Visual Change Tracking for Business Process Models

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Abstract. Basically there are two options to display process change: (a) showing the corresponding process model before and after the change, or (b) including change tracking options within the process model. In this paper we want to find out how to support users best in grasping process changes. For this, first of all, a conceptualization of Change Tracking Graphs (CTG) is provided that is independent of any process meta model. The CTGs are then visualized in different ways following aesthetic criteria on the one side and mental map aspects on the other side. Further, different visual properties are applied. All different combinations of change representation for process models are evaluated based on an empirical study with 117 participants. This study provides a first stepstone towards a more user-centric application of process change.

Keywords: Business Process Modeling, Information Visualization, Conceptual Model Evolution

1 Introduction

In this work we present an visual framework for change tracking in business process models. Following a human-centric view, we argue that the inclusion of change information in a graph supports traceability and transparency of the changes, and allows the user to achieve change awareness by providing a picture of the whole process and its elements affected by the change. The following challenges of considering change tracking in graphs are focused in this work: (a) How to consider change as content in graphs?, (b) How to layout change tracking graphs?, and (c) How to visualize change in the change tracking graph? To tackle these questions, our approach includes: (1) the description of the change tracking graph and the change tracking states of graph elements by means of a general series-parallel digraph, (2) the description of change as it is considered in tracking graphs, namely by means of change patterns and the assignment of visual properties to changed elements in the change tracking graph, (3) the description of two intuitive options of change tracking graph layouting (future perspective, and past perspective), and (4) a survey to elicit users' preferences concerning change tracking graph layouting and the visualization of changes in the change tracking graph. Our hypotheses are the following:

Hypothesis 1: Change tracking in the business process model supports the process user in getting a holistic view of the changes implemented.

Hypothesis 2: There is a varying preference of the process users concerning the layout of the change tracking model that is either grounded in the layout of the initial model (focusing on the mental map) or in the layout of the adjusted model (considering particular aesthetic criteria).

Hypothesis 3: Particular visual properties (like *color(hue)* and *brightness*) help the process user to better understand the change performed on the business process model.

In this work we focused on the control flow of business process models, particularly considering activities, execution constraints, and their ordering. Other components of business process modeling, like information modeling (data representation) are not further considered in this work.

2 Main Issues of Visual Change Tracking

In this section we discuss the corestones of our visual framework for change tracking: aesthetic criteria, mental map, and visual properties.

2.1 Aesthetic Criteria

Aesthetic criteria are particularly important when layouts are produced for human consumption and should optimize the graph drawing to increase the readability [12] [14]. There are various aesthetic criteria discussed in the visualization research community, some of the commonly used ones are, for example, edge crossing minimization, bend minimization, layout size/area minimization, angle maximization, length minimization of edges, reflection of symmetries, clustering of nodes to reveal the structure of the graph, and layered drawings [14][8][20][28][23]. Often the aesthetic criteria are only presented for drawing static graphs without changes. Therefore, it is recommended to preserve the mental map of a graph after each update [9][7][3]. However, the aesthetic criteria often compete against each other and depending on the priorities set for particular aesthetic criteria the graphs vary in their layout [20]. Already existing experimental results show that there is a trade-off between aesthetic criteria for 'drawing a graph nicely' and efforts to preserve the mental map [20]. Therefore, we analyze the mental map separately from the common aesthetic criteria to find out which approach is better suited for the visualization of changes in business processes.

2.2 Mental Map

Graphs which represent business processes are usually dynamic graphs, because business processes can change over time. The changes can spoil the layout of the graph (e.g., an added node may overlap an existing node) and therefore layout algorithms were developed which rearrange nodes and edges in consideration of aesthetic criteria [10]. However, layout algorithm which completely rearrange the nodes and edges are not helpful, because they destroy the abstract structural information which users form about a graph (or called users' *mental map* about a graph) [10][3]. Therefore, other aspects gained importance especially for dynamic graphs which concentrate on the preservation of user's mental map. In other words, these aspects take the initial model's layout into account when changes are implemented. It is argued that similarity of the graph's layout (or layout stability [22]) before and after change helps the user to keep their orientation in the graph [22]. This saves much time otherwise users have to relearn the structure of the graph after each update [6]. Keeping the mental map means that the layout of a graph is preserved as much as possible after a change. This can be supported, e.g., by the following requirements [10][22][21][7]: (a) move as few nodes as possible (only the part of the graph should be affected by the change where the change occurs), (b) move nodes as little as possible and (c) keep uniform scaling.

2.3 Visual Properties

Visualizations encode the components of data by means of visual properties [2]. According to [5], there exist planar (e.g. *spatial position*) and retinal variables (e.g. *color(hue)*, *size*, *brightness*, *shape*, *texture*, and *orientation*). In case of business process models, the spatial positions defines the flow of the process and retinal variables can be used to make changes in processes transparent. It is important that the visual properties support users to interpret the data quickly and therefore it has to be avoided that visual properties are used as decorative elements, or as unnecessary graphical effects. The choice of the visual properties depends strongly on their purpose and therefore not all visual properties work well for each visualization. For example, *orientation* of elements plays a role according to aesthetic criteria for graph drawing which can be a contradiction with the recommendation to maximize consistent flow direction for the visualization of business processes [4]. Or, the usage of the visual properties *shapes* and *textures* is restricted because *shapes* or *textures* often strongly depend on the used business process modeling notations. To make change information between processes transparent in our approach, we concentrate on the visual properties *color(hue)*, *brightness*, and *size* which allow us to be independent of the used business process modeling notations and aesthetic criteria.

3 Visual Framework for Change Tracking in Graphs

In this section we introduce our approach of including change tracking information in graphs. In the following, we use the term *graph* to refer to series-parallel digraphs. In a first step we describe our approach by means of a series-parallel digraph, as such a graph serves as an illustrative general graph for business process models. In a second step we show the application of our approach to particular workflow modeling notations.

For our approach we assume that change is to be conducted to an already existing graph by following a predefined set of change patterns [29] at a specific date. To perform change on a graph, some pre- and postconditions need to be met, as listed in the following. Precondition 2 and Postcondition 3 refer to quality metrics of graphs (e.g., correctness). As we use change patterns for performing the change on existing graphs, the quality metrics are assumed to be maintained when graphs are changed. Therefore, we do not further discuss quality metrics in this work.

Precondition 1: There already exists an initial graph A.
Precondition 2: The initial graph A corresponds to certain quality metrics.
Precondition 3: Change is predefined by means of change patterns.

Postcondition 1: Three graphs are available: initial graph A, change tracking graph A^*, and adjusted graph A'.
Postcondition 2: The graph A^* is designed according to two layouts. A^*_{MM} considers the layout of the initial graph A. A^*_{AC} considers the layout of the adjusted graph A'.
Postcondition 3: The graph A' correspond to certain quality metrics.

Change tracking graph. The change is conducted by transforming the initial graph A to the adjusted graph A'. Thus, A' is the resulting process schema from the application of the change to A. In our approach we introduce the *change tracking graph A** which contains the graph elements of the initial graph A that are not affected by the change, the graph elements of A that are deleted, and the graph elements that are added during change. Further, we introduce three possible change tracking states of graph elements. Graph elements that are inserted are signed as *activated* elements, deleted elements are denoted as *deactivated* elements, and graph elements that are not affected by the change are marked as *initial* elements.

Change primitives. We could compute A, A', A* based on the set-based definition as presented above. However, as change is typically applied in an incremental manner, and we do actually know the change, we opt for determining the change tracking graphs by exploiting the changes. The basis for this is that we can express all kinds of change patterns by means of the following change primitives [25]: 'delete node', 'delete edge', 'insert node', and 'insert edge'. Using the two change primitives *insert* and *delete* also allows us to easily mark the change conducted with particular visual properties without challenging the graph user with an exaggerated number of new visual appearances of the graph elements. All presented change patterns in [29] can be separated into these four change primitives. In Figure 1, the sequence of the change primitives is presented for the change patterns serialInsert, Delete, serialMove, Replace, Swap, and Parallelize process fragment(s). The selected change patterns serve as illustrative examples of change and provide an insight into our approach.

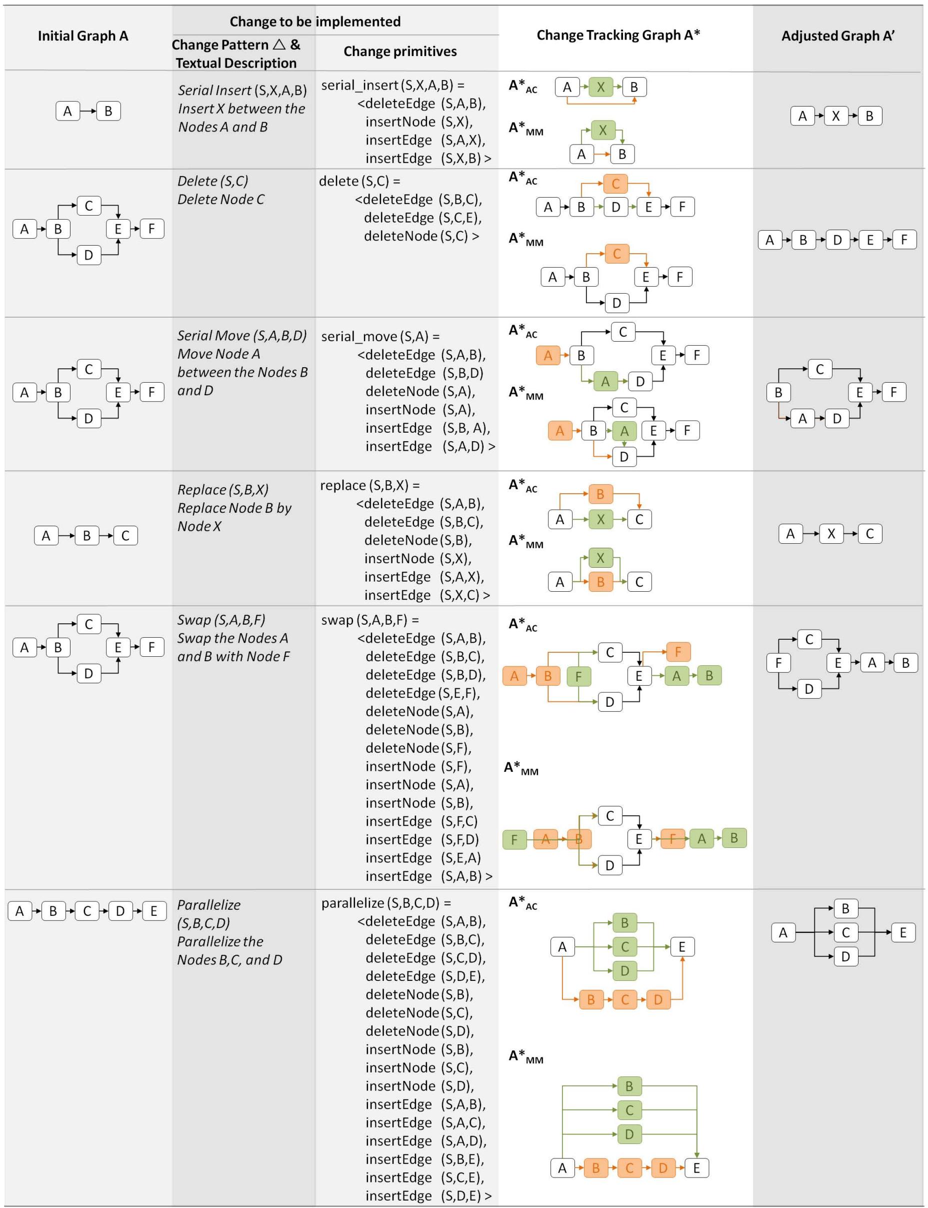

Fig. 1. Change tracking in series-parallel digraphs.

Visual properties. Based on the change tracking state the graph elements are marked by means of selected visual properties. As mentioned in Section 2 we propose to use the visual properties *color(hue)*, *brightness*, or *size* to visualize change in the change tracking graph A*, as they do not change the shape of the elements used in a particular process modeling notation (e.g., changing a square into a circle). We further propose that graph elements that are not effected by the change remain in their original notation.

Layout. There are two options of layouting the change tracking graph A*. One layout option is to consider the layout of the initial graph A in A^*, called A^*_{MM} that intends to maintain the current *mental map* of the process captured in the initial graph A, and thus reflects the *past* layout in A^*. Preserving the mental map of the initial graph A means to keep the graph as much as possible unchanged after change by moving as few nodes as possible and by moving the nodes as little as possible. Deleted elements remain on their initial positions in order to reflect the layout of A, and then the inserted elements are considered in the layout. The alternative option refers to the $future$ layout in A^* by taking the layout of the adjusted graph A' into consideration that is characterized by prioritized *aesthetic criteria* applied to the remaining initial and inserted (activated) graph elements. The resulting change tracking graph is called A^*_{AC}. We suggest the following aesthetic criteria mentioned backward-sorted according to their priorities: focus on the control flow, minimization of edge crossing and number of overlapping elements, maximization of connecting node and edge orthogonality, and minimization of the number of bends. The inserted and initial graph elements are placed according to the aesthetic criteria first, and then the deleted elements are considered in the layout.

4 Survey

The goal of the survey was to evaluate, if visualization of changes can support users, and which visual properties they prefer for making changes in graphs visible. Further, we wanted to find out, if users prefer to see changes in the initial graph, or if they prefer to trace the changes in the layout of the adjusted graph. For this survey, we primarily concentrated on the extremes of both layout approaches, as according to Purchase and Samra [24] extremes of layout adjustment (low and high mental map preservation in dynamic graphs) produce better performance than a layout approach that makes a compromise.

4.1 Methodology

The user survey included questions and tasks to analyze our hypotheses and contained closed, open-ended and rank-ordered questions. In addition to an introduction, a description about the purpose of the survey, and demographic and introductory questions, the questionnaire was structured into two parts: visual properties and layout. The part *visual properties* included questions and tasks to analyze Hypothesis 1 and Hypothesis 3. We wanted to find out (a) if the participants perceive it is absolutely necessary to visualize changes in graphs and (b) if the different visualization properties help them to trace changes. To answer these questions the initial graph along with the adjusted graph was presented to the participants who were then asked to identify the changes that occurred. In a next step, three further graphs were shown and each graph visualized the change information with the help of another visual property. For the visual property *color(hue)* the color orange was used to visualize deleted elements, and the color green was used for added elements. In contrast to *color(hue)*, light gray (for deleted elements) and dark gray (for new elements) were used representing the visual property *brightness*. To evaluate the visual property *size*, deleted elements were shown smaller, and new elements were visualized larger than the already existing elements. After each graph version, participants were asked if they had the feeling to see all changes in comparison with the version which shows no change information. The part *layout* concentrated on Hypothesis 2, and to analyze, if the participants prefer to track changes in the initial graph (with focus on the mental map) or to see the changes already in the adjusted graph which considers the aesthetic criteria. To answer this question, the participants saw both layout versions in regard to their visual properties and they were asked which of these layout versions they prefer. We undertook a pre-test involving three persons to be sure that the questions and tasks were clear and consistent with the survey goals. Based on their feedback the questionnaire was modified.

4.2 Results

We primarily concentrated on persons who had at least basic knowledge about business processes and experiences with graph visualizations. The findings of our empirical study were based on 117 interviewees, mainly computer science students, but also business process specialists from industry and science. For the evaluation, we used generalized examples to be independent from a specific domain which allows us to get a large number of participants.

The gathered data was analyzed in a descriptive way. For the responses from the open-ended questions, we applied the qualitative content analysis to evaluate participants' reflections. The findings of our empirical study are listed according to our hypotheses.

Hypothesis 1: When no change information was visualized in the graph, the most of the participants (51.3%) were unsure or had not the feeling (27%) to identify all changes between the initial and adjusted graph. Only 1.7% of the particpants preferred the version without change visualization. The results about the rating how well the different versions supported the participants to detect changes underpinned our observation that change visualizations are helpful for users to trace changes in business processes.

Hypothesis 2: The results of the comparison showed that there exists no clear favorite. Half of the respondents stated that they preferred to see changes in the adjusted graph, and the other half of the participants found it more helpful to see the changes in the initial graph to have a better orientation.

Hypothesis 3: Most participants (70%) preferred the visual property *color (hue)* followed by the visual property *brightness* (40% of the the participants) and more than half of the respondents stated that they were completely sure to see all changes with the help of the visual property *color(hue)* or *brightness*. The participants noted that colors (52 nominations) and brightness (37 statements) helped them to get a good overview about the changes which occured in the graph. However, it was also mentioned that the colors were too dominant and grabbed the viewer's attention too much (stated by 3 participants). Furthermore, it was mentioned that the usage of color is often insufficient for users who were color blind (mentioned by 3 participants). To avoid this problem, it would be a good alternative to combine color with brightness. Only 5% of the particpants preferred the visual property *size*. The most named reasons were that the representation was unclear and the nodes and edges were difficult to read when the size was perceived too small (8 statements). The users' preferences in regard to the different visual properites were also recognizable in the rating results concerning how well the different versions support the participants to detect changes.

5 Related Work

In respect to graph layout, there exist many layout approaches (e.g., [27] [19] [11] [15]) and aesthetic criteria (e.g., [14] [28] [23]) for general graph classes. Furthermore, several layout approaches targeted specifically toward business process graphs were published (e.g., [12] [1] [26]). While most of the works on graph drawing concentrate on single static graphs, visual representation of graphs which can change over time (e.g, by adding or deleting nodes or edges) have received little attention [9] [3]. Especially in business process, changes can occur over time and therefore it is necessary that users are notified about the relevant changes. Several works exist which discuss approaches to support user to trace changes, for example, [18] present an traceability-based change notification approach. Furthermore, in the field of UML there exist several approaches to make changes transparent, e.g., for detecting differences between class diagrams [16]. Although there exist several approaches to make changes in software transparent (e.g., [17, 13]), change visualization for business processes has received little attention in the last years. In our work, we present a conceptualization for change tracking in series-parallel digraphs in general which is independent of any process meta model.

6 Conclusion

In this work, we presented a visual framework for change tracking in series-parallel digraphs in general by introducing the change tracking graph. Two different layouts of the change tracking graphs were presented, in which the tracked change was embedded. We conduced an analysis of user preferences with 117 participants, mainly computer science students, which helped us to find out that change tracking was helpful for the users to identify the conducted changes on the process model, and most of the users preferred the visual property $color(hue)$ to visualize change in the change tracking model. About half of the survey participants preferred to see the past layout designed according to mental map aspects whereas the others preferred to see the future layout designed according to aesthetic criteria. We derive from this result, that probably both layouts should be offered to the process users when change is performed on process models so that each process user can choose his or her preferred layout.

In future work, we will concentrate on large collections of business processes and process model sets that, e.g. contain a vast number of subprocesses, in order to analyze how change can be represented throughout various modeling levels, e.g. in the reference model, in subprocess and process families. Moreover, we will investigate how our approach can help to make changes transparent between similar processes or between different versions of a process. Further, we will work on an adequate implementation focusing on usability aspects and continue to refine the visualizations of change.

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