasks.

The data agents are responsible for the management of the data (information, content). It means that they must facilitate the retrieval of the data (by users). Also they must, together, facilitate the management of the entire collection of data by supporting the import of new data, the restructuring of the collection, etc. Therefore, these agents must collect knowledge on the use of the different data elements.

In principle the user agent acts as the intermediary between the two relevant levels of knowledge. It performs two tasks. First, it assesses whether the standard procedure (application) is appropriate for the present task based on: the goal, a formal description of the standard procedure and the quality of the available information. This includes communication with certainly process agents and perhaps data agents. The agent must have knowledge on similar situations in order to advice the

user on the assessment. One might say that this task mainly requires the use of meta-information about both the task at hand and the information needed for that task.

The second task of the user agent is to collect the necessary information from the heterogeneous information sources: this involved communication with data agents. The information that is needed depends on the procedure that is followed: the standard procedure or an ad hoc solution that is created for the task at hand. This means that the agent must build user profiles that can be used to learn which data is usually necessary or preferred.

In order to perform its tasks the user agent should obtain the following knowledge:

- Formal description of the standard procedure: from process agents
- Type and location of necessary information (including persons): from other user agents and data agents
- Formal description of alternative steps to be taken: from process agents and other user agents
- Goal formation rules to plan the ad hoc procedure: from its own knowledge base

The different agents need to use a communication language. We will use KQML ([Fea]), but we use only a few performatives that we have predefined and for which a clear semantics is given. These performatives are things like ASSERT, COMMIT, REQUEST, etc. We use KQML in two places: first for the communication between process agents and user agents in the translation from processes to tasks (including the assessment in the Action Workflow style), and then for the communication between user agents and data agents to determine the concrete information retrieval.
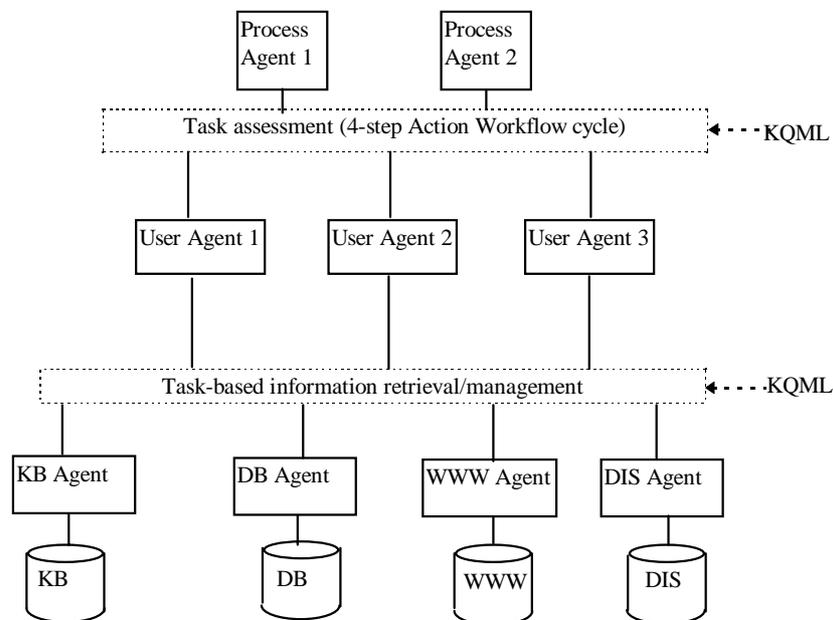
We end with an important remark. In practice the approach can imply that the cooperating agents help the humans to decide on the procedure to be used. While in some cases the agents can be developed to automatically assess the properties of the procedure and information, in most cases the humans will act as the users of the knowledge delivered by the agents. This means that the humans are in control and they combine their own professional expertise with the knowledge from the agents to decide on the procedure to follow in order to achieve the goal at hand.

8 Conclusion and future work

The new generation of integrated information systems, specifically those that support communicating individual using local database applications imply new requirements. These requirements acknowledge that integrated systems can only operate in practice by using the communicating employees as the linking pins between the higher level business processes and the lower level information system applications. While many of the current approaches use a process focus and try to model the entire organization using activity-based process models, we suggest to use a combination with goal-based models. By integrating the activity-based and goal-based approaches we can offer an

organization a more flexible and more robust mechanism to support the groups of office workers. In many practical situations we have experienced that the less rigid character of this combined approach, suits a more efficiently operating information system. We suggest to implement the approach using an architecture of cooperating information agents. By having agents interchange the right information, we can obtain a system in which the business goals, the collected data and the human users can effectively operate together in a dynamic setting.

At the moment we are involved in implementation projects in banking applications and in electronic commerce environments. We want to learn how the practical implementation can be designed most efficiently. At the same time we are involved in research and practical projects that investigate the issue of the management of the data collection. While many approaches exist (in practice) for supporting the retrieval of information, we feel that additional effort is needed to produce the proper support for the data management process.

Acknowledgment

The authors like to thank F. Van Everdingen for the cooperation in the practical case that has figured for the example used in this paper.

References

[AS] Kenneth Abbott, Sunil Sarin, "Experiences with Workflow Management: Issues for the Next Generation", ACM Conf. on Computer-Supported Cooperative Work, 1994, p. 113-120.

[Fea] T. Finin, R. Fritzon, D. McKay, R. McEntire, "KQML as an agent communication language", Third International Conf. on Information and Knowledge Management, 1994.

[MWFF] Raúl Medina-Mora, Terry Winograd, Rodrigo Flores, Fernando Flores, "The Action Workflow Approach to Workflow Management Technology", Computer-Supported Cooperative Work 92, 1992, p. 281-288.

[KUW] St. Kirn, R.Unland, U.Wanka, "Mamba: Automatic Customization of Computerized Business Processes", Information Systems, Vol. 19, No. 8, 1994, p. 661-682.

[Sea] A. Sheth e.a., "Report from NSF Workshop on Workflow and Process Automation in Information Systems", SIGMOD Record, Vol. 25, No. 4, 1996, p. 55-67.

[VD] Egon Verharen and Frank Dignum, "Cooperative Information Agents and Communication", Cooperative Information Agents 1st Int. workshop, (Springer LNAI 1202), 1997, p.195-209.