USING WEB SERVICES AND ARTIFICIAL INTELLIGENCE TECHNIQUES TO DEVELOP SIMULATION MODELS OF BUSINESS NETWORKS

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ABSTRACT

The research described in this paper introduces a new approach for developing simulation models using web services and artificial intelligence (AI) techniques so as to address the current challenges in modeling business processes within business networks. The approach is based on the Web service business process specification standards for identification and extraction of structural elements of business processes and also it is based on AI neural network techniques for modeling behavioral aspects of each of activities within the business process. The paper first formulates the current challenges in modeling business processes of business networks. Next, some related works on this area are discussed. After that, the approach for developing business process simulation models of business networks is explained step wise. The paper concludes by stating the expected benefits from using this new methodology.

INTRODUCTION

Just as in evolution theory, where the fittest organisms are those that are the most adaptable, organizations that are capable of adapting quickly to the rapidly changing environment are the most likely to survive and thrive. In the current era, organizations are using interorganizational relationships i.e. business networks, as a means of adapting and increasing their performance level (Hengst and Sol, 2001) because the current era is characterized by high competition, high information flow, high demand for timeliness and accurateness of information, change of business needs, and change of customer needs. According to Hengst and Sol (2001) trends such as deregulation of markets, increase use of information and communication technology, outsourcing, and globalization, indicate this fact. By using these business networks, organizations bring together their core competencies to create "best of all" products or services.

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Because there is so much interdependence between the nodes (organizations) within the business network, each organization needs to have a sufficient insight into the operational business processes of partner organizations to make appropriate assessments to increase performance level. Simulation models of the operational business processes of organizations in business networks looks like a very good candidate to give sufficient insight to decision makers in an organization when assessing the functioning of the other organizations (see Figure 1).

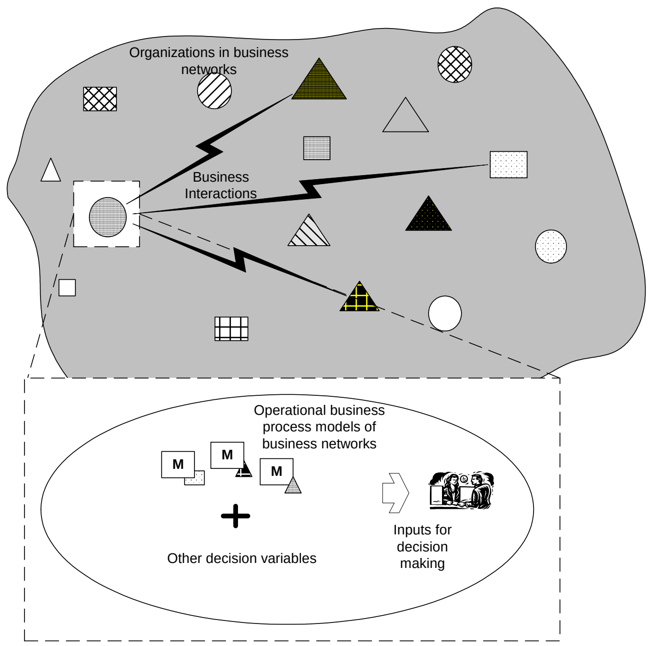

Figure 1: Business processes of organizations

Simulation models of these business processes can give insight into the dynamic behavior of organizational business processes (Aguilar, M. et al, 1999). However, getting or creating such models is challenging given the fact that organizations in the business network are autonomous and not transparent. Even though collaboration in model development between the organizations in the network is another option for constructing interorganizational simulation model, it usually takes time to build interorganizational operational model of all the partners involved in business networks, each organization might be interested in different aspect of the interorganizational interaction, and finally, the organizations might not be willing to share such information with other organizations.

The emerging web services technologies promise to facilitate collaboration among business partners by helping potential partners to find one another and integrate their business processes. It also enables organizations to specify and model their processes as services. Web services allow organizations to describe and discover processes (Benatallah et al, 2003). Once the processes are describe using web service standards, the abstract (public) operational business processes becomes visible to other organizations.

Artificial intelligence techniques on the other hand provide ways to model behavior of a system, e.g. business process, that appear as a black box. Neural networks are one type of artificial intelligence techniques that are used for modeling behavior by monitoring the input and output parameters of the system. In theory, these neural network models can also be used to describe/model the dynamic behavior of the processes of organizations in a business networks when the inputs and outputs are known.

This paper shows an approach for developing simulation models of operational process models of business networks by using and integrating the Web Service business process choreography standard and a neural network. The rest of the paper is organized as follows: Section 2 presents some of the related research in this area, Section 3 describe the proposed approach, Section 5 states the implementation planned, and finally Section 6 discusses the expected findings.

RELATED RESEARCH

There are several research works available on the use of simulation and neural networks for different purpose. Panayiotou et al. (2000) used a neural network model in order to overcome one of the limitation of simulation: low computational speed. In their approach, neural network model is used as a "surrogate" model of the original system capturing the relationships between input and output, but computationally more efficient than simulation.

Kilmer et al (1994) used supervised neural networks as a metamodeling technique for discrete-event, stochastic simulation. In their study, neural network estimates are used to form confidence intervals, which are compared for coverage to those formed directly by simulation.

Chandrasekaran et al (2002) investigated the synergy between web service technology and simulation. According to this research, simulation can be used to understand and design composition of web service in order to get better performance. By using the JSIM package, they indicated that users can do "what-if" scenarios and visualize the Web process in action before enactment.

In the area of operational business processes integration, there are several works that make use of the current web service technologies. There are several standards proposed by different industry sector such as RosettaNet[1], ebXML[2] and OpenXchange[3]. Wombacher et al (2003), for instance, work in automating matchmaking of business processes of potentially compatible partners by using web service standard WSCL and UDDI business process tModels. Benatallah et al (2003) proposed a way to conceptually model web service conversation among different partner organizations. By building on top of Web standards they proposed a framework for defining extensible conversation meta-model to enable description of generic abstraction such as temporal constraints and implications of service conversation.

APPROACH

The approach that we are going to explain uses two technologies: the web services business process choreography standards and the artificial intelligence technique neural networks. The reason for using the web services business process choreography standards is that they describes structural elements of business processes of organizations by specifying the possible sequence of interaction with the web service of organizations. In order to construct a simulation model of business processes, structural elements (building blocks) of the process are not enough. Behavior of each of the blocks must be modeled as well (e.g. service time distributions). However, modeling behavior of each blocks of organizational business processes is not as straightforward because the internal mechanism of these processes is not transparent to other organizations in the business network. Only the input and output of these processes can be monitored. For this purpose, we use neural networks for modeling the behavior of the building blocks. We are aware there are several AI techniques besides neural networks for modeling black box systems and we chose to use neural networks for the reason that it is possible to develop models from data without an initial model and it can handle noise and irregularities in inputs. Before we describe the approach, we will discuss something about both technologies.

[1] http://www.rosettaNet.org
[2] http://www.ebXML.org
[3] http://www.openXchange.org

Web services

Web services are being considered as a contemporary paradigm for the development of distributed, Internet-based and platform-agnostic business applications(Yang et al, 2000). The main appeal to the business community is the fact that they can facilitate interaction between complex, heterogeneous and highly distributed, enterprise information systems using standards for virtually all interoperation aspects (Heuvel et.al, 2003). Web services are composed of different technologies and standards: SOAP (a standard based on XML that is used for exchanging messages within the web service infrastructure), WSDL (an XML based description for services), UDDI (a standard for publishing and discovering services), and some other standards for choreography and aggregation. A visualization of the technologies is presented in Figure 2.

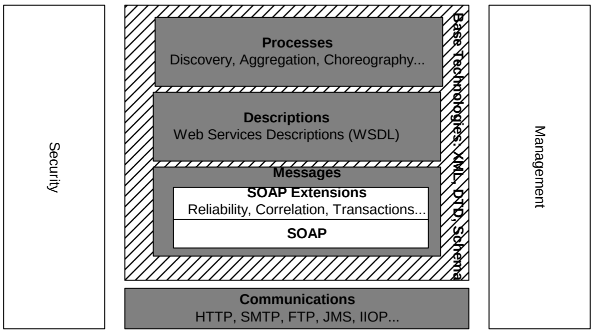

Figure 2: Web service technologies

For enabling and designing business transactions, there are several proposed web services standards: Business Process Executino Language for Web Services - BPEL, Business Process Modeling Language - BPML, Web Service Choreography Interface - WSCI, Web Service Conversation Language - WSCL. These choreographic languages are used for modeling, representing, and describing internal and external parts of their operational business processes so that they can be recognized as web services. The public part of the business processes are used for collaboration with external business partners while the internal part is used for modeling and understanding those parts of the business processes that are private (confidential).

Conceptually, services can be comprised of three levels: messages, abstract processes, and execution processes. The message level describes the message that are exchanged and the syntax involved. WSDL and EDIFACT are examples. Abstract processes describe the sequences in which messages are exchanged. Example of standards used at this level are WSCL, the abstract part of BPEL, cpXML and ebXML BPSS. Execution processes are used to implement abstract processes for execution within an organization. The executable part of BPEL is an example of a standard addressing this level. Abstract processes are considered as public business processes that can be revealed to other organizations while execution processes are usually internal and confidential. In the ebXML framework, for instance, potential business partners register their profiles (including their abstract business processes) within public registries (see Figure 3).

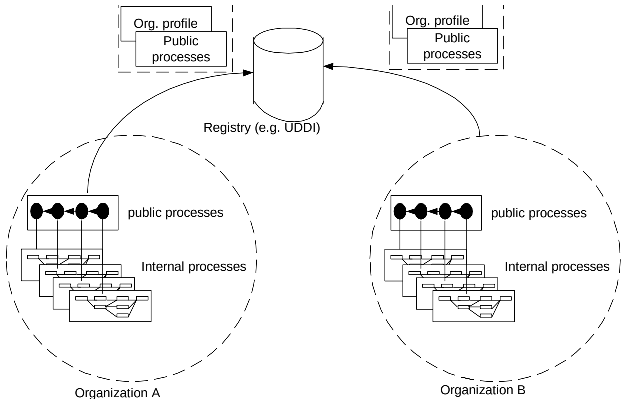

Figure 3: Public and internal processes of organizations

In this paper, the focus is on abstract processes that describe the sequence of message exchange between trading partners. For illustration purpose, we chose to use the WSCL standard for specifying and modeling abstract processes.

Neural networks

Neural networks are one of a group of artificial intelligence technologies for data analysis. They differ from other classical analysis techniques by learning about the chosen subject from input and output data, rather than being programmed in a traditional sense. Neural networks discover patterns by detecting patterns and relationships in the data, learning from relationships and adapting to change. Compared to other data mining methods, neural networks are powerful for behavior modeling because they can successfully deal with nonlinearities. Noise and irregularities in input can be handled by the neural network models and the models can also be updated easily and quickly. The two main advantages of neural network techniques are processing speed and facilitation of model development in situations where there is limited theory describing the cause-effect relationship between the independent and dependent variables (Chao et al, 1994, Flood, 1990). The picture below shows a type of neural network model called Multilayered Feedforwared Neural Network (MFNN) (see Figure 4).

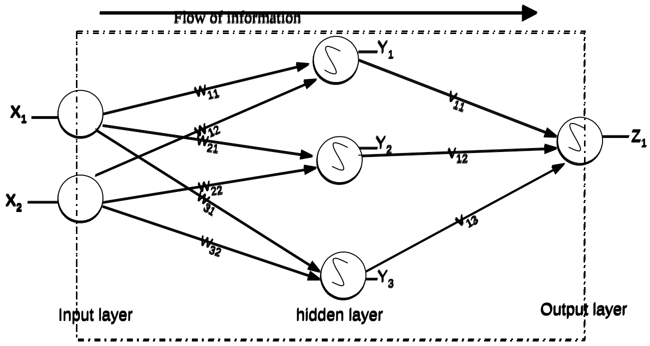

Figure 4: Multilayered Feedforward neural network

These type of models can mimic the behavior of a black box system by extracting relationships between the input data and output data. Once the model is trained, it responds with the same behavior as the black box system given a set of inputs.

There are different classes of neural network models, depending on the problem type (e.g. prediction problem, classification problem, or clustering problem), the structure of the model and the model building algorithms.

There are several other artificial intelligence techniques: Expert systems/Knowledge based system, Genetics algorithm, and Intelligent agents. However, the application areas of these AI techniques is different:

- Expert System: for diagnostic or prescriptive problem type which is based on strategies of experts. It uses expert's know-how
- Genetics algorithms: for situation that require optimal solutions. It is based on biological evolution. It uses set of possible solutions
- Intelligent agents: for specific and repetitive tasks

Neural network on the other hand is suitable for identification, classification, and prediction problem types. It make use of patterns.

DEVELOPMENT OF SIMULATION MODEL

After covering the Web service technology and AI techniques, we describe here an approach to use them together to construct simulation model of operational business processes in business networks. As mentioned earlier, the business process choreography component of the web service provides a way to specify high level structural elements of operational business processes, where as neural networks help in modeling behavior of each process blocks within the business processes.

Sol (Sol, 1988) proposed a framework for presenting approaches in terms of way of thinking, way of working, way of modeling, and way of controlling. The way of thinking refers to the philosophy that is used in the approach. The way of working specifies the steps that are to be taken in order to realize the approach. The way of controlling specifies the guidelines and set of directives (e.g. management of time, means and quality aspects) that are to be followed while using the approach. Finally, the way of modeling defines the modeling concepts that are used in order to use the approach. In this paper, we will focus on the way of modeling, i.e. we describe the modeling concepts that are going to be used in order to use the approach in solving the problem, which is modeling dynamic behavior of operational business processes of a business network.

To start with, the purpose of a model is to reduce the complexity of understanding or interacting with a phenomenon by eliminating the detail that does not influence its relevant behavior (Curtis et al., 1992). In order to model dynamic behavior of operational processes in business networks, we adopt the problem solving cycle (Mitroff et al, 1974, Sol, 1982). Our concern here is on the first two problem solving activities: conceptualization (a way to define the problem structure) and specification (a way to define an empirical model that gives detail specification of the situation).

In order to develop a conceptual model of operational processes of organizations, structural elements (activities, sequence flow, and decision rules) are needed. Given the fact that organizations in business networks are autonomous and their operational processes are not transparent, it is challenging to get detailed structural elements of the processes. However, as mentioned in Section 3.1, the abstract part of the processes are visible and extractable. One of the ways to retrieve these information is by referring to business processes choreography specified in the many of the web services deployed (or in UDDI registries). The processes are deployed in several specification standards. Here, we show an example using one of the many proposed standard: Web Service Conversation Language (WSCL). Figure 5 shows a UML diagram of a simple purchase activity between two trading partners. Its representation in WSCL XML is shown in Figure 6.

WSCL XML schema uses four main specification elements to describe conversations between trading partners: *Document type descriptions* (specify the types i.e. schemas, of XML documents the service can accept and transmit in the course of a conversation), *Interactions* (model the actions of the conversation as document exchange between two participants), *Transitions* (specify the ordering relationships between interactions), and Conversation (list all the interactions and transitions that make up the conversation). Within the bounds of a *conversation* element, the two important elements for constructing conceptual model are the *Transitions* and *Interactions* elements. *Interactions* represent the abstract process building blocks/nodes of the processes and *Transitions* specify the sequence between the nodes in order to execute a business process. Therefore, from WSCL specification, it is possible to identify structural elements of the abstract part of an operational business process. Other choreography standards that have formal representation in XML or other similar types can also be used as well. The important thing to is to map the business process specification standard's metamodel to simulation model specification metamodel. Once the metamodel is mapped, the next step is to create simulation software specific constructs by using the existing building blocks of the simulation software. Afterwards, a parser is created that map an instance of business process (specified using the standards) to simulation model. By this way, a conceptual model of the business processes is created.

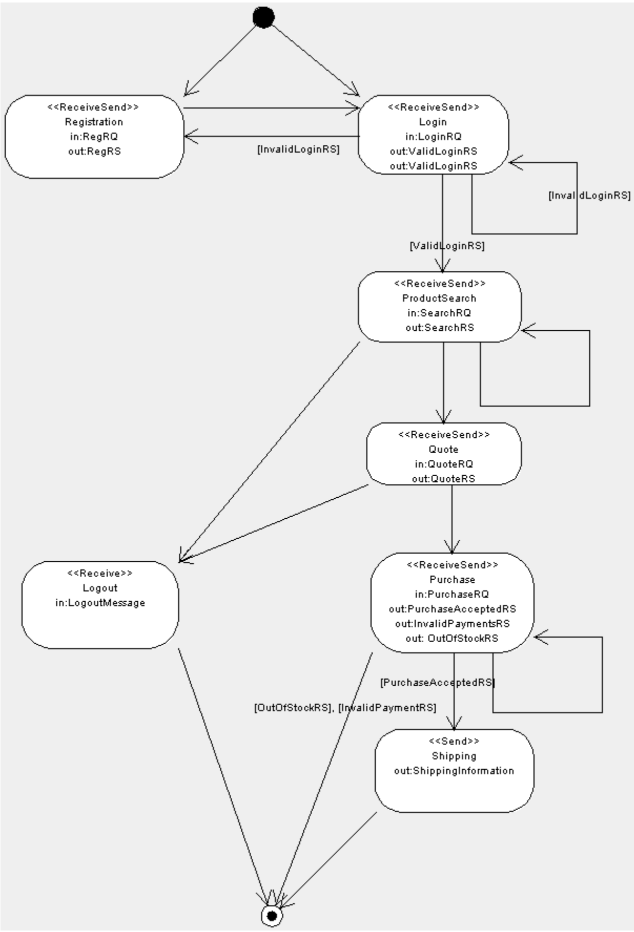

Figure 5: UML activity diagram of a purchase business process (extracted from W3.org site)

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Conversation name="StoreFrontServiceConversation"
      xmlns="http://www.w3.org/2002/02/wscl10"
      initialInteraction="Start"  finalInteraction="End"  >
 <ConversationInteractions>
  <Interaction interactionType="ReceiveSend" id="Login">
    <InboundXMLDocument hrefSchema="http://conv123.org/LoginRQ.xsd"
        id="LoginRQ"/>
    <OutboundXMLDocument hrefSchema="http://conv123.org/ValidLoginRS.xsd"
        id="ValidLoginRS"/>
    <OutboundXMLDocument hrefSchema="http://conv123.org/InvalidLoginRS.xsd"
        id="InvalidLoginRS" />
  </Interaction>
  <Interaction interactionType="ReceiveSend" id="Registration">
    <InboundXMLDocument hrefSchema="http://conv123.org/RegistrationRQ.xsd"
        id="RegistrationRQ"/>
    <OutboundXMLDocument hrefSchema="http://conv123.org/RegistrationRS.xsd"
        id="RegistrationRS"/>
  </Interaction>
  ...
 </ConversationInteractions>

 <ConversationTransitions>
  <Transition>
   <SourceInteraction href="Start"/>
   <DestinationInteraction href="Login"/>
  </Transition>
  <Transition>
   <SourceInteraction href="Start"/>
   <DestinationInteraction href="Registration"/>
  </Transition>
  <Transition>
   <SourceInteraction href="Registration"/>
   <DestinationInteraction href="Login"/>
  </Transition>
       ...
  <Transition>
   <SourceInteraction href="ProductSearch"/>
   <DestinationInteraction href="ProductSearch"/>
  </Transition>
  <Transition>
   <SourceInteraction href="ProductSearch"/>
   <DestinationInteraction href="Quote"/>
  </Transition>
  ...
 </ConversationTransitions>
</Conversation>
```

Figure 6: WSCL XML specification of a purchase business process

The next step is specification of the details of each processes i.e. behavior of each processes. The internal state and structure of these abstract business process is hidden is not transparent from outside. Therefore, the usage of neural networks is appropriate to mimic the behavior of each of the building blocks by monitoring actual business transactions and conversations and creating a relationship between input values/requests and output values/responses.

The final step is to combine the neural network models of each of the simulation building blocks with the building blocks extracted from the WSCL specification. The overall activity is depicted in Figure 7.

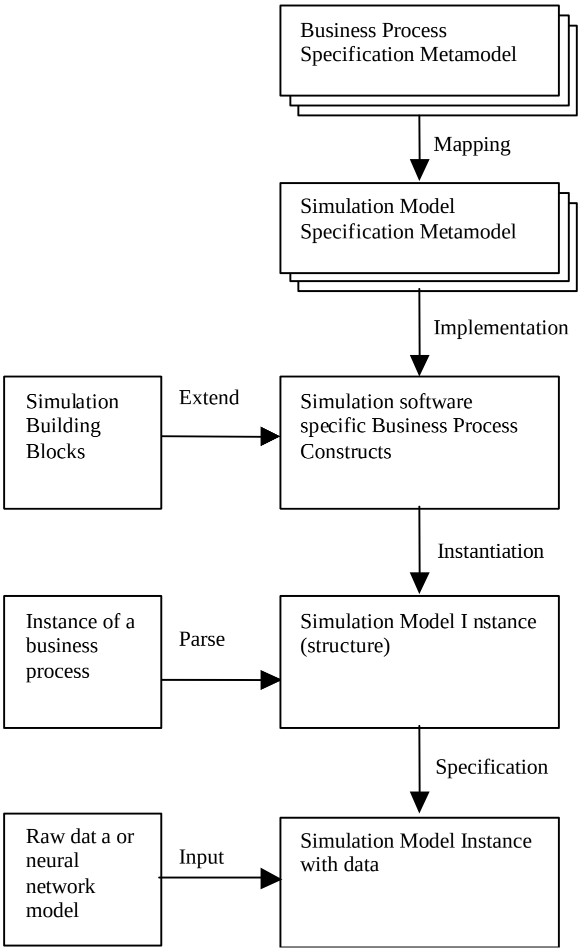

Figure 7: Steps taken to develop simulation models

FEASIBILITY TESTS AND CONCLUSIONS

Experiments have been conducted to evaluate the described approach for modeling operational processes of organizations in a business network by using a case study that consists of two supply chain partners in interaction.

The case is as follows:
"A kitchen equipment store in New York frequently orders espresso machines from a manufacturer in Italy. The store uses make-to-stock ordering policy. The store is known for its high quality service. The store manager wants to keep the service quality of the store and at the same time wants to lower costs by avoiding high stock quantity of espresso machines. An out of stock situation for the store is not an option, since it affects the service quality. Therefore, the store manager wants to model, among other things, the order processing delay of the expresso-making machine manufacturer"

In the experiment, we assume that both the supply chain partners are using electronic means to conduct business transactions. Moreover, we adopt the emerging paradigm of business interaction/exchange as a service. The supply chain partners exchange by opening their services to outside using web service technology. Interfaces of the available services are opened and descriptions of each of the interface (including the data types) are made visible. A service is also considered as consisting of sub services that address different tasks (layering of services). The Web services paradigm allows organizations to describe external structure of their processes.

To construct operational business process models of a supply chain partner, an identification of the structure and behavior of the process blocks are necessary. We follow two approaches to construct the structure and behavior of the business processes blocks. The structure of the business processes has in this case been constructed from the interface description of the different web service blocks in WSDL (Web Service Description Language) that constitute the business process. The behavior of each of the process blocks is modeling using a neural network. By monitoring the input and output of the service blocks i.e. monitoring the different business transactions (requests/responses), the behavior of a particular process block has been modeled. In this case a Multilayered Feedforward neural network architecture was used, together with a Java based neural network engine, in order to implement the approach. The supply chain case has been programmed in Java and the interaction between the supply chain partners was simulated using the Java based discrete-event simulation engine D-SOL (Jacobs, et al., 2002). The neural network was loosely integrated with the supply chain simulation model. A simple operational process with one input and one output was used to model the behavior of the business processes. Thereby, a model could be made in spite of the fact that the underlying real business process of the partner remained hidden. The aim was to see whether the supply chain actor could model the processing delay time of its partner by monitoring its order request and response delay. In the experiments, the neural network was trained in real-time from the start of the simulation and provided predictions fro every next interaction with the partner. After less than 100 business interactions, the average predicted value produced by the the neural network was significantly close (error of less than 5%) to the actual value that was unknown to the model. This indicates that the neural network can indeed be used for modeling the behavior of other partners, at least in cases where we reduce the business processes to one input-output neural network model. However, further detailed studies needs to be conducted to see whether it can be applied to more complex operational processes that depend on time and other factors.

The next step will be to identify and extract the structural elements of business processes from Web services business process specification standards such as WSCL and BPEL. The moment these models are automatically generated, they can be easily combined with the neural network behavioral models that have been discussed in this paper.

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