A Decomposition Framework for Inconsistency Handling in Qualitative Spatial and Temporal Reasoning

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Abstract

Dealing with inconsistency is a central problem in AI, due to the fact that inconsistency can arise for many reasons in real-world applications, such as context dependency, multi-source information, vagueness, noisy data, etc. Among the approaches that are involved in inconsistency handling, we can mention argumentation, non-monotonic reasoning, and paraconsistency, e.g., see [2, 3, 10]. In the work of [7], we are interested in dealing with inconsistency in the context of Qualitative Spatio-Temporal Reasoning (QSTR) [6]. QSTR is an AI framework that aims to mimic, natural, human-like representation and reasoning regarding space and time. This framework is applied to a variety of domains, such as qualitative case-based reasoning and learning [5] and visual sensemaking [9]; the interested reader is referred to [8] for a recent survey.

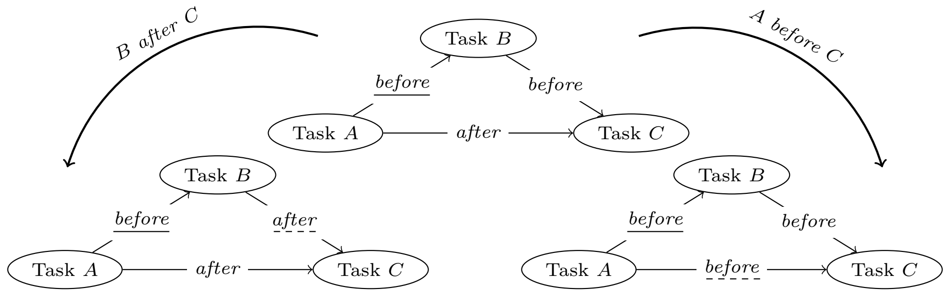

Figure 1 A decomposition of an inconsistent qualitative constraint network (QCN) into consistent subnetworks (components).

Motivation. In [7], we study the decomposition of an inconsistent constraint network into consistent subnetworks under, possible, mandatory constraints. To illustrate the interest of such a decomposition, we provide a simple example described in Figure 1. The QCN depicted in the top part of the figure corresponds to a description of an inconsistent plan. Further, we assume that the constraint Task A $\{before\}$ Task B is mandatory. To handle inconsistency, this plan can be transformed into a decomposition of two consistent plans, depicted in the bottom part of the figure; this decomposition can be used, e.g., to capture the fact that Task C must be performed twice. More generally, network decomposition can be involved in inconsistency handling in several ways: it can be used to identify potential contexts that explain the presence of inconsistent information; it can also be used to restore consistency through a compromise between the components of a decomposition, e.g., by using belief merging [4]; in addition, QCN decomposition can be used as the basis for defining inconsistency measures.

Contributions. We summarize the contributions of [7] as follows. First, we propose a theoretical study of a problem that consists in decomposing an inconsistent QCN into a bounded number of consistent QCNs that may satisfy a specified part in the original QCN; intuitively, the required common part corresponds to the constraints that are considered necessary, if any. To this end, we provide upper bounds for the minimum number of components in a decomposition as well as computational complexity results. Secondly, we provide two methods for solving our decomposition problem. The first method corresponds to a greedy constraint-based algorithm, a variant of which involves the use of spanning trees; the basic idea of this variant is that any acyclic constraint graph

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in QSTR is consistent, and such a graph can be used as a starting point for building consistent components. The second method corresponds to a SAT-based encoding; every model of this encoding is used to construct a valid decomposition. Thirdly, we consider two optimization versions of the initial decomposition problem that focus on minimizing the number of components and maximizing the similarity between components, respectively. The similarity between two QCNs is quantified by the number of common non-universal constraints; the interest in maximizing the similarity lies mainly in the fact that it reduces the number of constraints that allow each component to be distinguished from the rest. Of course, our previous methods are adapted to tackle these optimization versions, too. Additionally, we introduce two inconsistency measures based on QCN decomposition, which can be seen as counterparts of measures for propositional KBs introduced in [11, 1], and show that they satisfy several desired properties in the literature. Finally, we provide implementations of our methods for computing decompositions and experimentally evaluate them using different metrics.

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Category Extended Abstract

Related Version This is an extended abstract of our KR 2023 paper [7].

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