

Multidimensional modeling and analysis of business processes

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Abstract. The paper describes the use of new possibilities of the Spread Page notation for knowledge representation, such as Three-dimensional Representation, Time-varying Representation, Layered Representation, Scaled Detail Representation, Aspect-oriented Representation to describe activities and data in business processes. The knowledge representation methods have been developed allowing you to describe in a single model both static and dynamic properties of objects.

Not only model editing is concerned. Equally important thing for business processes is their analysis. The paper presents methods for business process execution analysis in interactive, multidimensional and scalable environment.

1. Introduction

Nowadays in almost all scientific notations we use flat, two-dimensional, monochromatic representation of knowledge, based on written language, sporadically enhanced by figures and drawings. The paper page is considered as a medium for all notations currently used in any scientific discipline: from biology, medicine or chemistry to math and computer science. We use mainly rectangular boxes with a name in it connected with different kind of arrows. This is how we describe almost everything.

New technologies, however, have brought significant improvements. Today, one electronic tablet can hold and present content of thousands of books, hyperlinked text allows the reader to pass instantaneously from one part of the book to another without having to look for books on the shelf and flip pages. Multimedia became an indigenous component of presented content. Today's electronic devices are inexpensive, handy and robust. Their screens are increasingly eye-friendly, quickly and precisely react to touch, soon enough they will provide tactile feedback and true 3D display capabilities. All that clearly enables us to use new, intuitive, interactive, dynamic ways of presenting content.

Scientific modelling is a scientific activity, the aim of which is to make a particular part or feature of the world easier to understand, define, quantify, visualize, or simulate by referencing it to existing and usually commonly accepted knowledge. It requires selecting and identifying relevant aspects of a situation in the real world and then using different types of models for different aims, such as conceptual models to better understand, mathematical models to quantify, and graphical models to visualize the subject.

The paper describes the use of new possibilities of the Spread Page notation for knowledge representation, such as Three-dimensional Representation, Time-varying Representation, Layered Representation, Scaled Detail Representation, Aspect-oriented Representation to describe activities



and data in business processes. The knowledge representation methods have been developed allowing you to describe in a single model both static and dynamic properties of objects.

Not only model editing is concerned. Equally important thing for business processes is their analysis. The paper presents methods for business process execution analysis in interactive, multidimensional and scalable environment.

A prototype of modelling tools as well as analysis tools that allow you to model business processes in a multidimensional, scalable and aspect-oriented environment will be presented in the paper, a poster or a spoken presentation enriched with above mentioned tools.

2. Business Process Modeling

A business process is a collection of related, structured activities or tasks that in a specific sequence produces a service or product for a particular customer or customers. A business process may often be visualized or modeled as a flowchart of a sequence of activities with interleaving decision points or as a process matrix of a sequence of activities with relevance rules based on data in the process.

Business process modeling (BPM) in business process management and systems engineering is the activity of representing processes of an enterprise, so that the current process may be analyzed, improved, and automated. BPM is typically performed by business analysts, who provide expertise in the modeling discipline; by subject matter experts, who have specialized knowledge of the processes being modelled; or more commonly by a team comprising both. Alternatively, the process model can be derived directly from events' logs using process mining tools.

Modeling business processes means not only determining the course of activities, their sequence and roles. The business process, in order to function properly, must operate on the data [23, 24].

The appearance of certain data in the organization initiates the business process. For example, the receipt of an order initiates the production and delivery process, the holiday request initiates the process of handling the holiday.

During the process execution, the input data is supplemented with other data available in the company. To a large extent, these are data from registers that the company carries out. For the production and delivery process, it will be data about your assortment, time and cost parameters of production processes, necessary components and materials, inventory levels, availability of personnel. For the process of handling your holiday request, it will be information about employees, their vacation leave, alternate possibilities, and required approvals.

The process itself also involves the production of additional data. As a result of subsequent tasks of the process, entries in the registers are inserted or modified. At the end of the process, modified, consistent and verified entries reflecting the current state appear in the company's registers.

In addition to the data, the documents are also processed. From a process point of view, documents are threat as data with a strict format. And as in the case of data, the fact of the appearance (delivery to the company) of new documents may cause the business process to start. The data in the documents most often require additional processing, so that they can be extracted, verified and used in the process.

The new documents may complement data of already running processes. This is an advanced aspect of business process modeling and not all notations are ready for such an eventuality. More often, separate processes are used to model such a phenomenon.

Business rules are another element of business process modeling. In short, these are some formally described principles by which parameters are determined in business processes. Parameters, however, affect the flow of the process, because decision points are based exactly on these parameters [25].

The business process model would not be fully described if it did not include its participants, that is people (or sometimes automated systems) that perform tasks defined in the process.

Designating workers for tasks is an issue in itself. It is very rarely a simple assignment of a person to a role. In practice, it is also important to deal with issues such as selecting a worker from many equivalent workers, setting substitutes for workers who are not available when the task should be

performed, appointing workers based on parameter values in a particular process instance or even defining advanced designation rules based on workers' powers of attorney and rights given.

All these aspects of business process modeling unfortunately do not fit into single, two-dimensional diagrams, and in practice each of them is modeled using a different notation. This approach means that the modeler is not able to provide direct links between the modeled elements of processes. Applying the Spread Page approach may prove to be a way to fill in the gaps between models and cause that properly prepared process models will be much more complete and better readable for their recipients.

3. Spread Page approach in business process modeling

There are several Spread Page model representations. Each of them can be used to illustrate different aspect of a model being designed.

3.1. Three-dimensional Representation

Three-dimensional (3D) models represent a physical object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned. Their surfaces may be further defined with texture mapping.

Today, 3D models are used in a wide variety of fields. The medical industry uses detailed models of organs; these may be created with multiple 2-D image slices from an MRI or CT scan. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds [1]. The architecture industry uses them to demonstrate pro-posed buildings and landscapes in lieu of traditional, physical architectural models. The engineering community uses them as designs of new devices, vehicles and structures as well as a host of other uses.

Contrary to 2D models, 3D models may include many more details describing the modeled phenomena. Therefore, it is worthwhile applying them in software engineering as an extension of the previously used notation. First attempts of the modeling of business processes using 3D visualization were made at the Institute of Applied Informatics and Formal Description Methods at Universität Karlsruhe, Germany [2].

3.2. Time-varying Representation

In many scientific disciplines, there are models with elements or relations between them that vary in time. Dynamic networks are one of many examples. They are very often described as time-varying graphs which consist not only with node and edge sets but also have an additional time instants set that stores changes in the graph with time [3].

Time-varying models could be viewed as a film-strap object that allows skipping from the given point in time to the next one or the previous one. It could also play an animated movie for the given period of time.

3.3. Layered Representation

Modern digital maps are in fact collections of layers. At the beginning, digital maps had the same basic functionality as paper maps. They were just pictures representing roads outlined by the terrain encompassing the surrounding area. However, as digital maps have grown with the expansion of GPS technology in the past decade, live traffic updates [4], points of interest and service locations have been added to enhance digital maps to be more "user conscious" [5]. Traditional map views are now only part of digital mapping. In many cases, users can choose between virtual maps, satellite, and hybrid views.

However, layered representation is used not only for geographical map representation. Layers are commonly used in digital image editing and processing. In medical image analysis layers are very powerful tools for collecting data from different sources, presenting them together, separating different parts of image analyzed, and supporting doctors in decision making.

Many scientific notations can be represented as layers. This approach allows us to present individual aspects of constructed model on different layers and analyze them separately or together, depends on layer visibility settings.

Scaled Detail Representation

In geography, the larger the scale of the map, the better the features that can be de-tailed. A map that shows the water network of a small area may show the river as a polygon layer and will show the tributaries of that river. A small scale map covering the area would show that same river as a line feature and the tributaries would be removed (a process known as generalization). The smaller the scale of the map, the less the actual detail of a feature is preserved [6].

Computer graphics and animation systems use scaled detail approach to object representation. There is no need to draw every detail of an object that appears at a very long distance from the observer. However, in case when the same object approaches the observer it is necessary to unhide its details to make it look good at the screen.

In scientific models sometimes there is a need for looking at the model “from the distance”. That kind of view could be un-detailed. For instance at the general view of data model there is no need to show all attributes of entities. Rectangles representing entities, their names inside, and lines representing relations between them would be enough.

3.4. Aspect-oriented Representation

Sometimes a model could have a slightly different meaning depends on whom it is addressed to. For instance if we could imagine a model of a legal agreement, different parts of that model are important for different persons involved in approval and signing of it. Instead of delivering to them the whole text of the agreement, they could receive that parts that are important especially for them, and in the form they prefer. This is the main point of aspect-oriented representations.

Business process modelling with Spread Page principles gives some tangible benefits. Thanks to the techniques described in previous chapters the model can be more readable and detailed. The table below (table 1) describes how different Spread Page representations can be used in order to model business processes.

The use of Spread Page representations in business process modeling.

Spread Page model representations	Three-dimensional	Time-varying	Layered	Scaled Detail	Aspect-oriented
Document flow modelling aspects					
Business process diagram				X	X
Business process data		X	X		X
Process Documents					X
Business Rules				X	
Roles	X				X

For business process diagramming the scaled-detail representation can be user. It helps to present on a single diagram both the general view on the process and its detailed view. That approach helps to understand processes and gives the ability to switch into details without losing the context of the process part being analyzed.

Aspect oriented representation is also helpful with business process diagramming. Thanks to that kind of multidimensional diagrams, a process designer can focus him-self on the given aspect of the model, having its other aspects hidden as far as they are not important on that stage of analysis.

For process data modelling time-varying and layered representations are useful to show historical changes of data model. In addition, the aspect oriented representation together with the layered representation can be used to determine accessibility levels for different parts of process data. That approach is also the only way to establish individual data optionality for each task in the business process model.

A document content must not be the same for different groups of readers. Each of them could be interested in different part of the document and could look at it from different angles. That's why the aspect-oriented representation is best to adapt.

The scaled-detail representation can be used for business rule modelling. It helps to present on a single diagram both the general and detailed views on the business rule diagram.

The scaled-detail representation is also useful because of hierarchical arrangement of business rule models. Thanks to that, operations like drill-down and roll-up are possible to perform.

Any worker can play many different roles in business processes executed in the enterprise. In one process he or she could be the person that enters process data, in the other – the person that approves tasks. That's why the aspect-oriented representation is best to adapt.

Roles are independent from the organizational structure. However, workers are the part of the common for the organizational structure and roles in processes. This produces a rather complicated dependency grid. Thanks to the three-dimensional representation all these dependencies could be shown on a single diagram.

4. Three-dimensional Business Process modeling tools

Knowledge representation as in the Spread Page approach requires specialized tools. Preparation of multi-faceted and multidimensional models in the traditional way would be several times more labor-intensive. Such tools should first of all support three-dimensional diagramming, and, secondly, they should assist analysts in more or less automated separation of particular aspects of the model.

One of such tools is created in the Cybernetics Faculty of the Military University of Technology and the Tecna company under the name spModeler. It provides the environment for three-dimensional modeling and analysis of business processes. The framework is created as a web application accessible through a browser, by means of which it is possible to create both process diagrams and analyze their parameters in three-dimensional space. The application structure is shown in figure 1.

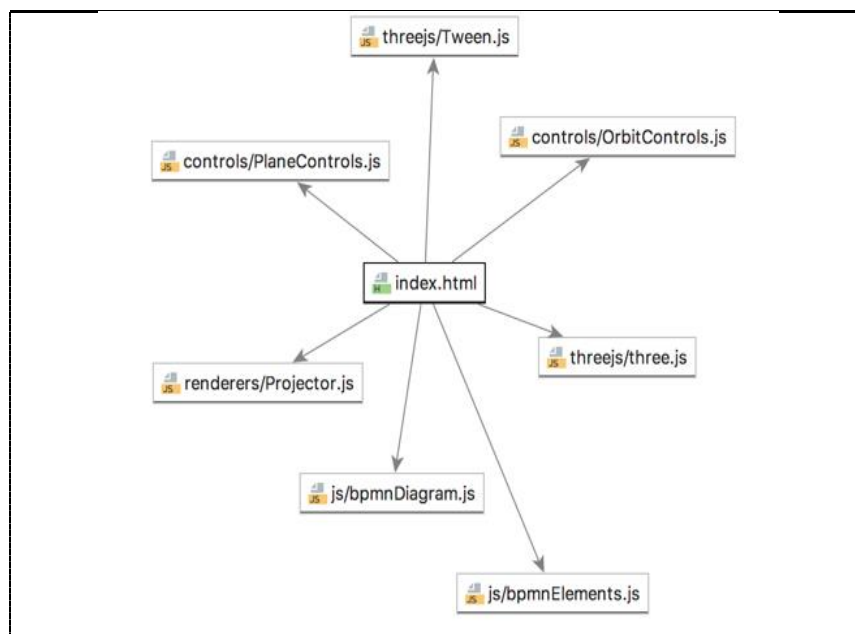


Figure 1. Package diagram to structure the application for modeling and analysis of business processes in 3D. Source: own elaboration.

For the purposes of representing the software function, a diagram from the BPMN 2.0 notation documentation was selected. Figure 2 presents the mentioned diagram and at the same time the method of its display in the spModeler tool in edit mode.

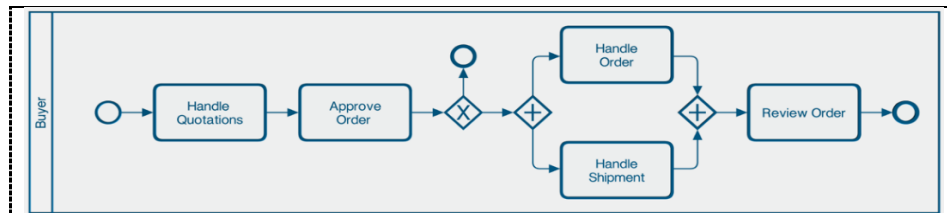


Figure 2. Business process diagram in BPMN notation. Source: Business Process Model and Notation Specification Version 2.0.

The source code describing the above business process diagram is shown below. A part of the repeating elements has been removed and replaced by the "(...)" mark in order not to increase the volume of this article unnecessarily.

```
<script src="js/threejs/three.js"></script>
<script src="js/threejs/Tween.js"></script>
<script src="js/controls/OrbitControls.js"></script>
<script src="js/renderers/Projector.js"></script>
<script src="js/bpmnElements.js"></script>
<script src="js/bpmnDiagram.js"></script>

<script>

    var diagram = new Diagram();
    diagram.init();

    var e1 = new Event( diagram, -1000, 0, 6 );
    diagram.addElement( e1 );

    var flow1Points = [
        new THREE.Vector2( -960, 0 ),
        new THREE.Vector2( -860, 0 )
    ];
    var flow1Shape = new THREE.Shape( flow1Points );
    var f1 = new Flow( diagram, flow1Shape, 4 );
    diagram.addElement( f1 );

    var a1 = new Activity( diagram, -685, 0, 7, " Handle\nQuotations" );
    diagram.addElement( a1 );

    (...)

    var g3 = new Gateway( diagram, 825, 0, 6, CONST_GATEWAY_TYPES.PARALLEL, "Text3" );
    diagram.addElement( g3 );

    var a5 = new Activity( diagram, 1155, 0, 7, "Review Order" );
    diagram.addElement( a5 );

    var flow11Points = [
        new THREE.Vector2( 1330, 0 ),
        new THREE.Vector2( 1430, 0 )
    ];
    var flow11Shape = new THREE.Shape( flow11Points );
    var f11 = new Flow( diagram, flow11Shape, 4 );
    diagram.addElement( f11 );

    var e3 = new Event( diagram, 1470, 0, 10 );
    diagram.addElement( e3 );

    //SWIMLANE
```



```

var s1 = new Swimlane ( diagram, 200, 0, 2750, 700, 4, "Buyer" );
diagram.addElement( s1 );

console.log("Diagram animate");
console.log( diagram.elements );
diagram.animate();
</script>

```

The spModeler tool allows you to model business processes in three-dimensional space. Thanks to this, it is possible to present certain process parameters using the third dimension. In addition, the modeled diagram can be rotated, zoomed in and out, changing the viewing angle.

Such operations allow to present various aspects of the process with varying accuracy depending on the context (figure 3 and figure 4).

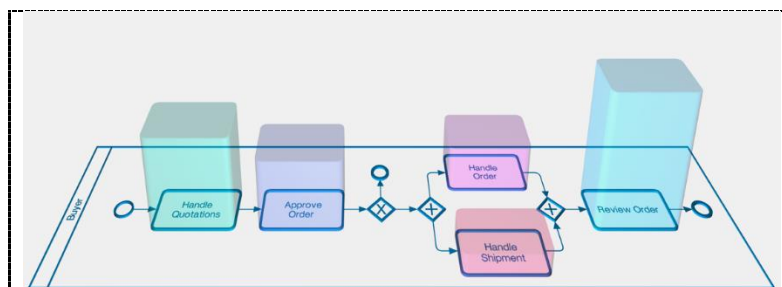


Figure 3. Business process diagram in the spModeler tool in analysis mode. Source: own elaboration.

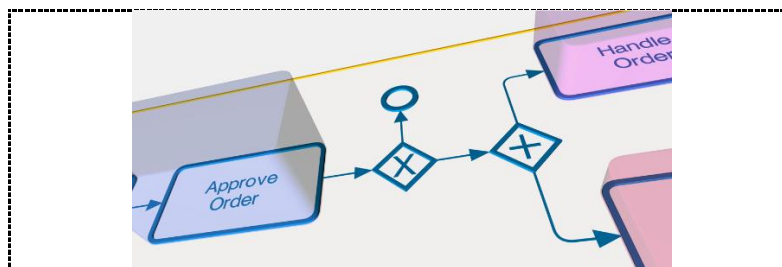


Figure 4. View of the diagram in three-dimensional space after transformations - zooming, changing the viewing angle, displaying parameter values as bars. Source: own elaboration.

5. Conclusions

Process modeling can be more accurate if we apply the techniques listed in the article. The Spread Page approach significantly expands the possibilities of model representation in comparison to traditional notations based on symbols depicted on two-dimensional, monochromatic, static diagrams.

The presented software, thanks to the use of techniques and solutions known from computer games, opens up the possibility of modeling processes in a more modern, dynamic, interactive way, giving both the possibility of analyzing the general image and drilling down into details.

A big progress should be expected in the methods of knowledge representation in the near future. Available now electronic media and possibilities of displaying the content dynamically and manipulating it with the help of a mouse or hand gesture are currently not fully used.

It is advisable to move away from traditional notations, which are limited by publishing possibilities to diagrams that can be put on paper or the pretending-paper media. It is a mistake to use electronic media in exactly the same way that paper ones are used.

Opening the possibility of publishing scientific and commercial articles in the way described by the Spread Page approach will allow for almost unlimited invention in the development of new notations and methods for creating models using them.

As a result, tools will be created to support business analysts in writing and reading models in the manner described in the article.

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