Measuring and Resolving Inconsistency in Declarative Process Specifications
(Extended Abstract)

Carl Corea,[1] **Isabelle Kuhlmann,** [2] **Matthias Thimm,** [2] **John Grant** [3]
[1] Institute for Information Research, University of Koblenz, Germany
[2] Artificial Intelligence Group, University of Hagen, Germany
[3] University of Maryland, College Park, USA
ccorea@uni-koblenz.de, isabelle.kuhlmann@fernuni-hagen.de,
matthias.thimm@fernuni-hagen.de,grant@cs.umd.edu

Abstract

We address the problem of measuring inconsistency in declarative process specifications, with an emphasis on linear temporal logic (LTL). As we will show, existing inconsistency measures for classical logic cannot provide a meaningful assessment of inconsistency in LTL in general, as they cannot adequately handle the temporal operators. We therefore propose a novel paraconsistent semantics for LTL as a framework for time-sensitive inconsistency measurement. We develop and implement novel approaches for (element-based) inconsistency measurement in LTL, and evaluate our results with real-life data-sets from the Business Process Intelligence Challenge.

An initial work on the topic at hand has already been published at the International Conference on Business Process Management (Corea, Grant, and Thimm 2022). Currently, the described contributions are further being pursued for an extended version.

Keywords. Declarative Process Specifications, LTL, Inconsistency Measurement

1 Overview

Linear temporal logic (LTL) is an important logic for specifying the (temporal) behavior of business processes in the form of *declarative process specifications* (Pnueli 1977; Di Ciccio and Montali 2022). The underlying idea is that time is represented as a linear sequence of states $T = (t_0, ..., t_m)$, where t_0 is the designated starting point. At every state, some statements may be true. Temporal operators specify properties that must hold over the sequence of states. For example, the operator **X** (*next*) means that a certain formula holds at the next state. Likewise, the operator **G** (*globally*) means that a certain formula will hold for all following states.

Traditionally, model checking has been used to verify that a particular model—that is, the assignment of truth values for statements over the time sequence—satisfies the requirements. However, a problem in this use-case arises if the set of formulas is *inconsistent*, i. e., contains contradictory specifications. For example, consider the two sets of LTL formulas $\mathcal{K}_1$ and $\mathcal{K}_2$:

$$\mathcal{K}_1 = \{\mathbf{X}a, \mathbf{X}\neg a\} \qquad\qquad \mathcal{K}_2 = \{\mathbf{G}a, \mathbf{G}\neg a\}$$

Both $\mathcal{K}_1$ and $\mathcal{K}_2$ are inconsistent, as they demand that both a and $\neg a$ hold in (some) following state, which is unsatisfiable. In such a case, the set of specifications cannot be applied for its intended purpose of process verification. This calls for the analysis of such inconsistencies, to provide insights for inconsistency resolution.

In classical logic, all inconsistent sets are equally bad. However, considering again the two sets, intuitively, $\mathcal{K}_2$ is "more" inconsistent than $\mathcal{K}_1$: The inconsistency in $\mathcal{K}_1$ only affects the next state, while the inconsistency in $\mathcal{K}_2$ affects all following states. This is an important insight that could prove useful for debugging or re-modelling LTL specifications or LTL-based constraint sets in general such as Declare. While there have been some recent works that can *identify* inconsistent sets in declarative process specifications (Di Ciccio et al. 2017; Corea et al. 2021; Roveri et al. 2022), those works cannot look "into" those sets or compare them. In this work, we therefore show how to distinguish the *severity* of inconsistencies in LTL, specifically, a variant of LTL which we coin linear temporal logic on fixed traces ($\mathrm{LTL_{ff}}$).

A scientific field geared towards the quantitative assessment of inconsistency in knowledge representation formalisms is *inconsistency measurement* (Grant and Martinez 2018; Thimm 2019), and therefore represents a good candidate for this endeavour. Inconsistency measurement studies measures that aim to assess a *degree* of inconsistency with a numerical value. The intuition here is that a higher value represents a higher degree of inconsistency. Such measures can provide valuable insights for debugging inconsistent specifications, e. g., to determine whether certain sets of formulas are more inconsistent than others, or pin-pointing those formulas highly responsible for the overall inconsistency. As we will show, existing measures are currently not geared towards LTL and temporal operators, and therefore cannot provide a meaningful analysis. Therefore, the main goal of this work is to develop new means for measuring inconsistency in linear temporal logic.

2 Contributions

The problem of inconsistency—and inconsistency measurement—is of high relevance in the field of AI. Likewise, this topic is of high relevance for (practical) settings of applying declarative process specifications. This work addresses the issue of measuring inconsistency in LTL from both these angles and bridges the gap between the fields of business process management and knowledge representation (a sub-field of AI). Here, our contributions are as follows.

- We formalise the problem of measuring inconsistency in $\mathrm{LTL}_{\mathrm{ff}}$ and propose a rationality postulate that should be met by quantitative measures applied to this setting. We show that existing inconsistency measures do not satisfy this property, and propose an approach for measuring inconsistency based on a novel paraconsistent semantics for $\mathrm{LTL}_{\mathrm{ff}}$.
- We show how our approach can be applied for measuring inconsistency in declarative process specification, in particular, for the Declare modelling standard. In this context, we also develop element-based measures, that can be used for pin-pointing the concrete formulas responsible for the overall inconsistency. This provides valuable insights in the scope of inconsistency resolution, e.g., as a basis for re-modelling inconsistent specifications.
- We discuss algorithmic aspects of measuring inconsistency in LTL and implement our approach. We evaluate these implemented results with real-life data-sets of the Business Process Intelligence Challenge[1]. Our implementation is made available open-source and can be used "out-of-the-box" to assess or compare inconsistency in declarative process specifications. In the context of evaluation, we also investigate the computational complexity of central aspects regarding inconsistency measurement in $\mathrm{LTL}_{\mathrm{ff}}$.

An initial work on the topic at hand has already been published at the International Conference on Business Process Management (Corea, Grant, and Thimm 2022). Currently, the described contributions are further being pursued for an extended version. As a main addition, the extended version will focus on the implementation of previous results and novel element-based inconsistency measures.

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[1]https://icpmconference.org/2020/bpi-challenge/