Chapter 19

Basic Topological Notions and their Relation to BIM

Norbert Paul
Technische Universität München, Germany

ABSTRACT

Each building sets up a topological space in the mathematical sense. Therefore every Building Information Model (BIM) has to store topological information. Such information can be found, for example, in the IFC (Liebich et al. 2005). The volume modelling part of the IFC uses a so-called 'IfcTopologyResource' which is a topological model on the local scope of each single building element. At a global scope, the 'IfcRelConnects' class and its subclasses are used for the connectivity of the building parts. This chapter presents a generalizing concept which handles both "local" and "global" connectivity information in a common way and provides means to mutually relate them.

1 INTRODUCTION

Even if the absence of a common concept for handling both "local" and "global" topologies is not considered a problem, ad-hoc-modelling of topological properties in BIM without adequate topological knowledge may end up with flaws. Such knowledge also helps distinguish spatial semantics from non-spatial semantics, and it avoids complicating the model. A good example for such complexity is the 'IfcRelConnects' class hierarchy: The class 'IfcRelConnectsElements' defines two attributes 'Related' and 'Relating' referencing two *elements* which are somehow connected. Another subclasses of 'IfcRelConnects', however, have a completely different signature and meaning: Namely, the class 'IfcRelSpaceBoundary' "relates" a room *element* to a *set* of boundary elements and a similar class 'IfcRelCoversSpaces' where a room *element* "is related" to a *set* of boundary surfaces. So we have an element-element, an element-set, and a set-element signature, and even a transposition of the meaning of "relating" and "related".

This small example shows that there exists a zoo of storage concepts for spatial data. Some of the enormous complexity of IFC, COMBINE

DOI: 10.4018/978-1-60566-928-1.ch019

II (Eastman 1999), and other BIM can surely be attributed to this. Then again, with all these numerous concepts at hand it is still difficult to precisely define the relation between rough sketches, working drawings, and the details used in such working drawings. These models also do not provide version control which keeps track of spatial changes without redundantly storing the unchanged parts of the model.

The primary aim of this chapter is to provide mathematical background on topology and demonstrate its potentials for BIM. Thus its use in BIM-research is advocated, as such background knowledge at hand may help to identify spatial properties and to handle them adequately. Additionally, this chapter advocates a separation of spatial modelling from other aspects of BIM.

The chapter also presents two simple straightforward topological data models: *topological data types* and *relational complexes*. These can be easily realized as conventional relational databases. The models might also be helpful to overcome the current heterogeneity in spatial data modelling. Indeed, they have initially been developed for *comparison* of spatial modelling approaches instead of providing a new one.

Additional knowledge on the theory of topological constructions is provided. This theory is needed because the proposed redefinition of standard relational database queries are topological constructions in topological databases. One of these topological queries will be shown to have a particularly useful application in a hypothetical BIM. The topological inner-join, which formalizes how sketches, working drawings, and libraries of details are related, will be presented.

2 BACKGROUND

Before we define our topological data model we want to introduce some basic concepts of topology. A large amount of the matter presented in this section can be found in topology textbooks such as, Brown (1988).

A Naive Approach to Topology

Topology deals with spatial properties, for example, of being "completely within" a set of elements or points (a shape) or at least "close to" it. A *space boundary* of a room within a building, for instance, is "close to" that room but neither element of the room's space boundary is "within" that room. A door, however, is "within" the shape made of the door itself together with the two rooms it connects. As every shape which has that door "within" itself intersects both rooms, the door is said to be "close" to either of these rooms. In fact, the elementary notions of topology are merely precise definitions of what can be considered "interior", "boundary", and "exterior". We will now specify these concepts for the case of the three-dimensional Euclidean space into which each building is embedded.

Euclidean Real Space and its Topology

If we define an arbitrary coordinate system then each point p in space can be expressed by three real numbers $p = (x,y,z)$ and hence we call the set IR^3 of all these three-tuples, the *three dimensional real vector space*, which is a common mathematical model of the space that surrounds us. A *shape* in space is simply a subset S of IR^3. The *Euclidean distance* $d(p,q)$ between two points $p = (x,y,z)$ and $q = (u,v,w)$ is known to be the function $d\colon \mathrm{IR}^3 \times \mathrm{IR}^3 \to \mathrm{IR}$, defined as

$$d(p,q) = ((x-u)^2 + (y-v)^2 + (z-w)^2)^{1/2}.$$

We now call a real vector space together with the Euclidean distance the *Euclidean real space*. This space can be of arbitrary dimension—only the distance function must then be adjusted to this dimension in the straightforward manner.

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