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Mereology for Steam and Education Research

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Abstract

Mereology is widely applied in STEAM and philosophy. However, serious applications tend to be restricted to specialist groups or the nature of applications is too focused. In addition, methodologies associated do not percolate to school or college-level classroom discourses in a clear way. This is worrying because mereology can be used for effectively understanding concepts, their interrelations, promoting innovative reasoning, and motivating complex directions in engagement in all branches of STEAM (and at all levels). Additionally, it is essential for a proper understanding of compositionality in artificial intelligence (AI) and machine learning (ML), and can be used as a powerful language for describing interactive aspects of learning tools. Further, they can be applied to the problems of evaluation, formalizability of discourse, and student- centric teaching. In this research, the current scenario and related issues are discussed, and possible directions of adoption at relevant levels are proposed.

Introduction

1. Mereology is the study of part-whole relations and those closely related to it such as is a part of, is an integral part of, is an essential part of, is connected to, is in contact with, is disconnected from, is apart from, and approximate part of
2. They can actually be used to organize knowledge in a number of non-equivalent perspectives, and adapted to handle soft ideas.
3. While experts in specific disciplines make abundant use of mereological methods, such use is far less common in the literature on education research, and in the school curriculum.
4. Therefore it is necessary to explain the problems that its' adoption can address, and the ways in which it can be done.
5. The subject has a long and diverse history that goes back to ancient times and almost every culture of the world has contributed to it – the latter aspect may be read as a license for universal adoption in school education.
6. Formal approaches to mereology are of more recent origin.

Mereology in STEM

1. In AIML practices: compositional representations are used to reduce the complexity of models of complex synthetic environments. Approximate part of relations are useful in identifying recurring parts, for example.
2. Mereology is heavily used in approximate reasoning – especially rough sets and granular computing (See [Mani, 2018; Mani 2012]). Some authors do not explicitly use mereology, and related ontologies become shallow.
3. Mathematics: Foundation of mathematics, Constructive reals, Point-free Geometry, Mathematics of Vagueness, Many parts of higher Math.
4. Life Sciences: Parthood statements can be complicated both by ontological vagueness and by epistemic indeterminacy. Mereological essentialism breaks down often for living beings because identity is determined by a number of complex factors.
5. Cladistics: Entities with a common ancestor form a clade. Related hierarchies lead to the best way of classifying and naming living and partly living organisms.

Applications to Education Research

1. Applications to knowledge representation and evaluation in the context of student-centered learning are proposed by the present author in [Mani, 2020b].
2. Her proposal additionally seeks to model approximate and vague concepts used by students and teachers and provides a way of solving the problem of formalizability in mathematics (for example, see [Adler, 1999; Barwell, Et al., 2016]) in particular, because of the higher order approach used.
3. The language used by students and teachers to express concepts, predicates, and predications in mathematics is frequently different from possible candidates of a standard language. They try to approximate these across semantic domains with partial success.
4. Mereology combined with a language of approximations can potentially be used to build higher order formalizations of concepts that go beyond the restrictions envisaged in [Jayasree, Et al., 2022] because the very idea of the formal is much broader in the former through its' accommodation of vagueness and uncertainty.
5. The work on concept mappings in [Kharatmal and Nagarjuna, 2016] additionally makes uses of parthoods in an essential way. The latter has been adapted to classroom contexts in a limited way.

The Signed Number Problem

1. The difficulties faced by primary school students in understanding negative numbers (the signed number problem) is well-known.
2. In school mathematics, mereological ideas of is-bigger-than, is-smaller-than, is-composed-of, is- connected-to and others are encountered by students. These are not always defined in clear terms, and may be part of word problems.
3. Solutions based on interpreting negative integers *as a change*, *as a state* or *as a directed relation between numbers and quantities*, and ideas of displacement that relate to a directed relation between numbers and quantities are known.
4. In a recent paper by the present author, it is argued that the problem of signs is due to inconsistencies in the ascription of ontologies to the real numbers.
5. If the *content of perception* is seen as distinct from *the result of inference through a logical process*, then entirely different concepts of emptiness are possible - an emptiness would be a perceived object in the former, while the latter would possibly yield a relatively absolute nothingness.
6. In the proposed approach, every emptiness needs to characterized in a way that is compatible with the context. For this it suffices to introduce a large number of common possible types of emptiness to enable concept development. Thus what is traditionally taught as an empty glass can be a -50 marbles empty glass if the glass in question can be filled with 50 marbles and it is that the proposed activity concerns filling glasses with marbles.

Geogebra and Simulation Based Learning

1. Geogebra is a versatile free software for learning a wide variety of mathematics including calculus through simulations and dynamic models. Unexpected concepts created through it may lead to errors in evaluation (especially when teachers are not sufficiently skilled).
2. Therefore there is a need to help teachers and with additional soft tools.
3. Students may also not be able to express their simulations and proofs in clear terms because it is for the language used to provide the necessary affordances.
4. A student, for example, can learn about aspects of Pythagoras theorem, the connection between circles drawn with the hypotenuse of a right-angled triangle, and circum-circles of such triangles without ever knowing much about the proof(s) proper.
5. The adoption of a spatial mereological languages can substantially solve the mentioned problems.
6. Note that simulations on Geogebra and similar software can be described formally in mereological language – however the existing ones are not sufficient for the mentioned solution strategy.

Taking Mereology to School

1. In the previous sections, it has been explained that mereological methods and concepts are essential for a wide range of theoretical and practical applications in all subjects, and that it can serve as a universal language for all subjects at all levels.
2. While dedicated chapters on parts and wholes can be taught, it is necessary to introduce more of the reasoning machinery in different subjects.
3. In a chapter dedicated to parts and wholes, it is not easy to cover such a wide range of applications by teachers or students.
4. Further, mereological predicates are too many in number, and inter definability does not happen always (apartness for example).
5. For these reasons, the best strategy would be to systematically revise, upgrade and add key topics to elementary mathematics, ICT-enabled mathematics, physical sciences, computer programming, life sciences and language.
6. Good grammar is a mereological discipline.

Additional Points

1. As already pointed out that lessons on fractions invariably concern measurable parts and wholes, however it is not stressed that not everything is measurable – this has a detrimental effect on students' attitudes towards vagueness, uncertainty, and scientific thinking.
2. Areas where software and simulations are used should be thrust areas to ease the process of adoption, because they can serve as avenues of exploration, testing, and practice of the concepts learnt.
3. A knowledge of mereological methods can provide the necessary affordances for reasoning with action as in Geogebra and similar software for describing proofs.
4. In primary school mathematics, apart from the novel approach to teaching the signed number problem, the language of arithmetic needs improvement especially in relation to the differences between unary (1-place) and binary (2-place) operations such as – (minus) and – (minus) respectively.
5. Parts and wholes feature in the study of fractions and multiplicative thinking, however the assumption of measurability or countability is too strong.
6. This excludes many types of functional parts from the discourse and generates tunnel vision in learners and teachers.

Forthcoming Research

In future work, the directions mentioned will be explored and described in more detail.

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