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Compound Logics for Modification Problems

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Abstract: We introduce a novel model-theoretic framework inspired from graph modification and based on the interplay between model theory and algorithmic graph minors. The core of our framework is a new compound logic operating with two types of sentences, expressing graph modification: the modulator sentence, defining some property of the modified part of the graph, and the target sentence, defining some property of the resulting graph. In our framework, modulator sentences are in counting monadic second-order logic (CMSOL) and have models of bounded treewidth, while target sentences express first-order logic (FOL) properties along with minor-exclusion. Our logic captures problems that are not definable in first-order logic and, moreover, may have instances of unbounded treewidth. Also, it permits the modeling of wide families of problems involving vertex/edge removals, alternative modulator measures (such as elimination distance or G-treewidth), multistage modifications, and various cut problems. Our main result is that, for this compound logic, model-checking can be done in quadratic time. All derived algorithms are constructive and this, as a byproduct, extends the constructibility horizon of the algorithmic applications of the Graph Minors theorem of Robertson and Seymour. The proposed logic can be seen as a general framework to capitalize on the potential of the irrelevant vertex technique. It gives a way to deal with problem instances of unbounded treewidth, for which Courcelle's theorem does not apply.

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