

# Response Letter to Reviewers' Comments

**Title:** *Aligning Data-Aware Declarative Process Models and Event Logs*

**Conference:** 19th International Conference on Business Process Management (BPM 2021)

We thank the reviewers for the thorough study and the helpful suggestions provided to improve our manuscript. We are happy to observe that the reviewers acknowledge that the paper presents an innovative idea and addresses an interesting and relevant topic. We have diligently worked in addressing all the comments, thus producing a revised version of the work, which tackles all the concerns raised by the reviewers. Due to the space limitations, we provide longer answers in this letter, and more compact descriptions are added to the paper. Within the revised version, for the reviewer's convenience, the (relevant) changed parts are highlighted, using a blue font color. The detailed actions taken to address all the individual points of the reviewers are listed below.

Best regards,

The authors

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## META REVIEW

*In the paper, the authors study the problem of alignments for data-aware declarative process models. The paper presents a sound conversion to a data-agnostic trace alignment problem, and comes with a proof-of-concept implementation.*

*The main weakness of the paper is that the authors are in two minds about the paper. This becomes clear in the presentation of the paper. It presents a) a novel conversion of data-aware alignments into data-agnostic alignments, and b) it proposes the use of automated planning techniques. However, the paper does not address the connection between the two parts sufficiently. As the initial problem can be converted to an data-agnostic alignment problem, why are current techniques insufficient for the converted trace alignment problem?*

**A)** We thank the PC chairs and the anonymous reviewers for asking questions allowing us to consolidate our paper. We genuinely appreciated these questions, as they allowed us to gain an extra page so to re-insert key details that were previously removed due to space constraints. Briefly, this article presents for the first time, to the best of our knowledge, the reduction of data-aware alignment into a data-agnostic alignment. In doing this, and differently from the previous approaches, we perform both an actual repair of the tracks, and we consider repair on the string data and not only on the numeric ones (**see S**). Despite the resulting data-agnostic alignment via Automated Planning being equivalent to customary cost-based aligners (**see G**), our previous work showed that the former outperforms the latter in such a scenario, and therefore we used the latter for both our framework outline and our experiment section (**see D**). Nevertheless, we rephrased several parts of our paper, and explicitly pointed out that the two aforementioned solutions are equivalent, and therefore their only difference is a matter of computational time.

*Therefore, an important aspect of the motivation should be a comparison with existing techniques, which is currently missing in the paper.*

**B)** In order to overcome such limitations, we expanded the Related Works section, clarified the equivalence between automated planning and cost-based alignment techniques, and clarified the contribute of SymBA-2\* to the overall paper in the introduction. We also refer to answers **D**), **G**), **K**), and **S**) for further details.

*The motivation and justification of the connection between the two parts should be improved to accept the paper at the BPM main conference.*

In order to address such a suggestion, we also bridged the notations from the two sections, and added explicit details on how the alignment problem is implemented as a goal-oriented planner program. We also refer to answers **D**) and **J**) for further details.

## REVIEWER #1

*This paper proposes an approach to align data-aware declarative process models and event logs. For this, any activity with a data operation is renamed to an 'atom' in both the model and the log. For example, an activity A that sets some data value to 5 may be replaced by an atom p that signals that A has happened and has set the data value to a value between 4 and 10. These values 4 and 10 are found by checking conditions on the data value.*

*The model is captured by a set of automata, whereas a trace of the log is captured by an automaton. All automata use these atoms, and hence the trace automaton can then be aligned on the model automata. If all automata reach a final state, the trace fits the model.*

*What I do not fully understand is the need to use Automated Planning techniques here. It seems that the alignment problem on the automata is not really different from the well-known alignment problem, using synchronous moves, log moves (inserts in this paper), and model moves (deletes). As such, it seems that the paper introduces two ideas that seem orthogonal: How can we align data-aware declarative models to event logs, and how can Automated Planning techniques be used to find alignments. As such, it feels that this paper lacks a single focus. As a result, if the paper would be accepted, I believe that the authors should make clear why the known alignment techniques do not work here. If these do work, the section on the Automated Planning is very odd. To me, it seems like the paper should be split into two papers.*

**D)** We thank the reviewer for this observation, as it allows us to clarify the paper's contribution. Automated planning has been chosen to show that the conceptual framework can be translated into an operational framework by taking existing solid techniques and extending them appropriately. As stated in the introduction, we exploited the SymBA\*-2 planner, that was effectively adopted in our previous work for trace alignment tasks [9,18]. In [9] we showed that such a solution outperformed the state-of-the-art aligners. As a matter of fact, in §5.2 we now acknowledged the fact that such aligners could be also used in place of SymBA\*-2:

*Similarly to customary cost-based trace aligners, each of these operations [deletion, insertion, replacement - A.D.] has an associated cost, [...]*

Still, the augmented automata introduced in the present paper have several more edges, as the atomization steps increase the number of possible labels as well as the overall number of states. As we needed to show the feasibility of our approach, we choose the aligner approach providing the best alignment performances: as stated in the experiment section, SymBA\*-2's heuristics efficiently handle the aforementioned increase in complexity with acceptable performance in case of a reasonably large number of data-aware constraints. Therefore, the proposed approach is sufficiently mature to be described in one single paper. We partly imported such discussion in §4 as follows:

*We also want to show that our conceptual framework can be translated into an operational framework by taking existing solid techniques and extending them appropriately. By reducing the data-aware alignment problem previously refined to a data-agnostic alignment problem, we choose the reduction to automated planning techniques, as our previous work [9,17] already showed that such a strategy outperforms customary cost-based trace aligners.*

*Minor comments:*

*p.1: "in the context data-aware" => "in the context of data-aware".*

*p.2: LTL<sub>f</sub> appears 'out of the blue'. Please introduce this before.*

*p.4: As a side note: Odd that there is no 'past' version for G.*

*p.5: "on the footsteps" => either "in the footsteps" or "on the footpath".*

*p.6: Here, LTL<sub>f</sub> is introduced, which is too late.*

As kindly suggested by the reviewer, we gave a brief description of LTL<sub>f</sub> in the introduction.

*p.6: "such that  $\sum_i t_i$ ": Unclear, what does this mean?*

**E)** It means that any trace composed of events  $\sigma_i$  can be expressed as a finite sequence of predicates  $t_i$  such that  $t_i$  is satisfied by  $\sigma_i$ . The notation is coming from [9] and an explanation of how to do that is given at §5.1.

Ex.1 (continued), last line: This seems incorrect. The  $F$  clause now also accepts if, say,  $B.x = 1$ , whereas the original  $F$  clause did not. If guess the or-clause should be in the  $G$  clause (and not in this  $F$ -clause):  $G(\text{not}(C) \vee F(B \wedge (0 < B.x \leq 3) \vee B.x > 3)))$ . This matches the decomposition into the three intervals much better.

**F)** Please observe that, at this step, the only change that is performed is on the data predicates, so the satisfiability is unaltered. On the other hand, this is just a preliminary decomposition step that only the outcome in  $\Sigma$  will prevent the possible flaw pointed out by the reviewer. Please refer to the subsequent parts of Example 1 for the final decomposition and atomization producing the  $\Sigma$  as required by the alignments. In such, we also consider the  $y$  variable jointly with  $x$ .

p.9: [i]t seems replacements are not used to augment the trace (see next page). Why introduce them here?

**G)** In this section, we introduce the mathematical notation for repair sequences generated by the PDDL. Despite replacements might be seen as a syntactic sugar for deletions immediately followed by insertions, the definition of such a constraints has direct implications on the final outcome of the alignment: as we observed in the paper, replacement operations might be favored instead of insertions or deletions by assigning to the latter an inferior cost. In fact, the usage of only insertions or deletions will only favor single insertions or deletions operations, while rearing one single event trace might be perceived as less costly than inserting or removing events from a trace. Last, this notation also allows us to gracefully merge the two main contributions of the paper (**see J**).

Def.1: Unclear what is being defined here. Reads more like a theorem. Given a trace  $t$  and and a model  $M$ , a repair sequence  $r$  is a sequence of operations (deletion, insertion, replacement) such that  $r(t)$  conforms to  $M$ . The repair sequence  $r$  is called optimal if there exists no repair sequence  $r'$  such that the costs of  $r'$  are lower than the costs of  $r$ . The conformance checking problem is to find an optimal repair sequence for trace  $t$  and model  $M$ . (?)

**H)** As stated in the previous line and as did in (Maggi et al. 2018), we just remarked the definition of the conformance checking problem that we intend to solve in the paper. By doing this, we motivate the required formalisms that will follow.

Def.1: "it exists" => "there exists".

The typo was fixed according to the reviewer's suggestion.

p.10: A delete operation corresponds to a move on model, whereas an insert operation corresponds to a move on log. This suggests that we now have the standard problem of aligning a trace on a model, and could use the standard alignment techniques. Is this correct? If so, using the planner as suggested is an option, but standard alignment techniques could also be used, right?

Please refer to our previous answers **G)** and **D)**, where we explained how the goal-oriented planning technique can be replaced with a customary cost-based aligner. Answers **G)** and **D)** were summarized and inserted in the current version of the Working Assumptions section.

Fig.4: The arc from  $s_5$  to  $s_6$  is labeled  $p_7$ . I think this should be  $p_8$ .

p.10: No replacements

We acknowledge the typo. We fixed it as suggested.

## **REVIEWER #2**

*The paper introduces an alignment-based approach for data-aware Declare models using planning tools. To this purpose, data-aware constraints are converted in data-agnostic automata which can be enriched with repair operations which can lead the planning to suggest optimal alignments.*

*The topic of (data-aware) Declarative alignments is interesting, and the paper has a clear elaboration. The examples guide the reader through the formalisms which underpin the approach well. The authors have clearly considered the topic to its fullest details.*

Thanks for the positive consideration of our research.

*My main concern is that within the scope of BPM, the planning part could use with a bit more detail. E.g. Section 3 mentions the use of a STRIPS fragment without any context. [...]*

**I)** he STRIPS fragment allows the formalization of the planning problem as in the previous paragraph. We added this remark in text.

*[...] Next, Section 5.3 does not link that well with 5.1/5.2, and the predicates are understandable but not intuitive given the prior formalisation. It is a hard balancing act, but this could confuse some non-informed readers, also concerning the suitability of planning. [...]*

**J)** We deeply thank the reviewer for this suggestion. To solve this issue, we extended §5.3 by describing how the planning strategy generates the repair strategy that is going to be exploited in §5.4 to repair the trace. Therefore, we imported in §5.3 the notation for the repair strategy from §5.2 and in §5.3 onwards we changed the sigmas and phis with t-s and e-s, so to uniform the mathematical notation with the one for PDDL.

*[...] Can this be formulated as other optimisation exercises as well? The related work section also does not line up the latest in planning to quickly get a grasp of the field, except for the recent usage of it in the declarative process modelling community.*

**K)** We thank the reviewer for the suggestion. Despite these considerations could be indeed be inserted in the Related Work sections, an extensive analysis of such techniques did not fit in the present paper. Still, we appreciate this suggestion as we decided to plan to consider state-of-the art planners as part of our future works. This consideration was added in the last section of the paper as an interesting future work.

*From Section 5.4, it is not completely clear whether the planning optimises just the single trace, or the cost for the whole model as the planning problem focuses on a goal condition which lines up with a (single) constraint automaton. Given that the experimental evaluation deals with full Declare models, it would have been nice to have a better insight into how the overarching output could inform the improvement/repair of the whole model with an example.*

**M)** In the present paper, we are interested in repairing the trace so as to make it conformant to the model, as we assume that models represent the golden standard while the traces might contain the anomalies to be detected. Still, we repair a trace by taking the model as a whole via its automaton representation. We rephrased such a section to clarify our intent.

*The paper is very well written, only a few apparent typos were present:  
- Abstract: ‘...in the context data-aware declarative...’: rephrase*

- Page 2: can can: repetition
- Page 3: two constraints could be not in conflict: rephrase
- Page 5, very minor: walking on the footsteps: walking in
- Page 6: post mortem – just post analysis? Sounds quite strong

We thank the reviewer for the suggested improvements to the article. We fixed all of the changes: post mortem was rephrased as “[when] traces reach [their] completion”.

Overall, the paper has a high degree of maturity and clearly illustrates its strengths and can be considered for presentation.

Thank you.

## **REVIEWER #3**

*This very nicely executed paper provides a valuable extension to our knowledge and tools set in the area of conformance checking between process execution traces and declaratively specified process models. More specifically, the paper develops a framework for checking conformance between execution traces and data-aware declarative process models specified in a data-aware variant of DECLARE. Unlike previous work on conformance for data-aware DECLARE, the framework in the current paper includes an implemented algorithmic approach for “repairing” a trace if it does not comply with the process model. The framework relies on (a) using a “cellular decomposition” of the space of continuous data values to reduce things to a propositional context, (b) mapping the propositional version of the DECLARE process model into a constraint automata, (c) constructing a second automata that captures the idea of repair steps (insert, delete, and a form of replace) against a given trace, and (d) building a planning problem based on simultaneous traversal of the 2 automata. The paper also provides some benchmarking experiments, showing the practical utility of the framework on modestly sized traces (up to length 30) and a modest number of constraints (up to 10).*

*Minor questions:*

*1) in Section 3.2 you say that your atoms have the form “A.k R c”, where c is a constant. Would your framework easily extend to the case where you have atoms of the form “A.k R A’.k’ “ ? I think that your \Sigma-encoding (what I might call “cellular decomposition”) can be extended to create a propositional representation. Would other parts of the construction also carry through? (One sticking point might be for the case of inserting steps and inventing values).*

**Please refer to answer P).** At the present stage of the paper, value invention is carried out when repairing a trace by adding new values or altering existing ones within event payloads. Please refer to §5.4 for additional details.

*2) in Section 4 you say that each event trace should be associated to just one activity label. But, if I understand your running example you seem to have both B and C as “labels”, which I take to be “activity labels”. Is there an inconsistency here? Also, if you require that there is just one activity label, then why bother with them? [...]*

**N)** In §4, we said that “each event trace” (so, each event which is part of the trace) should contain just one label. So, each trace might be composed of events carrying out different events, where each of them might have a distinct label.



[...] Also, if I wanted to use multiple activity labels then I could simulate that by using a single dummy activity label and using a field in the payload to hold my multiple activity labels, right?

**O)** We thank the reviewer for this observation. Multiple activity labels are also supported by our previous work on extending the property graph data model for big-data scenarios [6]. We added it as a reference motivating the reviewer's claim.

## **REVIEWER #4**

*The paper contributes to the concept of alignments used in conformance checking tasks. The proposed approach provides a data-aware alignment strategy for data-aware declarative process models including a trace repair strategy existing approaches usually omit. After the problem is reduced to a data agnostic trace alignment problem the authors describe a solution based on Automated Planning techniques from the AI research field. The approach is evaluated via a proof-of-concept implementation and regarding computation times to sketch the approach's scalability with respect to the size of the model and the noise in the traces.*

*The paper is well-structured and is built upon a clearly formulated problem statement. A mostly informative description of necessary background knowledge is provided, too. The clearly formulated working assumptions are important and answer many questions that might arise in advance, hence, making the approach (more) convincing. The description of the approach is based on a strong and, as far as I can assess this, sound formalization. Additionally, the technique is accompanied with a proof-of-concept implementation that was setup for a performance measurement giving informative insights regarding the dependencies of computation time to influencing factors like trace length, number of constraints and repair costs.*

We are grateful to R4 for the positive reflection about our paper, and the very nice and correct highlight on its importance.

*However, though I am mainly convinced that the paper is a valuable contribution to the BPM research domain, I also have some points of criticism, which are explained in the following.*

### *Criticism:*

*- Related Work: While the discussion about applicability of alignment-based approaches for conformance checking with procedural models is informative and concise, the discussion of related approaches for declarative models comes up a bit too short. The authors mention two approaches directly related to the proposed approach that "only" lack repair strategies. It would be interesting to know, if those approaches are not able to provide repair strategies or if the authors of the cited publications simply left this out of scope. In case of the latter, it is questionable to "discard" those approaches without a thorough comparison. If the underlying formalism does not allow for repair strategies instead, this should be stated clearly in section 2.*

As **S)** addresses a different facet for the same problem, we merged the answer for this in **S)**.

*- Section 3.2: Though I like the concise definition of MP-Declare, when referring to activation and target conditions one might ask for the correlation conditions, too. Is it possible to integrate them in the suggested approach, too, or is this a drawback? If so, this should be clearly mentioned as a limitation in the overall evaluation, since it restricts application scenarios to those that do not require correlation conditions.*

**P)** We thank the reviewer for giving us the opportunity of writing a more exhaustive motivation to our work. Despite this is actually a limitation, in §3.2 we have already motivated our choice in the light of previous works, where no correlation conditions are considered. Quoting from §3.2:

*This is a widely adopted assumption, that spans from data-aware procedural models [18] to data-aware declarative models [8].*

The adoption of such conditions would require us to either support our PDDL approach to support Büchi automata, or to substitute a planning system with a data-aware knowledge base. Still, we acknowledge the anonymous reviewer that this might be a limitation for our current work, that we planning to expand as now suggested in the final section of the paper:

*We will also investigate the possibility of supporting correlation conditions by either extending the planning problem by encoding Büchi automata as well as performing alignments over data-aware knowledge bases [24], which potentially quicken the time required to test the satisfiability of the data conditions by conveniently indexing (i.e., pre-ordering) the payload space [14]. This will give us the opportunity of comparing two possible alternatives for computing alignments.*

- Section 4, assumption b): “we restrict the space of the possible alignments of the log trace repairs to the traces generated by the automaton representation of the Declare model” -> It was announced that the assumptions (and restrictions) can be inferred from the literature. However, assumption b) lacks a corresponding reference. Furthermore, to me it is not clear what consequences arise from this restriction. Actually, this whole sentence part is hard to read and I want to encourage the authors to simplify it for reasons of comprehensibility.

**Q)** We added the reference to the paper [9] from where we actually drew our assumption. We also simplified the sentence as suggested: the aim is to restrict the possible repairs of a given trace to only the traces that are both conformant to the Declare model and are generated by its associated automaton. Quoting from the revised paper:

*b) we restrict the space of the possible alignments of the log trace repairs to the traces generated by the automaton representation of the Declare model [9];*

- p. 9: “E.g., by assigning a higher cost to insertions and deletions and a lower one to replacements, we will favor replacements when possible.” -> I wonder how appropriate costs for the three operations can be determined. Is this arbitrary? I am also a bit concerned about uniqueness. Let us consider, for instance, the response constraint (and let us stick to plain Declare): response(A,B). This means a trace like AAAAC would violate the constraint. In that case it is easy to see that it can be repaired by inserting a B. But what about the trace AC? I could delete A or insert a B. From an algorithmic perspective it must be defined whether the insertion or the deletion is applied. One way would be to choose different costs for the two operations. This should be briefly clarified (probably at the end of section 5.2).

**R)** We thank the reviewer for this clarification request, thus allowing us to better explain our solution. As customary in traditional trace alignments (Adriansyah et al, 2011) preferred repair strategies are always modeled by assigning different costs to insertions, deletions, and replacements (**see also D**). We expanded our example to better describe the different possible repair solutions as suggested.



Figure 4 shows the automaton augmented with the repair operations  $\mathcal{A}_{\varphi(\mathcal{M})}^+$  obtained for the model  $\mathcal{M}$  from Example \ref{ex:first}. Intuitively,  $\mathcal{A}_{\varphi(\mathcal{M})}^+$  accepts all the string sequences conformant to the model and have been obtained by adding/removing the missing/wrong atoms to/from  $t_{\sigma}$ , where atomic operations are explicitly marked. As required, both augmented automata do not accept  $t_{\sigma}=p_5; \texttt{C}; \texttt{C}$ . If insertions are associated to the lowest cost, the best alignment strategy adds  $p_8$  at the end on the trace; by explicitly marking such repair with  $\textit{ins\_}p_8$ , the augmented automata now accept  $\hat{t}_{\sigma}=p_5; \texttt{C}; \texttt{C}; \textit{ins\_}p_8$ . On the other hand, if replacements are associated to the lowest cost, the best alignment strategy would replace the last  $\texttt{C}$  with  $p_8$ , thus requiring to first delete  $\texttt{C}$  and then insert  $p_8$ ; the resulting  $\hat{t}_{\sigma}=p_5; \texttt{C}; \textit{del\_}p_8; \textit{ins\_}p_8$  is also accepted by both automata.

- The main flaw of this (apart from this well-written and sound paper): The paper rather directly jumps into an explanation of how to transform the model-trace alignment problem into a planning problem. I completely miss any discussion of alternative solution strategies and, consequently, advantages and drawbacks of the proposed approach, too. What about transforming the problem into a satisfiability problem and applying optimized SAT solvers instead? It is clear that space is limited but if a new tool is suggested it is essential to comment on alternative solutions and reasons why the strategy chosen is superior.

**S)** We thank the reviewers for this observation, that gave us the opportunity of clarifying the novelty of our contribution. In fact, some of the discussion of the Related Works was previously removed due to the lack of space. As we were granted to extend the paper with one more page, we re-introduced such comments in the Related Works section. In particular, we expanded the discussion related to one of our references, that was already using SAT solvers. Quoting from the revised paper:

In [8], the authors provide an algorithmic framework to efficiently check the conformance of Multi-Perspective Declare (MP-Declare) with respect to logs. In this work, the authors reduce the data-aware conformance checking problem to a maximum constraint-satisfaction problem, where both data and model constraints are encoded. Alternatively, the alignment of data-aware declarative processes can be also reduced to a constraint satisfaction problem, where an optimization function is used to assess the alignment cost [7]. The two aforementioned works are, to the best of our knowledge, the only ones providing numerical characterization of the process conformance. Even though they provide a numerical approximation of the degree of conformance of a log trace against the model, no repair strategy is given. As we will observe in §5.1, the possibility of repairing traces is strictly related with the definition of strings and numerical data as elements of a partially ordered set, where missing values are the minimal elements of such a set. Furthermore, our work also extends the previous ones by also considering string data as well as numerical data.

Minor remarks:

- p. 1: “while the former fully enumerate the set of all the possible allowed traces, the latter provide a compact process representation” -> This is a bit oversimplified. The first part is at least language-dependent. In BPMN, for instance, we have a concept of swimlanes but they lack a clear definition of their execution semantics. Hence, the model is in that regard underspecified, which means that the model is not able to enumerate the set of all possible allowed traces. Considering the data perspective, it is even worse. Additionally, if declarative models are compact depends on the processes they represent. For instance, a simple sequence of two activities can be represented in a

*compact way in BPMN but requires comparatively many constraints. I want to encourage the authors to reformulate this sentence.*

**T)** We thank the reviewer for his clarifications on the problems related to BPMN semantics. We rephrased the sentence by only referring to modeling languages (or fragments of such languages) with clear execution semantics, while removing any reference to the compactness of declarative models' representation.

*In conformance checking, models can be described by either procedural (e.g., safe Petri Nets) or declarative languages (e.g., Data-Aware Declare) having a clear data-aware semantics; while the former fully enumerate the set of all the possible allowed traces, the latter list the constraints delimiting the expected behavior [15,27]*

*- p. 5: What are numeric fluents? I'm not an expert in Planning Problems but this seems to be a specific term of the PDDL language and, consequently, should be introduced to improve comprehensibility.*

**U)** A (numeric) fluent is a variable which applies to zero or more objects and maintains a value throughout the duration of the plan. Numeric fluents can be altered through the effects of both actions: a numeric fluent is used in our scenario for keeping track of the alignment cost. We added this clarification in the text. Due to the lack of space, we simply referred to those as “global numeric variables”.

*At the end of this section: “We also freely assume that missing values are represented with specific values, such as an empty string, -1, or  $\infty$ , depending on the type.” -> Declaring a set of maybe valid values (an empty string could be meaningful, too), is on the one hand valid but on the other hand questionable since it might lead to misbehavior in practical applications. Hence, it should be mentioned as a limitation of the approach in the overall evaluation.*

**V)** We brought this notion from a data-cleaning perspective, where missing information is seen as a data error and should be imputed with some real-world values. As our implementation relies on POSets, we can always generalize the argument by assuming that any missing value could be represented by a minimal element being neither a specific float nor a string value. We rephrased our claim as per the anonymous reviewer's suggestion. Please also observe that such extension does not alter the experiments that we already run, as no missing data was generated by the log generator: that might only require a slightly re-configuration of the tool's implementation. We then rephrased our claim as such:

*As both strings and floating point numbers have non-strict partial orders and are hence posets, we can also freely assume that missing values are represented as an extra minimal element  $\epsilon$  being neither a string nor a specific floating point number.*

*- p. 13: Until this page I have tried to figure out what the notion of a “goal condition” is and which role it plays for the proposed alignment approach. Maybe this could be clarified (probably with a simplified summary) earlier in the paper.*

**W)** Planning systems are an artificial intelligence technology showing how to reach a prefixed goal configuration given an initial world configuration by exploiting a set of actions that could be change the world configuration so to reach the goal configuration. We rephrased such an explanation at the beginning of §3.3. The sequence of actions resulting from the execution of a PDDL plan provide the repair sequence that is going to be exploited to repair the trace, thus describing how the trace should be possibly transformed to be accepted by the model. In particular, the initial world configuration contains the description of the two augmented automata, thus including their initial and final states. On the other hand, actions are the alignment

strategies that are enacted to reach the final goal configuration, i.e., reaching a final state in both automata. As now stated at the end of §5.3:

*As the goal requires that in both augmented automata an accepting state is reached, the actions will encode the strategies to visit both automata by exploiting their transition functions, while assigning different alignment costs to each of the strategies. When the goal is reached, the resulting action sequence (where **syncs** are stripped) represents the repair sequence  $\varrho$  that we are going to exploit in the next section.*

*Spelling, grammar, typos, etc.:*

- Abstract: “in the context data-aware declarative process models” -> “in the context of data-aware declarative process models”

- p. 2: “After representing the data-aware” -> formatting issue (consider “overfull hbox” warnings in your LaTeX editor)

In the next line: “using a data agnostic LTL...” -> “... data-agnostic”

p. 5: “should be associated to just one activity label” -> “... associated with just one ...”

All the remarked typos were fixed as suggested.

*Fulfillment of Open Science Principles (incl. transparency, reproducibility, and replicability):*

*All research artifacts are available via a given link to a Google Drive folder. A Readme and a provided video enable reviewers and researchers to reproduce the results included in the paper in a transparent way.*

Thank you.

## References:

de Leoni, M., Marrella, A.: Aligning real process executions and prescriptive process models through automated planning. *Expert Syst. Appl.* 82, 162–183 (2017)

Adriansyah, A., van Dongen, B.F., van der Aalst, W.M.P.: Conformance checking using cost-based fitness analysis. In: *EDOC 2011*. pp. 55–64. IEEE (2011)

Maggi, F. M., Marrella, A., Capezzuto, G., Cervantes, A. A.: Explaining Non-compliance of Business Process Models Through Automated Planning. In: *ICSOC* (2018)