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Computational Modeling of Business Processes

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Abstract

In this paper we investigate the modeling and analysis of business processes with the goal of improving their efficiency and effectiveness. The main objective of this research is to develop a computational model of business processes that takes into account relevant economic, social, organizational facets of a business process. The research develops a computational tool that will help uncover insights into the interdependencies among agents, activities, and resources in a business process.

1. Introduction The process-oriented approach to organizational design envisions an organization as comprising a number of business processes, each process having it own objectives. In order to have an efficient business process one needs to bind a number of interdependent activities, entities, and resources in a coherent manner. In this paper we investigate the modeling and analysis of business processes with the goal of improving their efficiency and effectiveness. The main objective of this research is to develop a computational model of business processes that will take into account relevant economic, social, organizational facets of a business process. In this paper, we first discuss the requirements for modeling business processes where we identify major aspects of business processes and issues related to modeling these aspects. We then give an informal specification of a generic process model that builds on the requirements specified in the previous section.

2. Requirements for Process Modeling There are four major aspects of business processes that must be considered: workflow relationships, decision structure, information structure, and incentive and motivation. That the above four aspects form an important part of business process redesign is evident from a number of reengineering initiatives reported in the literature [Hammer and Champy (1993), Barua, Lee and Whinston (1996)]. Each aspect encompasses a number of design issues. In addition, there are several interdependencies among the four aspects which need to be considered while redesigning business processes.

Workflow relationships focus on the activities within a business process [Huber and McDaniel (1986), Thompson (1967)]. We can describe workflow relationships on a spectrum; as being sequentially interdependent at one extreme and concurrently interdependent at the other. Sequential interdependence occurs when one activity/process is directly dependent on another for its inputs or resources. Concurrent interdependence on the other hand is characterized by simultaneity or synchronization of activities [Malone (1987), Drucker (1988)]. Workflow relationships aspect is perhaps the most easily representable aspect in a process model.

Our definition of decision structure includes the decision-makers, the decision problems faced in the business process, the decisions to be made, and the decision rules and mechanism used by each decision maker [Rao, et. al., (1994)]. To model decision structures, we center on designing processes as consisting of interacting decision making members with a common process goal. Each member could have different viewpoints with different decision structures, and each one could do his/her own inferencing, as long as, ultimately, the objectives of the process are met. The modeling language should be able to express and model such behavior. The decision structure should be expressible in terms of rules, procedures, declarative statements and axiomatic relations. Within such a computational model, it should be possible to vary parameters pertaining to the various process members and simulate different situations through the synthesis of computational and behavioral viewpoints. The computational model would allow analysts to tackle the problem of design of decision structure or of relating such structures to performance as to be able to identify or map how process performance varies with changing decision structures. This would allow us to meet the goal of gaining an understanding of the variations in process performance with variations in plausible decision structures.

The information structure defines what information is supplied to what decision maker and who supplies the information (or in the words of Arrow (1985) ".....the assignment of signals to agents"). To be able to model and simulate various information structures and their linkage to process performance, it is necessary to design a language to express information in a conceptual model. The information, knowledge, experience of each process entity should be expressible and be available for manipulation and control. The modeling language should be able to accept axiomatic inputs and declarative statements about information content and information flow.

More often than not, individual members' objectives and interests are not the same as process objectives. Incentive mechanisms are a means to align process objectives with that of the agents'. Here we are mainly concerned with the issues of measuring the inputs provided by the agents and motivating agents to obtain the desired inputs[Demski (1972), Holmstrom (1982)]. Important design parameters of incentive mechanisms and performance measurement systems are the number and nature of performance measures, extent of risk sharing, multi-agent and multi-period effects, career concerns of agents and market conditions. To the best of our knowledge, no business process modeling approach has considered the effects of incentive aspects explicitly. There is however theoretical evidence to the effect that incentive contracts affect process performance [Barua, Lee and Whinston (1993 and 1996)] to a great extent. Our modeling approach therefore considers the incentive aspects of a business process. More specifically, we provide features for explicitly modeling axioms of utility theory and agency theory through mathematical equations and declarative statements. Additional hypotheses on agent behavior can also be added through declarative statements as well as rules. This will enable redesigners to test hypotheses on agent behavior under different incentive contracts and performance measurement systems.

3. Specifications for a Generic Process Model Because of the complexities of reality it is not possible to map every object in the real world into the computational environment. Therefore, we must, to quote Simon (1990 p 7), "separate what is essential from what is dispensable in order to capture in our models a simplified picture of reality, which nevertheless will allow us to make inferences that are important to our goals." Therefore, based on the discussion, we present some informal specification of our generic process model.

Workflow Relationships: Workflow relationships are commonly represented as a set of states and actions in process modeling literature[Bajaj and Ram, 1996]. We consider the workflow in a business process as consisting of a set of activities that process information [Marshack and Radner (1972)]. From this perspective, each system state would be associated with a set of information signals. Actions act on the information signals associated with a state and yield a set of new information signals and hence a new state. Precedence relationships among the set of actions is handled by appropriately defining the action values corresponding to each state. Each definition of action includes information on who performs the action (agent information), what resources are needed (resource information), and the time required for completing the action. Agents and resources together are termed "entities" in the process model.

Decision Structure: For each system state there is an associated choice set of actions. The decision structure defines the set of choice sets of actions associated with each system state. The designer would thus be able to specify a number of alternate action sequences from each system state. This enables the designer to test a number of different hypotheses regarding system behavior.

Information Structure: As mentioned before, each system state is associated with a set of information signals, and actions act on this set of information signals to transform system state. The information structure of the system is therefore embedded in the set of information signals associated with the system states.

Incentive and Motivation: Our specification for the generic process model recognizes the importance of agent's motivation in performing his functions. Hence, specific provision is made for representation of entity information. Each entity is assumed to be associated with a number of payoff functions. A payoff function computes the returns(expenses) to an entity as a result of performing a particular action. If the entity is an agent, normally payoff functions would compute the incentives and/or penalties associated with a particular action. If the entity is a resource, the payoff functions would compute the costs and benefits associated with the use of that resource. The system payoff function computes the costs and benefits accruing to the business process from performing a particular action. The provision for the definition of entity payoff and system payoff as separate functions enables us to incorporate axioms of principal-agent theory into our model.

Based on the above discussion, we define our generic process model as a six tuple [Moore and Whinston, (1987), Moore, Rao and Whinston, (1994)]:

$$GPM = \{X, D, E, A, M_a | a \varepsilon A, w\}$$

Where,X - the set of possible (mutually exclusive and discrete) states. D - The set of decisionsE - The set of entities in the process (agents or resources)A - The set of actions or activities. M_a - The information structure associated with action a ε A (Each M_a is a partition of X, as will be explained later)w - The process payoff function. The set of payoff (cost) functions for the process is defined as: w: X x D x A x R -> R; where R is the set of real numbers Each element of the entity set E is assumed to consist of functions and descriptors that define entity_descriptor, entity_role, entity_state, entity_objective, entity_payoff. Entity_descriptor identifies the entity's type (agent or resource). It is assumed that for each entity, the entity_payoff function defines the payoff or cost to the entity from performing an action, i.e.,

entity_payoff: X x D x A x R -> R.

It should be noted that for particular combination of state, decision and action, the process payoff and entity payoff can be different thus bringing in the concepts of principal-agent theory into our computational model. Associated with each action a ε A is a set of information signals Y_a, and a function I_a: X->Y_a. Each Y_a is assumed to contain a finite number of different signals. The set of functions I, represents the information processing functions in the business process. Since, an action transforms the system state, and each system state is associated with an information signal, actions are assumed to generate information. Due to precedence constraints, not all actions are meaningful in a particular state. Therefore, the function I_a is assumed to contain "null" information whenever an action is not legal in a particular state.

4. Concluding Remarks A process modeling tool based on the above specifications is programmed in an object oriented environment. We intend to present our experiences in process modeling with this tool using some reengineering initiative data collected by us over the past year.

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