A layer-based, matric oriented business process simulation solution

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Abstract: Aim of this paper is to review and compare different business process modeling techniques, reveal their capabilities and use a combination of their elements to create a model of applicable simulation solution that is easy to understand on the one hand but enables integration of innovative complex dynamics on the other hand. We develop a simulation solution proposal that is based on three layers and defines business process with matric structure. With graphical model we present simplified layer interaction and numerical formulation of simulation properties. Work supported by Creative Core FISNM-3330-13-500033 'Simulations' project funded by the European Union, The European Regional Development Fund. The operation is carried out within the framework of the Operational Programme for Strengthening Regional Development Potentials for the period 2007-2013, Development Priority 1: Competitiveness and research excellence, Priority Guideline 1.1: Improving the competitive skills and research excellence.

Key-Words: business process management, modeling, simulation, layer-based architecture, matric orientation, software development

1 Introduction
Getting realistic and relevant insight about future state of addressed problem can be speculation based on risky ground if we approach it with inappropriate methodology. Therefore we transferred static models into dynamic interchangeable environments, simulations. “Modeling, analysis, simulation and improvement of processes are on the increase as only a thorough comprehension of the processes within on organization can lead to effective, efficient and value-adding systems” [4]. Doomun and Jungmun argue how important it is to provide “to-be” visualization, especially when we are dealing with process optimization, having variety of improvement indications and several possible solutions [6]. That is why analytic simulation is very important, providing us with review of “to-be” scenarios and their local and system-wide consequences. Capable business process management suites cannot produce efficient and satisfactory results, “current behavior and performance prediction” [7] without being capable to provide simulation of established process model. But they approach to the simulation generally, creating smaller possibility that we well be able to simulate and examine our problem, especially when it is integrated of different disciplines and approached from specific point observation.

This paper continues with problem formulation, where we define motivation of our research. Third part of the paper contains theoretical review of selected business process modeling approaches where we briefly present main properties of included techniques and compare them in tabular form. We continue with critical theoretical presentation of modeling techniques’ predispositions for development and translation into dynamic, scenario based simulation. We conclude with presentation of findings that are based on this theoretical research, promotion of developed simulation approach and proposal for further theoretical and practical research.

2 Problem formulation
Greasley finds process simulation as useful tool in change management within business systems [7]. Kano et al. argue it holds powerful analytical capability for evaluating business solutions [14], while Maruster and van Beest in their case study apply simulation dynamics to workflow models of activities and transactions among them [18]. Approaches to business process simulation are set on comparable logics and used for similar purposes, but even though we cannot neglect discrepancies in details of individual modeling techniques, that serve as a starting platform for simulation development.
Not every modeling technique is appropriate for simulation of any process dynamic, especially when our aim is to simulate process characteristics that were originally not meant as primary source of simulation.

One of such cases is source, influence and flow of knowledge within the business processes. For purpose of this paper we will set our research problem scope to determine which of selected process modeling techniques shows the highest predispositions of being used for purpose of development and testing of external scenarios and integration in originally estimated business process simulation framework. We want to define usable, simple to understand and near intuitive simulation environment, that will be “layer-based” [2] and “grid oriented” [25] and will allow us theoretical simulation, applicable on practical problems, concerning with integration of business process management and activity flow scenario analyses.

3 Review of selected modeling approaches

3.1 IDEF0

Process modeling with IDEF0 rules is a method, based on function which is defined as “a set of activities that takes certain inputs and by means of some mechanism, and subject to certain control, transforms the inputs into outputs” [16]. It uses ICOM (Input, Control, Output, and Mechanism) concept as a main process presentation. “Function transforms inputs into outputs under the influence of a control, using the mechanisms provided. Inputs and outputs are information or physical objects. Controls activate or regulate or synchronize the function. Mechanisms are resources necessary to perform function. ICOM boxes are connected by arrows; outputs of one box can be inputs or controls of other boxes” [12]. IDEF0 modeling is simple and its notation is standard enough that it can be easily transformed in normalized database what practice results in many applications, developed on such [8]. But on the other hand time, such modeling approach causes inability to note time dimension, or to define correctness or conformity criteria in the model itself. Possibility exists to detect and highlight model incorrectness when it is originating in failure to follow the schematic modeling rules [12].

3.2 IDEF3

We use IDEF3 for description of process flow. Plaila and Carrie described it as modeling method that enables possibility to discern what estimated system optimization is and what is prediction model of processes within the system [21]. It presents “the behavioral aspects of an existing or proposed system”[11]. The most significant difference between IDEF0 and IDEF3 is that “IDEF3 does not let us create a model of the system, but captures precedence and causality relations between situation and events in a form that is natural to domain experts” [21]. Models are presented by four types of elements that by description of Kim et. al are units of behavior (they define objects, time intervals in which they occur, relationships with other processes), junctions (logical mechanisms that define the time and relationship of single unit of behavior), links (they define destination of single unit of behavior) and referents (additional information about single unit of behavior) [15].

3.3 Tabular application development

“TAD (tabular application development) is an object-oriented methodology. This methodology describes the functioning of the organisation using several tables” [5]. As Damij defines, the TAD approach results in tabular description and presentation of business process environment. It consists of entity table that defines and describes all subjects and their associations within the business system. Following table is named activity table and maps every single activity that operates as a part of the process and going even further, we design the task table that defines connection between entities and work tasks within every activity in the process [3]. “Each activity occupies one row of the table. A non-empty square (i, j) shows a certain task or work represented by the activity defined in row i performed by an entity defined in column j. Developing the activity table is a result of interviews organized with the internal entities defined in the columns of the table. In the rows of the activity table we first register each activity identified during an interview and then link this activity with the entities in the columns, which cooperate in carrying it out. To make the activity table represent the real world, we link the activities horizontally and vertically. The purpose of defining horizontal and vertical connections is to define their similarity to the real world in which they occur” [5].

3.4 Petri net

“The classical Petri net is a directed bipartite graph with two node types called places and transitions. The nodes are connected via directed arcs. Connections between two nodes of the same type are not allowed. Places are represented by circles...
and transitions by rectangles” [23]. “When every place incident on a transition is marked, that transition is said to be enabled. An enabled transition may fire by putting one token into each of its output places” [9]. Bobbio describes Petri net as a graphical visualization of activity flow within the complex system. Further, comparing the approach with the others similar modeling techniques, she finds Petri net appropriate way to describe “a natural way logical interactions among parts or activities in a system. Typical situations that can be modelled by PN are synchronization, sequentiality, concurrency and conflict” Bobbio [1], and they have been “applied mostly in manufacturing and safety-critical systems” [20].

3.5 Gantt chart
“Gantt charts are widely used to represent production plans, schedules, and actual performance” [13]. Pankaja defines Gantt chart as a graphical presentation of the work breakdown structure, combined with total time duration defined for single task, entities delegated to the tasks and overall process completion percentage [19]. “Gantt gave two principles for his charts: one, measure activities by the amount of time needed to complete them; two, use the space on the chart to represent the amount of the activity that should have been done in that time” [10]. Wilson further develops definition, explaining that Gantt chart logic in first plan uses systemic solutions and pays no attention to algorithmic solving of the problem [24]. “In a Gant chart, each task takes up one row. Dates run along the top in increments of days, weeks, or months, depending on the total length of the project. The expected time for each task is represented by a horizontal bar whose left end marks the beginning of the task and the right end marks the completion of task” [19].

3.6 Business process modeling and notation
BPMN is a modeling approach that consists of graphical presentation model, describing business process on the control-flow base with core graphical elements and extended specialized set. Recker defines core elements as a set that provides a graphical presentation for substantial business processes in simple, intuitive models, while together with extended specialized set, they enable presentation of advanced problems, such as “orchestration and choreography, workflow specification, event-based decision making and exception handling” [22]. The approach is easy to understand and clear to interpret, but as Lerner et al. [17] find out, not supported by formal semantic background, what causes risk that different process models are not understood equally, or on the other hand, designed almost identically but with discrepancy in their core meaning. Similar deficiency is described by Recker, who writes about lack of precisely defined and integrated common business rules, what causes additional need that user is forced to improve by himself [22].

3.7 Comparison of selected modeling approaches

<p>| Table 1, modeling approaches comparison |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Modeling approach</th>
<th>Type of mapping and notation</th>
<th>Syntax components (process components)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>IDEF0</td>
<td>semantically supported graphical diagram</td>
<td>box (function), arrow (input, control, output, mechanism, call)</td>
</tr>
<tr>
<td>2.</td>
<td>IDEF3</td>
<td>semantically supported graphical diagram</td>
<td>process schematics: box (unit of behavior), arrows (links); object schematics: circle (object), label (object state), arrows (links)</td>
</tr>
<tr>
<td>3.</td>
<td>Tabular application development</td>
<td>symbol based notation</td>
<td>entity (letter &amp; numeric symbol), activity (letter &amp; numeric symbol)</td>
</tr>
<tr>
<td>4.</td>
<td>Petri net</td>
<td>bipartite directed graph, symbol based notation</td>
<td>circle (place), bar (transition), arc from place to transition (transition input relation), arc from transition to place (transition output relation), black dot (number of tokens)</td>
</tr>
<tr>
<td>5.</td>
<td>Gantt chart</td>
<td>semantically supported tabular/ graphical diagram</td>
<td>timeline (time window), tabular columns (task, task hierarchy, task duration)</td>
</tr>
<tr>
<td>6.</td>
<td>Business process model and notation</td>
<td>syntax modeling, graphical diagram</td>
<td>circle (activity), box (activity), diamond (gateway), full arrow (sequence flow), dashed arrow (message flow), dashed line (association)</td>
</tr>
</tbody>
</table>

<p>| Table 2, modeling approaches comparison |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Primary dynamic</th>
<th>Secondary dynamic</th>
<th>Model hierarchy</th>
<th>Integration possibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>function representin activity, process or transformat ion</td>
<td>fork (division), join (merger), node (parent box)</td>
<td>top-down decomposit ion</td>
<td>business process management, knowledge management, software engineering</td>
</tr>
<tr>
<td>2.</td>
<td>relations between</td>
<td>junctions (and,</td>
<td>Situation/ev ent based order</td>
<td>business process</td>
</tr>
</tbody>
</table>
4 PROPOSED 3 LAYER SIMULATION SOLUTION

After comparing selected process modeling techniques, we set following evaluation, exclusion criteria for translating model into simulation: 1) definition of system framework, 2) translation in matrix based process layer, 3) development and integration of scenario layer, 4) integration of external third layer dynamic. First criterion evaluation divides assessed techniques into who general groups: first that relies its architecture mainly on diagrammatical presentation (IDEF0, IDEF3 and BPMN), second that builds it equally on symbolic notation supported with graphic presentation (TAD, Petri net, Gantt chart). IDEF0 and IDEF3 hold framework definition within the diagram syntax (they mark the location of function or unit of behavior), while BPMN tries to define it separately by distinguishing different organizational departments, getting closer to intuitive process architecture. Petri net makes consists of diagrammatical representation of the activity based process but on the same time runs semantic execution that can be written as a vector or matrix, but lacks clear definition of organizational system’s widgets. Gantt chart provides us with simple and clear tabular based framework that defines time dimension of process dynamic and notation of activity hierarchy, but on the other hand excludes any other information about system’s architecture. TAD, comparing it to other selected techniques, without any additional development defines organizational system with following components: departments, entities, activities, sub processes and business processes.

By the second criterion exactly TAD provides us with simplest solution translating process dynamic into matrix notation. Process modeling with TAD means creating nonlinear table that includes symbolic notation which by default defines matric relations among activities and entities. Petri net as well by default allows dynamic’s notation within several matric structures that consist of relation between place and transition, that is in fact position of token, and supports its mathematical description. In the same group Gantt chart sets foundation for matric notation but fails to provide us with crucial subscription information for matrix definition that would by default enable development of process simulation. Three techniques of the first group do not provide us with default sufficient information that would make possible to create process matrix. We could create linear matrix to describe relations of primary dynamic but with such representation we would not be able to include and present relation between primary dynamic and organizational entities, which is crucial for efficient process simulation. We could also adopt Gantt chart matrix formulation and define relations among time frames and primary dynamic, but since such solution is not being integrated part of original modeling techniques, and it would demand notable deviation from original modeling logic and its primary dynamic, we on the first hand allow possibility of further development, but on the other hand exclude it of our simulation proposal set.

Third criterion that reveals possibility of translating static model into dynamic simulation is development as integration of the scenario layer that is set on originally designed process layer. Scenario layer creates numerically evaluated context weights for every single link and every single node in previously defined process matrix “expressed in mathematical, logical, and symbolic relationships” [4]. At this stage of development deficiencies of single modeling techniques are getting clearly visible. For being able to run simulation flow we must define its elemental discrete relations. “A discrete-event simulation model focuses on the state of the process at specific time points when the events occur” [4]. In our case this is relation between entity and activity in the time of the process run. Gantt chart clearly set the time window but fails to provide us with information about
organizational entities which means that we would need to switch weighting into labeling relation: activity-time with entity weight, creating actually entity exchange flow that is a simulation possibility, but slightly different than our primary concern. Petri net provides us with a better approximation to organizational system and offers its matric based firing sequences for development into simulation layer, what creates definition gap in primary process layer and pushes the simulation model away from pursued near-intuitive three layer architecture. Way to overcome this deviation is held in inclusion of TAD original architecture that maps organizational system simple but precise enough for us to be able to clearly define entity-activity relation in discrete defined time windows.

To be able to successfully apply our third simulation layer we propose unity of TAD and Petri net modeling techniques. TAD is powerful tool for nonlinear matric notation of organizational system fully supported by tabular descriptive records, while Petri net covers good dynamic logging in form of matrices and vectors.

Fig. 1: Proposed 3 layer simulation solution

With unity of both, third layer that actually runs “to-be” dimension of the simulation is nothing more than selected changes that overrun original architecture of second layer relations. Simplicity and of such solution enables transparent simulation of any scenario and layer based structure intuitive recognition and understanding of process elements and properties of its execution.

5 Conclusion

The results of this paper are concised in graphical model that elaborate business process simulation logics in three layer based and matric oriented architecture. Such model can serve us for several important purposes. First: it is simple learning tool, revealing structure of simulation mechanism that run business process scenarios, making it easier to understand and study observed organizational dynamics. Second: it creates an opportunity to rethink and retailor our perception of what business process simulation is and what it offers, creating behavioral complexity, integrating external (black swan theory) and internal (human factor) unpredictability, even establishing possibility to observe business processes from the econophysics and sociophysics perspective. Third: it provides us with good theoretical platform that can serve as a starting stage for development of process simulation software environment that can be fully adjustable for simulation of any kind of processes.

We cannot claim there is no process simulation tool among business process management suits, that would enable easy, user friendly modeling and scenario design, but usually limitations of existing applications stay with basic dimensions of business observation, which are money and time. When we wish to observe process complexity in new, unusual context, we must find a way to overcome these limitations. Innovative simulation solutions can be good example of such step.

References:

[1] Bobbio, A., System modeling with petri nets. Retrieved April, 10th, 2013, from ftp://95.31.13.230/mirea/6/os-2010/petri/Petri%203D/Petri%203D/%D0%9A%D0%BD%D0%B8%D0%B3%D0%B0/opetrinet.pdf.


