CHANGE VISUALIZATIONS IN BUSINESS PROCESSES
Requirements Analysis

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Abstract: Many business processes are highly dynamic, because process changes result from unplanned events and exceptions which are unforeseen (e.g., demands of customers have changed, new legislature or design errors are detected). The management of the large collections of the different process model versions which evolve over time requires visualization approaches. Visualizations of changes between different process versions are often essential, because processes in combination with change information can become very complex. In this paper we discuss visualization requirements for process changes with the focus to support users to understand changes more easily. The requirements analysis is based on insights which we gained from: (1) literature review to get an overview about different characteristics of changes in process as well as existing visualization approaches and (2) a user survey to identify users' experiences and expectations in this field. With the proposed requirements we want to support researchers to identify directions for further work in regard to process change visualization.

1 INTRODUCTION

Managing large collections of business process models plays an important role for any organization, because organizations tend to collect hundreds or even thousands of business process models over time. One reason for this proliferation of process models is that they evolve over time in order to, for example, react on changing environmental conditions (Rinderle et al., 2004). Fast changing business environment requires flexible approaches to support companies to adjust their business processes in regard to dynamic structural changes. The need of flexibility of processes can be found in many applications. For example in health care it is necessary to coordinate and plan tasks but it is not convenient as well as cost effective to define all possible task sequences in advance (Reichert and Dadam, 1998). Unplanned events or exceptions can occur and therefore flexibility in processes is necessary to allow ad-hoc deviations from the preplanned processes (Reichert and Dadam, 1998).

Especially for critical and sensitive situations and/or domains (e.g., health care) users are involved in order to resolve exceptions or to deal with unplanned events. Therefore it is absolutely essential that users get a quick overview about their tasks and to understand the logic behind a process and to comprehend possible effects/consequences if changes of the process model or process instances are necessary (Rinderle et al., 2006). Based on the best known saying "a picture is worth a thousand words", words are often not sufficient (e.g., especially to describe relationships of processes or to analyze change log files only in textual form). Visualizations help users to see the unseen, because visual representations make patterns transparent and provide a deeper understanding of subjects (West et al., 2006). Moreover, visualizations of change information for processes allow users to generate insights, which can influence their further decisions (e.g., users can detect conflicts) and help to make the structure and dependencies between elements in processes more transparent. Several research studies have been conducted to analyze how visualization techniques can help users to understand processes and there exist several tools that offer process visualization approaches to support users to model and monitor business process models and instance data (Matković et al., 2002; Aguilar-Savén, 2004; Bobrik et al., 2006). Business processes often describe with the help of business process modeling notations (e.g., see (Aguilar-Savén, 2004; Lu and Sadiq, 2007; Rajabi and Lee, 2010) which describes process as a graphical representation (e.g., UML, Petri nets, BPMN) to reflect the process logic.

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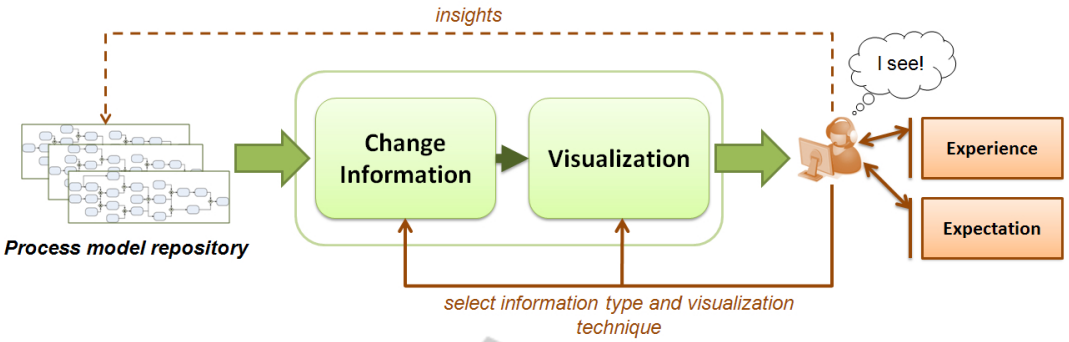

Figure 1: Framework for visualizing change information.

However, process visualizations are often ill-suited to deal with change information, because they concentrate more or less on an idealized version of the preferred process while ignoring graphical support to highlight changes and human activities at design time and at run time according to business process life cycle. For an effective usage of such visualizations it is necessary to find a user-friendly design which allows users to track the changes in business process models and instances. For example, a visualization (e.g., graphical representation of change log files) can be helpful to monitor the changes and can support users in their decision if a redesign of the process model would be necessary.

Based on the challenge to select an appropriate visualization, it is useful to know the requirements and expectations of such change visualizations. In this paper we want to give researchers a first overview of different characteristics of changes and visualization approaches in combination with a survey to identify users' experiences and expectations. The paper should support researchers to identify directions for further work to bring forward the process change visualizations. Moreover, we discuss requirements for process change visualization which can be used as foundation for designing change visualizations for process models which meet users' expectations.

This paper is structured as follows. In Section 2, the basic considerations for the visualization of changes in processes are presented. The methodology used in this work is discussed in Section 3. Moreover, we give an overview about different characteristics of process changes and visualization approaches in Section 4. In Section 5 we discuss the findings of the survey to identify users' expectations and experiences with graphical representation of change visualization. Based on the gained insights from the literature review and user survey, we identify requirements which are relevant for the process change visualizations in Section 6. Finally, the paper is concluded and gives an outlook on future work in Section 7.

2 BASIC CONSIDERATIONS

Fast changing business environments require visualization approaches to support companies in adjusting their business processes in regard to changes. To make this change information between different versions transparent it is necessary to identify first how the process models have changed as depicted in Figure 1. The information can range from the identification of the reason for the process changes (e.g., demands of customers have changed or detected design errors) to the specification how the control and data flow of processes has changed (e.g., by adding or deleting process elements). The next step is to visualize the change information. Different visualization approaches exist (e.g., dynamic representation of changes can be used for tracking changes between different versions) to enable users to comprehend changes more easily and to generate insights, which can influence their further decisions (e.g., users can detect conflicts). Users can influence both steps (identification of change information and their visualization) depending which kind of information they want to see and how this kind of change information should be visualized. The choice of the visualization approach and which change information should be visualized often depends on users' experiences with other visualization tools and which expectations they have on such visualizations.

3 METHODOLOGY

For the development of change visualizations it is important to identify visualization requirements with respect to users' expectations and experiences on such

change visualizations. However, identification of requirements is not an easy task. Therefore we decided to find answers to the following questions: (1) What are the characteristics of changes in processes?, (2) Which visualization approaches do already exist?, (3) Which experiences do users have with process visualizations? and (4) Which expectations do users have on the visualization of changes in processes?

To explore the first and second question a literature review is used to get an overview about the different characteristics of changes in processes and visualization approaches. Literature review is often used in the early beginning of the development process to get relevant basic background information (e.g., by searching traditional literature databases). Often literature review is combined with user surveys to contact specific experts in this field to obtain additional insights. Therefore, the third and fourth question are answered by the findings of a user survey to identify users' expectations and experiences with graphical representations of processes and changes. For this reason, we used online questionnaires to obtain qualitative and quantitative data.

4 LITERATURE REVIEW

The literature review should give researches a first overview about different visualization approaches and different characteristics of changes. For the literature review databases – like IEEE Computer Society, ACM Digital Library, Sciencedirect, and SpringerLink – were searched.

4.1 Characteristics of Changes

Changes in business processes (which are usually changes in data sets) result from (1) incomplete specifications because events cannot always be predefined and (2) modifications which are based on new or changed conditions (van der Aalst and Jablonski, 2000; Rajabi and Lee, 2010). Several works (e.g., see (van der Aalst and Jablonski, 2000; Kettinger et al., 1997; Rajabi and Lee, 2010; Nurcan and Barrios, 2003; Reichert and Dadam, 1998; van der Aalst, 2001)) exist which concentrate on the specification and criteria of process changes:

- *Reasons for Changes.* Different factors exist which influence process changes, e.g.: (1) if the context or the environment is changed (e.g., new products or demands of customers have changed), or (2) if a new legislature or new technology exists, or (3) if design errors or missing data sets are detected (van der Aalst and Jablonski, 2000; Nurcan, 2008; Wörzberger et al., 2008; Nurcan and Barrios, 2003).
- *Ad-hoc vs. Evolutionary.* Literature distinguishes between ad-hoc changes and evolutionary changes (Schonenberg et al., 2008; Reichert and Dadam, 1998; Nurcan, 2008; van der Aalst, 2001; van der Aalst and Jablonski, 2000; Rajabi and Lee, 2010). Ad-hoc changes are only relevant for one or more selected process instances if the process definition is unsatisfying for the process execution or to handle rare events. Such changes have to be undone before any further instances is allowed to start. Evolutionary changes are modifications of the process model that are relevant for all instances (e.g., to correct a design error) and therefore migrating strategies are necessary for already running process instances.
- *Entry Time vs. On-the-Fly.* There exist two possible moments to integrate process changes: (1) entry time means that changes can be performed only before or at the moment the process instance is created and (2) on-the-fly means that changes can be performed at any time (Schonenberg et al., 2008; van der Aalst, 2001; Reichert and Dadam, 1998). This can have an impact on running as well as new process instances. It must be generated that such changes do not have a negative impact on run time performance and do not disturb process participants who are not involved.
- *Change Patterns.* Both for ad-hoc and evolutionary changes, change patterns exist that specify how control and data flow of processes can be changed (Reichert and Dadam, 1998; van der Aalst, 2001; Weber et al., 2008; Wörzberger et al., 2008).

4.2 Visualization Approaches

Business processes are usually visualized as directed graphs to make the flow of resources, tasks and time visible. In general, different graph layout algorithms exist (e.g., see (Eades et al., 1993; Sugiyama, 2002; Hong et al., 1998; de Fraysseix et al., 1988)) as well as layout approaches tailored for business process graphs (e.g., see (Effinger et al., 2009; Albrecht et al., 2010; Diguglielmo et al., 2002; Zhao et al., 2009; Six and Tollis, 2002)).

Orthogonally, several approaches suggest to visualize business processes in 3D such as (Schönhage et al., 2000; Brown and Recker, 2011; Betz et al., 2008; Brown, 2010; Eichhorn et al., 2009). The question to visualize processes in 2D or 3D is intensely

discussed in the research community. One point of view is that the third dimension is a possibility to encode further information and enables interaction with larger business process models (Brown and Recker, 2011). For example, (Betz et al., 2008) state that a 2D representation of business processes is limited in regard to the amount of information which can be integrated in an understandable way. Furthermore, the authors mention that 2D representations of process information interfere each other. Another point of view is that the third dimension has the effect to make the visualization and interaction more difficult (e.g., certain information might be hidden). For users who are not familiar it is more difficult to interpret the data with a 3D visualization. A well-organized 2D representation is more easily accessible and accepted by business people (Schönhage et al., 2000).

Another challenge addressed in literature is the visualization of complex business processes due the multitude of different information such as control flows, data flows, or resources contained within one process model. Generally, it is hard to visualize all the information effectively without introducing new problems (e.g., cluttered or overcrowded view). Some approaches (e.g., see (Bobrik et al., 2007; Bobrik et al., 2006; Bobrik and Bauer, 2007; Matković et al., 2002; Jablonski and Goetz, 2008; Polyvyanyy et al., 2008)) propose to visualize different perspectives on business processes for breaking down the complexity of business processes and to improve the comprehensibility of the process structure. For example, (Jablonski and Goetz, 2008) present a business process visualization approach which enables to be flexible with respect to the different perspectives of business processes. (Polyvyanyy et al., 2008) introduce an approach - named Abstraction Slider - which enables users to control the abstraction levels of process models. A further approach is described by Proviado (Bobrik et al., 2007; Bobrik et al., 2006; Bobrik and Bauer, 2007) which enables different views on the process and related data with an adapted visualization and a customized granularity of information that reflects interests and needs of different user roles.

Animation is a typical way to visualize how business processes are executed (Rinderle et al., 2006) and is used in tools such as ARIS or IBM WBI Modeler. Furthermore, several research studies point out that the usage of animations can help users to trace changes and to understand the process flow more easily (e.g., see (Burkhart and Fusco, 1996; Eichhorn et al., 2009)). However, there is also criticism on using animation. (Beck et al., 2009), for example, point out that the cognitive load is the major problem for animations, because humans can only see a single image and therefore it is not possible to follow all changes in the visualization. Visually keeping track of business process changes has been addressed only by few approaches such as (Kabicher et al., 2011). The question, if a static or dynamic graphical representation is more suitable to visualize changes in data sets can not be answered at this point, because it depends on the type of dynamic data and on the decision which tasks should be performed.

5 SURVEY

The primary goal of conducting a survey was to gain more information about users' experiences and expectations.

5.1 Sample

The invitation of the online survey for participation was sent via mailing lists to persons who had at least basic knowledge with business process models and/or process visualization. Fifteen persons responded to the questionnaire. The participation was voluntary and anonymous.

5.2 Survey Design

The design of the survey is inspired by questionnaire guidelines, such as (Lumsden, 2005; Stone et al., 2005; Wilson, 2007). The participants can control the survey and have the possibility to skip questions if s/he does not want to answer it. Additionally to an introduction and a description about the purpose of the questionnaire, the questions are classified into the following categories:

- *Background Questions.* This category includes introductory questions to identify more about the users' background. This information should help us to classify users' characteristics to get a general picture about particular user groups. For example the category contains questions how they would rate their knowledge of business processes or with which of the visualization techniques they are familiar.
- *Experience Questions.* This category includes questions to analyze users' experiences in regard to process visualization and change visualization. Furthermore, the category contains questions to find out the experiences with visualization tools and what they like or dislike about these tools. The answers will give us the possibility to find out what works well and what works not so well.

- *Expectations Questions.* The last category contains questions about expectations in regard to change representations.

5.3 Results

The results are based on quantitative and qualitative analysis. For the responses from the open-end and combined questions, we applied the qualitative content analysis to evaluate participants' answers. The findings of the survey are classified into the three questionnaire categories listed in the previous subsection.

5.3.1 Background Questions

The findings of the survey are based on the answers of seven experts, five semi-experts and three non-experts. In our case experts are persons who have a high knowledge about business processes and are occupied with them very often and intensive. Semi-experts describe persons who have basic knowledge about business processes and use them only sometimes. Non-experts are persons with low knowledge about business processes and use them rarely.

The participants stated that they would describe their role in regard to business process management as researcher (6 statements), analyst (3 statements), designer (2 statements), business leader/manager (2 statements) and two persons did not define their role.

We also wanted to know how familiar they were with different visualization approaches (e.g., graphs, different diagram types, 3D representation, and animation). The responses showed that most participants stated that they were very familiar with node-link representations (see Figure 2). The responses to the question which of the visualization techniques they preferred showed very well that graphs (rated by 20% of the particpants) and diagramm types (especially bar charts with 16%, pie charts with 14% and Gantt charts with 9%) were the clear favourites. A possible reason for this result could be that most of the business process tools use usually node-link representations in combination with different digram types and therefore other visualization techniques (e.g., icon techniques) are not so popular to the user.

5.3.2 Experience Questions

86.67% of the participants stated that they used tools to visualize processes and the responses showed a wide range of tools. Following tools were named (in alphabetical order): Adobe Illustrator, AdoBEN, ADONIS, ADOit, ADOlog, ADOscore, AdoXX, ARIS Express, AristaFlow, BonitaSoft, Dia, eduWeaver, @enterprise Reporting Component, FreeMind, IBM WebSphere ILOG JRules, IBM WebSphere MQ Workflow, Intalio, Microsoft Excel, Microsoft PowerPoint, Microsoft Project, Microsoft Visio, MindMap, OpenOffice Draw, Oryx, SeMFIS, Poseidon for UML, VisualParadigm, Yaoqiang BPMN Editor, and YAWL. The most named tools were Microsoft Visio (8 nominations), Microsoft Excel (5 nominations), Microsoft PowerPoint (4 nominations) and ARIS Express as well as ADONIS (3 nominations each). Most of the named tools used node-link representations and/or different digram types such as bar charts, Gantt charts, or pie charts. Furthermore, the result showed that also draw tools were named (e.g., Adobe Illustrator, Microsoft Visio, OpenOffice Draw, and Dia) which usually are not suitable to visualize large processes.

Although the relevance to visualize change information was noted by the practitioners, e.g., *for shared processes or when a process model is changed while other instances are still alive*, only 40% of the participants stated that they already had experiences with tools which visualized change information about processes. The following tools were named: ADONIS as well as Aristaflow (2 nominations each) and SeMFIS, IBM Blueworks as well as @enterprise Reporting Component (1 nomination each). According to the question how the changes were visualized, two approaches were listed: (1) the usage of color to make changes transparent in graphs and (2) the usage of tables/textual form to list process changes (4 statements each). They stated that the change visualization was a good possibility to analyze and to compare possible scenarios depending of the performed modifications. However, only half of the 40% of the participants (who already had experience with change visualization) stated that they had the feeling that the visualization gave them a good support to track the changes. They criticized that changes can not be tracked between the different versions or shared processes.

Although 53.33% of the participants stated that they used version visualizations, most of them (75% from the 53.33% of the participants) listed only tools to maintain current and historical versions of files such as source codes, web pages, and documentations. The most named tools were: Microsoft Word, SmartGit and Apache Subversion (3 nominations). Only ADONIS, ADOit, ADOlog as well as ProcessWiki (1 nomination each) were stated for tools which would support version representation for processes. The possibility to track changes and the accept/reject options in Microsoft Word were stated as most named advantage to use such version visualizations (3 nominations). Furthermore they liked if changes were col-

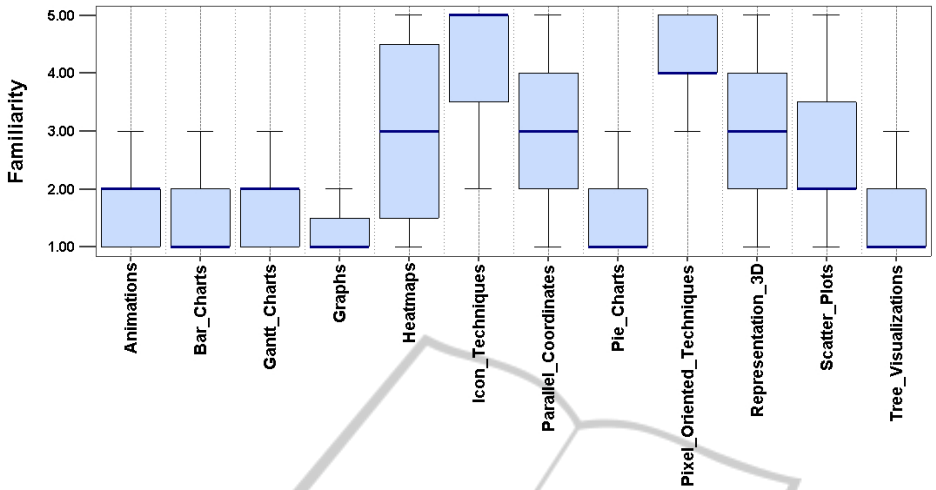

Figure 2: Familiarity of the participants with different visualization techniques (from *Excellent* (1) to *Not Familiar* (5)).

ored in version visualizations to make the changes faster visible. However, they noted if more changes should be visualized, the version visualizations may overcrowd soon. In this case it would be not clear where the changes occured and the graphical representation could be confusing for long-running processes with many changes (beause of a long history).

5.3.3 Expectations Questions

The participants were asked what they generally expect from a change visualization and the responses can be divided into the following categories:

- *Clear Representation* (11 Statements): Participants expected that the visualization should give them a fast, simple and clear overview about the changes in process models as well as instances and the changes between the different process versions. Furthermore, it was noted that it should be avoided that the representation is overloaded with too much information. For example, it was stated that the visualization should provide a show/hide function to enable which information should be visible or slide shows of a series of pictures on the same subject along the time line can be used to slide the time back or forth.
- *Change Information* (4 Statements): Participants stated it would be helpful to have the possibility to not only see the different kinds of changes but also to see additional change information such as a short description why the business process was changed or the name from the person who made the change.
- *Effects of Changes* (3 statements): Participants expected that the graphical visualization of changes should make effects in processes visible to see how the changes affect the whole process and to detect possible problems or conflicts.
- *Version Visualization* (2 Statements): Two participants noted that they would also expect that a change visualization should support them to compare changes between different process versions.

6 REQUIREMENTS

The literature review shows us that there exist several visualization approaches to make changes in data transparent, but the responses of the survey indicate that process changes are often only highlighted (e.g., via color) in the process graph or they are listed in textual form in practice. Moreover, the survey shows us that change information (e.g., which person changed what elements in the processes) is often missed. Often tools are used which are only suitable to visualize small parts of the process and not to comprehend the whole processes or to see the relationships between different versions.

Based on these observations, we discuss in this section different change visualization requirements and give possible directions for further work.

6.1 Clear Change Representation

All changes in processes should be recorded and the visualization should support users to get a fast and clear view about the changes between the different process versions. One big challenge is to visualize changes prominently enough to draw users' attentions to them and that they understand the logic behind a

process to comprehend possible effects/consequences in the case of changes (Rinderle et al., 2006; Chen, 2005). For an effective usage of such visualizations it is necessary to find a user-friendly design which allows users to track the changes between the different versions of the models without being overwhelmed with change information.

Usually, file comparison tools apply change marks to make the changes between different versions visible. This approach can be adopted to make changes in processes transparent. For example, visual properties (e.g., color, size, shape, and texture) and icons can be used to highlight process changes between different versions. It is important that the change marks support users to see the change information quickly and therefore visual properties should not be used as decorative elements or as unnecessary graphical effects. Not all visual properties work well for each kind of process visualization and therefore the choice how the changes should be visualized depends strongly on different aspects. For example, the usage of shapes and textures is restricted because shapes or textures often strongly depend on the used business process modeling notations. Although colors can be used to make change information clearly visible, it is necessary to consider that it is often insufficient to code the information with colors only, because, e.g., users can be color blind (Stone et al., 2005). Moreover, traditional or existing icons should be used and the representation of the icons should be clear such that users can see for which function or action the icon stands for (Galitz, 2002).

6.2 Visibility of Relationships between Versions

All process versions should be taken into consideration not only the latest version of the process and there should be an easy way for users to see the dependencies between the different process versions. The representation of interconnections between the process versions makes it more comprehensible for the users and allows to make comparisons between them.

A version graph (or version tree) is a well-known approach to make relationships between versions transparent (e.g., see (Diehl, 2007; Freire et al., 2006; Therón et al., 2007; Gulla, 1992; Kejser and Grønbæk, 2004)). The graphical view of the version history as graph can be used to get a general view of the different process versions and can make branched and merged information visible.

In addition to specific version information (e.g., comments, time stamps, and names of the persons who changed the processes), the version graph should also enable users to compare how the processes have changed between different versions. For example, Figure 3 shows a concept how the version graph for processes can be combined with the process graph to make change information visible. The version graph presents the versions of the process as nodes and the relationships between the versions as edges. Delta Δ describes the differences between subsequent versions. In the case a node is selected in the version graph the corresponding process graph is presented (see (a) and (c) in Figure 3). If two nodes are selected in the version graph then the corresponding processes are merged and the changes are highlighted (see (b) in Figure 3).

6.3 Different Views

Only highlighting of changes is often not sufficient for users to comprehend the changed processes or to identify further consequences. However, designing a visual representation, which combines different information in a single view, is limited. Displaying information about changes in multiple views simplifies the design. The different views should be linked together to support users' understanding of the information (e.g., selected objects in one view should also be highlighted in corresponding views) (Green et al., 2008; North, 2001; Roberts, 1998).

Multiple levels of abstraction are needed to analyze changes from different angles. For example, one view can present additional change information (e.g., revision date, author of revision, number of changed elements, short description about the reason for the changes). It can be helpful for users to see each others work (e.g., who is working on which part, and who made what changes) so that they know whom to ask if there is any understanding problem. Or another view can support users to analyze effects in processes and to see if the changed element is in conflict with other elements or the planned change is not valid. Moreover multiple views can be helpful to coordinate the abovementioned combination of the version graph with the process graph with the corresponding change information (see Figure 3).

6.4 Interaction

Although the presented visualization approaches in Section 4.2 support different levels of interactivity, the results of the literature review show that the description of the different approaches concentrate primarily on the visual representation and less on the used interaction strategies. However interaction strategies play an important role for analyzing change

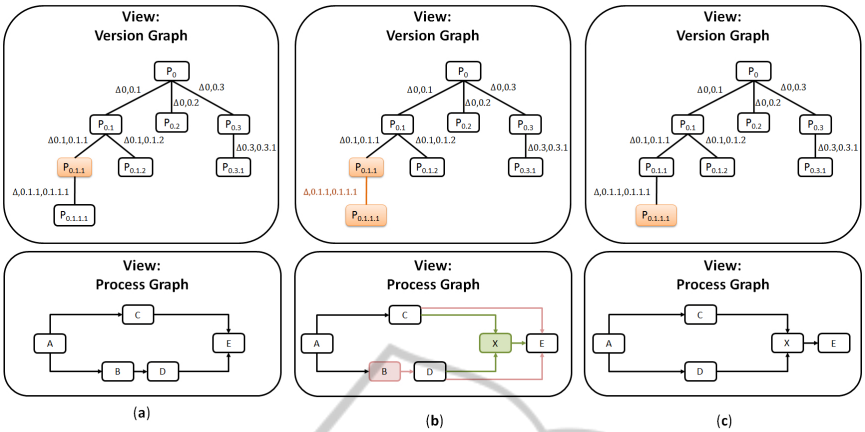

Figure 3: Combination of version graph with change information in the process graph: (a) process version is selected, (b) the two selected processes are merged and colors are used to visualize the change information between the both processes (color *green* for new elements and color *red* for deleted elements) and (c) subsequent version is selected.

information between different process versions. Because of the limited screen space it is only possible to represent a small portion of information in more detail and a visual representation alone is often not sufficient in many cases.

Especially, the visualization of change information should be organized in a meaningful and useful way for easy navigation and switching between the different views. There exist several interaction strategies (e.g., brushing and linking, zooming and panning, or scrolling) which can be used for analyzing process changes. Moreover, it is necessary that users can manipulate the visualization to decide which information should be visualized. It is important to find manipulation strategies, e.g., if more than two process versions should be analyzed or for long-running processes with many changes. The responses of our user survey show us that the strategy from Microsoft Word to track and manipulate changes with the help of accept and reject options is a good possibility to manipulate changes in documentations. This strategy can also be applied to manipulate the change information between different process versions. Furthermore, the visualization should provide filter functions to enable users to decide how long change information should be visualized in the processes. For example, users should be able to decide if it is sufficient to visualize only the change information between the two selected process versions or if it is necessary to visualize also change information from the previous versions.

7 CONCLUSIONS

The motivation of this paper was to support researcher to identify directions for further work to bring forward process change visualizations. In this paper, visualization requirements were presented with the focus on supporting users in comparing changes between different process versions. However, before we discussed visualization requirements, we conducted a literature review to get an overview about the different characteristics of changes in processes and about already existing visualization approaches. Furthermore, we combined the literature review with a user survey to obtain additional insights about users' experiences and expectations in this field. The responses showed that the used visualization tools only highlight changes in processes but they do not allow to track changes between the different versions. In addition to clear change representation, users expected that visualization should also make the effects of changes in processes (e.g., to detect conflicts) and additional change information (e.g., author of revision) visible.

The identified requirements will enable possible directions for further research. We will concentrate to find out which forms of presentation are best suited for analyzing change information in processes and design solutions to make changes in processes suitable regarding users' needs. For example, we will investigate the graphical representation of version graphs to support the management of large process collections. Further, we intend to refine change visualizations in regard to further aspects such as actors (e.g., person who made the changes) and time (e.g., temporal relations). Additionally, extensive evaluations of our solutions are planned.

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