VISUALIZATION IN BUSINESS PROCESS SIMULATION

Xiaoming Du[(a)], Terrence Finandor [(b)], Kuzhen Wu [(c)], Jialiang Yao [(d)]

School of the Built Environment (Thinklab)
University of Salford, Manchester, UK

[(a)]x.du@salford.ac.uk, [(b)]fernando @salford.ac.uk, [(c)]k.c.wu @salford.ac.uk, [(d)]j.yao @salford.ac.uk

ABSTRACT

Visualization in Business Process Simulation (BPS) studies techniques and methods for graphically representing abstract business concepts and data set which are produced in simulation design, execution and analysis. Its main goal is to enhance, simplify and clarify the understanding of BPS. Although data/ information visualization has been actively studied, current research is lack of complete and systemic description on how visualization is used in BPS. This paper focuses on the visualization techniques in BPS. Firstly, the procedure of BPS is defined and the role of visualization in BPS is analyzed. Then, three typical visualization techniques are summarized. According to the BPS steps, different visualization usages in different BPS phase are illustrated. Finally, challenges of enhancing the impact of visualization in BPS are concluded.

Keywords: business process improvement, business process simulation; information visualization; process visualization

1. INTRODUCTION

Simulation is thought of as a key technique for business processes improvement. The technique of using simulation in this context is referred to as Business Process Simulation (BPS). It can be used to test decisions prior to their implementation in real business environment. Furthermore, it allows for the integration of variability and uncertainty into the anticipation of business process performance (April, Better, Glover, Kelly, and Laguna 2006). Such capabilities are often aided by BPS software tools which not only provide users with a variety of analysis possibilities based on the key simulation performance metrics, but also with a visual interface to aid decision making (Bradley, Browne, Jackson, and Jagdev 1995; Vullers and Jetjes 2006). Such user-friendly visual interface for process modeling, simulation execution and result analysis is seen as key criteria for enhancing the usability of BPS tools.

There are many literatures concerning visualization techniques which can be categorized into two major groups: "scientific visualization" and "information visualization" (Tory and Moller 2004). However, most these papers are related to general ideas or concrete domain-specific applications (Streit, Pham, and Brown 2005; Aouad, Ormerod, and Sun 2000; Steel and Iliinsky 2000). Current research is lack of complete and systemic description on how visualization is used in BPS. Visualization of BPS can be regarded as a kind of information visualization. It interprets abstract or behavioral data into visual image that represents as an analogy or metaphor in the problem space.

In this paper, we focus on the visualization techniques in BPS. Our goal is to review the visualization methods and point out its current and potential usage in BPS. To achieve this goal, we firstly define BPS procedures, then summarize the visualization techniques and analyze its application patterns in BPS as a whole. Finally, the challenges of enhancing the impact of visualization in BPS were presented.

2. PROCEDURE OF BPS

Tumay (1996) provides an overview of BPS research work. Regarding the simulation implementation, some basic steps can be distinguished. Figure 1 essentially illustrates four steps in conducting BPS: 1) choosing and defining business, 2) building business model, 3) running business model and 4) analyzing performance and making decision.

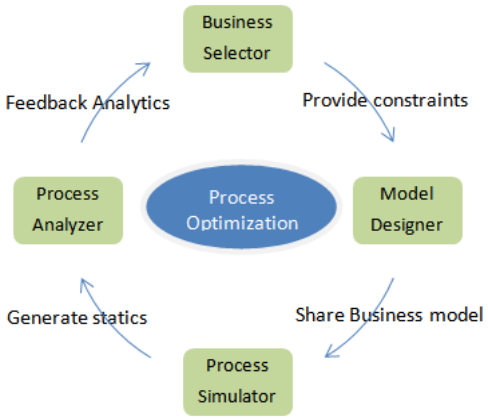

Figure 1: Implementation Steps of BPS

Before starting simulation, the real business process should be chosen and mapped into a process model,

supplemented with business process scenarios and necessary documents. In this context, the sub processes and activities are identified; the control flow is created by entities and connectors which abstractly show the system structure and execution order; the resources are assigned to the activities where they are necessary. In addition, the performance indicators, such as throughput time and resource utilization, also need to be defined.

In order to statistically obtain valid simulation results, typically, business models are executed for many times during the simulation. A simulation run should consist of multiple sub-runs which require substantial time in order to get a valid result. The simulation tool may show an animated picture of the process flow or real-time fluctuations of the key performance measures. After simulation is finished, the simulation results can be collected to aid drawing useful and correct conclusions. Meanwhile, statistical data analysis and visualization should be performed to assist user in decision making. The feedback of analysis result can bring optimization to the real business process.

3. VISUALIZATION TECHNIQUES USED IN BPS

The main advantage of BPS is its ability to incorporate the variability and inter-dependence factors in order to obtain and compare the different process performance. However, such capability simultaneously require an efficient visual interface to support stakeholders who need a communication channel to manipulate complex data, validate the model and evaluate the operation of (re)designed business process in a fast and effective way.

Visualization is "the process of representing data as a visual image (Latham 1995)". In the context of BPS, the data is normally composed of business resources, activities, constraints, running information, results output etc. The purpose of the visualization in BPS can be categorized as validation, analysis and marketing (Bijl 2009; Balci 1997). Visualization can be regarded as a dynamic validation technique because displaying animation of a model and comparing it with the real life operation can help user to identify discrepancies between the model and the real system. Visualized analysis refers to the process of gathering information, displaying 2D&3D graphs and drawing conclusions from the simulation. Consequently, it can be used to locate business process bottlenecks. The third term, marketing, refers to increasing the confidence of people with the help of attractive and understandable graphs. This means convincing users of the validity of the simulation result.

Various visualization techniques play an important role in business knowledge transformation from text-based data to visual characteristics, patterns and tendencies. They appear to be simple, intuitive and natural, break the barrier between the business stakeholders and the knowledge of a specific subject domain. According to appearance style in BPS, we groups visualization technique into three categories:

3.1. Static Graph

Static graph is used to transform an initial representation of a data structure into a non-action graphical one. Though the graph can be visually examined and interacted with, the corresponding graph has no variation itself. The BPS analysis result can be shown as a bar or pie diagram. In term of vision perception, they can be 2D, 3D or multi-dimensional (Adams 2012).

During business process design phase, model could be described as a static flow chart, which consists of nodes (with different node types) connected by edges (of different edge types) (Owen and Raj 2012). In combination with node and edge labels, automatically arranging process graphs and reducing edge crossings to a minimum are complex tasks (Bobrik and Reichert 2005). Some commercial workflow management systems, like MQ Workflow, Lotus Workflow, Staffware, or Oracle Process Manager can support process model visualization (Leymann and Roller 2000). One flaw of above approaches is that model conceptual design and model execution monitoring should depend on the same platform. Process model cannot be visualized by different simulation engines. Other shortcoming is the poor options offered for customizing the way while process is being visualized.

As for the static visualization of analysis data, no matter original input data or result output data, it is mainly provided by automated graphing tools in the form of lines, boxes, arrows, various symbols and pictograms. Such tools could be independent such as MS Graph, Excel or integrated in a BPS tool suite. A scale and labels are also common. The elements of a graphic do not have to be an exact or realistic representation of the data, but can be a simplified version. Spatial layout and graph-drawing algorithms play a fundamental role in visualization.

3.2. Dynamic Animation

While static visualizations of business data are still valuable for the objectives of many studies, there is an increasing demand for dynamic, interactive visualization capabilities to facilitate the validation and understanding of complex business processes.

Dynamic (i.e. time-dependent) animation might help a viewer work through the logic behind an idea by showing the intermediate steps and transitions, or show how data changed over period of time. A moving image might offer a fresh perspective, or invite users to look deeper into the data presented. BPS should have its ability to capture and visualize the dynamic behavior of a process. There are two dynamic aspects, when implementing visualization in BPS, these needs to be addressed (Greasley 2003):

- Variability. Most business processes contain variability both in the demand on the system (e.g. customer arrivals) and in durations of processes (e.g. customer service times). The simulation permits the incorporation of

statistical distributions and thus BPS visualization should provide an indication of such dynamic behavior of the process.

- Inter-dependence. Most processes contain a number of decision points that affect the overall performance of the system. The simulation technique can incorporate various input data to model the likely decision options taken. Also the "knock-on" effect of such interdependent decisions can be dynamically assessed and shown over a time period.

Two application purposes of animation are presented: exploration and presentation (Steele and Iliinsky 2000). Some forms of animation are most suited to presentation, while others work well for exploration. It also discusses a hierarchy of different types of animation which shown as Table 1, ranging from changing the view to changing the axes. Since such classification is not especially designed for BPS, some subtypes may be not a real sense of dynamic visualization (i.e. subtype 1). In this paper, dynamic visualization of BPS is mainly for exploration which covers the second, third and sixth subtype.

Table 1: Type of Animation

No	Type	Function
1	Change the view	Pan over or zoom in on a fixed image, such as a map or a large data space
2	Change the charting surface	On a plot, change the axes (e.g., change from linear to log scale). On a map, change from, for example, a Mercator projection to a globe.
3	Filter the data	Remove data points from the current view following a particular selection criterion.
4	Reorder the data	Change the order of points (e.g., alphabetize a series of columns).
5	Change the representation	Change from a bar chart to a pie chart; change the layout of a graph; change the colors of nodes.
6	Change the data	Move data forward through a time step, modify the data, or change the values portrayed (e.g., a bar chart might change from Profits to Losses).

3.3. Virtual Environment

Although the quality of information visualization has been improved substantially due to the advanced 3D representation, there are several information visualization systems that were implemented in a virtual environment which gives user a feeling of being immersed in real-time 3D world (Kirner and Martins 2000). Virtual Environments (VE) provides unique advantages for information visualization such as "near-real-time" interaction and response (Bryson 2002). As a result, VE tends to be a more attractive and intuitive way in BPS visualization.

Within BPS context, VE based visualization particularly represents the transformation of abstract business data, normally shown as 2D graphs or spreadsheets, into 3D geometry which can be displayed as stereoscopic image and interactively manipulated by the user immersed within the simulation in term of visual experiences. Combined with VE technology, BPS visualization could integrate abstract visualization objects with real-world 3D spatial business sceneries, and support "near-real-time" interaction and response. This visualization metaphor can be used in most of data analysis domains such as tourist attractions, electricity consumption, water supply, crime distribution, spending power etc in which data to be analyzed can be organized by geographical location (Burdea and Coiffet 2003).

These three visualization techniques in BPS above can be categorized in term of user perception and interaction level. From static graph to virtual reality, it gets more complex, striking and intuitive for the user. In addition, advanced visualization techniques such as 3D and dynamic interaction can be used in any of above three visualization forms with different extent of application. However, advance technique does not mean better for problem solving. More suitable techniques need to be chosen according to the business domain characteristics.

4. VISUALIZATION APPLICATION IN BPS

Based on the procedure of BPS denoted in section two, different visualization techniques can be integrated into each steps of BPS.

4.1. Visualization in Process Modelling

The modeling of business processes has a significant role in BPS. Notably, business process modeling demonstrates two important functions (Lin, Yang, and Pai 2002): (1) to capture existing processes by structurally representing their activities and related elements; and (2) to represent new processes in order to evaluate their performance.

Business Process Modeling Notation (BPMN) is the new standard for graphically modeling business processes, which was defined by the Business Process Management Initiative (Owen and Raj 2003). The competing standard to BPML is the Business Process Execution Language for Web Services (BPEL4WS) created in a joint venture by BEA, IBM, Microsoft and others. Such notation and language are sets of graphical constructs and rules about how to combine these constructs. In addition, process modeling tools such as Microsoft Visio, IBM/Rational Rose, Arena etc can provide user and analyst with the ability to draw business processes. However, such tools only provide a 2D graphical static model editor making use of the appointed shapes such as rectangles, circles, and arcs etc which conform to these modeling grammars.

Modeling languages which use only 2D diagram for visualization limit the amount of information to be integrated into a process model in an understandable way. Betz, Eichhorn, Hickl, Klink, Koschmider, Li, Oberweis, and Trunko (2008) introduce a 3D technique into business process model which represents

information more compactly. In addition, 3D process model visualization allows user to change view-point interactively. As a result, this approach not only improves the layout of process models (e.g. by minimizing the number of crossings of arcs), but also increases the information content of a process model.

Recently, collaborative process modeling has appeared under some web-based experimental environments. In some circumstances such as large scale manufacturing system, modeling needs to be performed in a cross-organizational, distributed environment. Brown, Recker, and West (2011) describe a novel process modeling approach using recent 3D virtual world technology. Even without the support of 3D technology, some visualization tools can be extended to provide a complete and usable distributed environment for collaborative (re-) design of business processes. This approach increases user empowerment and adds significance to the collaboration and consensual development of process models even when the relevant users are geographically dispersed.

4.2. Visualization in Simulator Running

While modeling allows user to visualize the design of a business process, process running could offers a fresh perspective to look deeper into the data presented. There have been different approaches for visualizing the behavior of a simulator running in an understandable way for the relevant stakeholders.

Dynamic and interactive visualization techniques are mostly adopted during the execution of the business simulation. Similar to algorithm animation (Korhonen and Malmi 2002), the state change of data structure can be visualized at certain forms. For example, process simulation can be animated by continuously displaying the process state with a sequence of visual snapshots of data structure. In addition, user can control the process by interacting with system such as stopping or continuing the animation. Moreover, these animation steps could be recorded in order to give user the control of traversing the animation sequence back and forth. The replay or animation of the simulation shows the states of process model which might be used to reveal the bottleneck of process design (Vullers and Netjes 2006).

There are many commercial-off-the-Shelf (COST) tools, such as ARIS, Casewise, ExSpect, having sophisticated simulation capacity and animation function to support the visualization of time-based generation of process event. For example, Verbeek (2000) uses the concept of dashboards to track the key performance metrics' changes and reflect the dynamic behavior of a business process (e.g. by using flow meters, flashing lights, etc. as used in typical control panels). Moreover, interaction with the simulation via this dashboard is available. Comparing to the dashboard, Petri nets tend to support process visualization by showing the movement of graphical objects. Mimic library of Design/CPN supports the simulation system to manipulate graphical objects, allows user to interact with simulation via such graphical objects. As a result, user can get a good impression of the 'look and feel' of the final product. Other examples include the model of mobile phone communication and a graph transformation based animation such as GenGED (Kindler and Pa 1es 2004).

One recent example of process visualization, GapMinder, is an animated bubble chart designed to show trends over time in three dimensions. Both size and locations of bubbles smoothly animate as time passes. This technique appears to be very effective in presentations, where a presenter tells the observer where to focus by making the data come to life, and emphasizes the critical results of an analysis.

Since 3D visualizations can offer intuitive understanding of business processes simulations that every stakeholder can engage with easily, Brown and Cliquet (2008) develop a tool which can be used to provide 3D avatar-based visualizations, showing an avatar executing a workflow process in a 3D virtual environment. Thus, a workflow in principle can be designed within a standard 2D tool and then be visualized in a 3D environment for communication and validation processes. With 3D scene and human models, a typical service-based process can dynamically illustrated. Eichhorn, Koschmider, Li, Oberweis, St ürzel, and Trunko (2009) present an interactive 3D process animation based on Petri nets which support users to quickly identify the weak spots of the real business processes.

4.3. Visualization in Process Analyzing

In BPS procedures, process analyzing is considered as a post-simulation step after simulation has been completed. Apart from the static presentation and dynamic animation of business model, the simulation result of model execution should be appropriately harnessed and presented in order to aid decision making.

Static visualization technique is widely used in this phase. Of course, besides the traditional 2D form of tables, outlines, pie charts, line graphs, and bar charts, advanced information visualization such as multi-dimensional graphics has been used increasingly. The main purpose of the visualization in process analyzing is to support the last decision making after simulation result had been obtained. The result of BPS is different from other types of data which is normally abstract, discrete, multi-dimensional, hierarchical and networked. These characteristics make visualization more difficult (Tegarden 1999).

Although rich static graph is widely used for process analyzing, dynamic animation and visual reality technologies are getting more acceptable in some particular situation such as geography related business simulation in which the process analyzing is illustrated using 3D and animation dashboard along with 2D line graph and different color indication. Tegarden (1999) also presents some typical visual representations created by information visualization designers which include Kiviat diagrams, parallel coordinates, 3D scattergram,

3D line graph, volume rendering, floors & walls representation, maps and so on.

5. CHANLLENGES IN ENHANCING THE IMPACT OF VISUALIZATION IN BPS

Visualization apparently offers many benefits to BPS stakeholders. Academics, researchers and designers are continually striving to formulate new and creative methods for representing. However, they could face a number of challenges and choices summarized below.

5.1. Usability and Accuracy

Human factors play an important part in BPS visualization design. Creating an effective tool for BPS visualization should require a deep understanding of domain-specific problems and tasks (i.e. key performance metrics, metaphor designs etc). As most software developers, BPS developers also tend to do their development as quickly as. possible. Nevertheless, many efforts just focus on creating new visualization techniques with little attention on user needs and capabilities.

One common criticism of BPS visualization research is that it presents interesting techniques, rather than solutions to real problems. With new technology, the power and novelty of techniques can lead to using technology for technology's sake instead of providing real benefits to users and providing more information through visualization (Stone 2009). Few's Web site shows some examples of inadequate business visualization which require developers to further understand the data, the audience and the problem being solved (Few 2012).

5.2. User Interaction

Interaction in BPS visualization is essential for the users to conduct analytical reasoning, gain insight from complex data-set. BPS visualization tool has to provide not only effective visual representations but also effective user interaction to ease the exploration and help users to achieve understanding.

Due to the incorporation of advanced technology such as 3D, VE and Web into BPS, the user interaction becomes more complex. For example, in VE based BPS visualization, interaction with abstract data element and virtual environment requires a certain training and familiarity with nonconventional devices. On the other hand, another challenge for the interaction in BPS is to be able to dynamically build up visualization views along with certain criteria which may be specified via a direct manipulation interface. This technique involves graph reduction and graph aggregation which comprise choosing process objects and composing them in an appropriate way (Rinderle, Bobrik, and Reichert 2006). Furthermore, distributed user interaction in BPS visualization via Internet provides another challenge (Huang, Xiong, and Li 2004).

5.3. Collaborative Visualisation

Visualization is the key support during collaborative business process improvement in which visualization is evolving into mediators of human-to-human and human-to-data interaction. Current BPS visualization is user-centered and task (process) driven, which supports multi-disciplinary teams of users to collaborate and share ideas. However, how to design such digital information visualization systems that can adequately enhance collaborative business process improvement is still remain as a challenge.

Some exploring research work has being done in this area. For example, process modeling is a complex organizational task that requires many iterations and communication between business analysts and domain specialists, some state-of-the-art 3D virtual environments were developed with that in mind for collaborative (re-) design of business processes (West, Brown, and Recker 2010; Brown, Recker and West 2011). During the development of collaborative visualization of BPS, social interaction and information security could be the main challenges for researchers.

6. CONCLUSION

BPS visualization is a specialized area of information visualization, which focuses on improving business process understanding by providing visual representation of abstract business concepts and data set. No such a very common and proper visualization technology can be used over each phase of BPS and each application area. Visualization techniques need to be carefully chosen which conform to the problems and tasks of a particular domain. With the development of modern computer technology, new visualization approaches for solving business problems can go further. Though some challenges will be confronted with, visualization of BPS will continuously play an indispensable role in business process improvement.

REFERENCES

Adams, D., 2012. *Data Visualization*, Available from: www.CFOProject.com.

Aouad, G., Ormerod, M., and Sun, M., 2000. "Visualisation of construction information: a process view", *International Journal of Computer-integrated Design and Construction*, 2(4):pp206-214.

April, J., Better, M., Glover, F., Kelly, J. and Laguna, M., 2006. Enhancing business process management with simulation optimization, *Proceedings of the 38th Conference on Winter Simulation,* pp.642-649. December 03-06, Monterey, CA, USA.

Balci, O., 1997. Chapter Verification, Validation and Testing, in: *Handbook of Simulation. Principles, Methodology, Advances, Application and Practice*, John Wiley and Sons, Inc. 335–393.

Betz, S., Eichhorn, D., Hickl, S., Klink, S., Koschmider, A., Li, Y., Oberweis, A., and Trunko, R., 2008. 3D Representation of Business Process Models, *Modellierung betrieblicher Informationssysteme– Online Proceedings* (*MobIS 2008)*, pp.73-87, November 27-28, Saarbrücken, Germany.

Bijl, J. L., 2009. *How game technology can be used to improve Simulations. literature survey*, Delft University of Technology, 2009.

Bobrik R., and Reichert, M., 2005. Requirements for the visualization of system-spanning business processes, *Proceedings of the 16th International Workshop on Database and Expert Systems Applications.* pp.948-954, August 22-26, Copenhagen, Denmark.

Bradley, P., Browne, J., Jackson S., and Jagdev H., 1995. Business process reengineering (BPR) – A study of the software tools currently available, *Computers in Industry*, 25(3):309-330.

Brown, R., and Cliquet, F., 2008. Communication of business process models via virtual environment simulations, *BPTrends*, 12(9):1-7.

Brown, R., Recker, J., and West, S., 2011. *Using Virtual Worlds for Collaborative Business Process Modeling*, Available from: http://eprints. qut.edu.au/41816 [accessed 20 March 2012]

Bryson, S. , 2002. Information Visualization in Virtual Environments, in: Stanney, K., ed. *Handbook of Virtual Environments*, LEA Associates.

Burdea, G. C., and Coiffet, P., 2003. *Virtual Reality Technology*, 2nd Edition, Wiley-IEEE Press.

Eichhorn, D., Koschmider, A., Li, Y., Oberweis, A., Stürzel, P., and Trunko, R., 2009. 3D support for business process simulation, *33rd Annual IEEE International Computer Software and Applications Conference*, pp.73-80. July 20-24, Seattle, Washington.

Few, S., 2012. Available from: http://www. perceptualedge.com/examples.php [accessed 20 March 2012]

Greasley, A., 2003. Using business-process simulation within a business-process reengineering approach, *Business Process Management*, 9(4): 408-420.

Huang, B., Xiong D., and Li, H., 2004. An Integrated Approach to Real-time Environmental Simulation and Visualization, *Journal of Environmental Informatics*, 3(1):42-50.

Kindler, E., and Païles, C., 2004. 3D-Visualization of Petri Net Models: Concept and Realization, *25th International Conference on Application and Theory of Petri Nets*, pp.464-473, June 21-25, Bologna, Italy.

Kirner, T.G. and Martins, V. F., 2000. Development of an Information Visualization Tool Using virtual Reality, *Proceedings of the 15th ACM Symposium on Applyed Computing*, pp.604-607, March 19-21, Como, Italy.

Korhonen, A., and Malmi L., 2002. MATRIX – concept animation and algorithm simulation system, *Proceedings of the Working Conference on Advanced Visual Interfaces. ACM*, pp.109-144. May, Trento, Italy

Latham, R., 1995. *The Dictionary of Computer Graphics and Virtual Reality*, 2nd Ed. New York, NY, Springer-Verlag.

Leymann, F., and Roller, D., 2000. *Production Workflow – Concepts and Techniques*, Prentice Hall.

Lin, F., Yang M., and Pai, Y., 2002. A generic structure for business process modeling, *Business Process Management*, 8(1):19-41.

Owen, M., and Raj, J., 2003. *Popkin Software, BPMN and Business Process Management*, Available from: http://www.BPMI.org [accessed 20 March 2012]

Rinderle, S., Bobrik, R., and Reichert, M., 2006. Business Process visualization – use case, challenges, solution, *8th International Conference on Enterprise Information Systems*, pp.205-211, May 23-27, Paphos, Cyprus.

Steele, J., and Iliinsky, N., 2000. Animation for Visualization-Opportunity and Drawbacks, in: *Beautiful Visualization, O'Reilly Media*, Inc. 329-352.

Stone, M., 2009. *Information Visualization: Challenge for the Humanities*, Available from: http://www.clir.org/pubs/resources [accessed 20 March 2012]

Streit, A., Pham, B., and Brown, R., 2005. Visualization Support for Managing Large Business Process Specifications, *Proceedings of third International Conference on Business Process Management*, pp.206-219. September 6-8, Nancy, France.

Tegarden, D., 1999. Business Information Visualization, *Communications of AIS* , 1(4).

Tory, M., and Moller, T., 2004. Rethinking visualization: A high level taxonomy, *Proceedings of Information Visualization*, pp. 151–158. October 10-12, Austin, Texas.

Tumay, K., 1996. Business process simulation, *Proceedings of the 1996 Winter Simulation Conference*, pp.93–98, ACM Press, Coronado.

Verbeek, E., 2000. ExSpect 6.4x product infromation, *21st International Conference on Application and Theory of Petri Nets*, pp.39–41, June 26-30, Aarhus, Denmark.

Vullers, M. J., and Netjes, M., 2006. Business process simulation – a tool survey, *Proceedings of the Seventh Workshop and Tutorial on the Practical Use of Coloured Petri Nets and the CPN Tools*, pp.77-96, October 24-26, Department of Computer Science, University of Aarhus.

West, S., Brown, R., and Recker, J., 2010. Collaborative business process modeling using 3D virtual environments, *16th Americas Conference on Information Systems Sustainable IT Collaboration around the Globe*, August 12-15, Swissôtel, Lima.