Reasoning about Cardinal Directions between 3-Dimensional Extended Objects using Answer Set Programming (Extended Abstract)

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Qualitative spatial reasoning (QSR) studies representation and reasoning of different aspects of space, such as direction, distance, size using parts of natural language rather than quantitative data. QSR models are useful in contexts where quantitative data is not available due to incomplete knowledge or uncertainty. Consider, for instance, exploration of an unknown territory such as disaster rescue, marine habitat discovery and underwater archaeology. QSR models are also useful in applications where agents need to express spatial relations or configurations by means of qualitative terms for the sake of sociable and convenient communication. For instance, while designing a building, it is more intuitive and understandable to describe the location of the transformer room as follows: "The transformer room must be at the back of the building, near the electric panel, and at a lower level than the entrance."

With these motivations, we study representation of and reasoning about cardinal directions in 3D space (e.g., to the north and above, the east and below, to the southwest and on the same level), based on the 2D Cardinal Directional Calculus (CDC) (Goyal and Egenhofer 1997; Skiadopoulos and Koubarakis 2004; Skiadopoulos and Koubarakis 2005).

Different from the related studies (Chen et al. 2007; Hou, Wu, and Yang 2016) on 3D CDC, instead of blocks (i.e., rectangular prism shape objects), we consider 3D objects of arbitrary shapes, that may be disconnected. We consider not only basic but also disjunctive 3D CDC constraints. We introduce a new type of constraint (called *default 3D constraint*) to represent default CDC relations (e.g., the garage is by default below and to the north of the entrance in a building). We call this extended version of 3D CDC as *3-dimensional nonmonotonic CDC (3D-nCDC)*.

We propose a formal framework (called 3D-nCDC-ASP) to represent 3D-nCDC constraints and to reason about them, using Answer Set Programming (ASP) (Marek and Truszczyński 1999; Niemelä 1999; Lifschitz 2002) based on answer set semantics (Gelfond and Lifschitz 1988; Gelfond and Lifschitz 1991). In particular, we study consistency checking problem in 3D-nCDC (i.e., the existence of a possible configuration of objects in 3D with respect to the given 3D-nCDC constraints), and present a general solution for this problem without restricting it to tractable cases. As part of 3D-nCDC-ASP, we also present solutions to other types of reasoning problems about 3D-nCDC constraints important for various real-world applications, such as explaining inconsistencies and inferring missing 3D CDC relations between objects.

We show the soundness and completeness of 3D-nCDC-ASP, implement it using the ASP language ASP-Core-2 (Calimeri et al. 2020) and the ASP solver CLINGO (Gebser et al. 2011), empirically evaluate its scalability, and illustrate interesting applications in marine exploration using underwater robots, building design and regulation, and evidence-based digital forensics.

For further information about 3D-nCDC-ASP, we refer the reader to our paper (Izmirlioglu and Erdem 2020).

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