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带孔洞面域间的拓扑关系的组合推理

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Combinational Reasoning of Topological Relations between Regions with Holes

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Abstract: According to the point-set topology theory, regions with holes are redefined. By analyzing the evolution plans of simple area objects' topological relations, a new method is put forward which can describe the special topological relations of regions with a hole. And then the new method is used to discuss the topological relations of two regions with a hole. Through the experiment, in theory, it has been proved that this method is feasible, can provide a theoretical method for improving the modeling and analysis capabilities of GIS.

Key words: topological relations; holes; area objects; combinational reasoning

摘 要: 根据点集拓扑学理论, 对带孔面域进行了定义。通过分析简单对象间拓扑关系的演变过程, 提出一种能描述带一个孔的面域间的空间拓扑关系的方法, 并用该方法详细推导了带一个孔的面域间有意义的拓扑关系。通过试验验证, 该方法在理论上是可行的。

关键词: 拓扑关系; 孔洞; 空间面域; 组合推理
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1 引 言

近年来, 空间关系理论一直是国内外地理信息及相关学科研究的重点, 它主要用于空间数据建模、空间数据库查询、空间推理、制图综合、自然语言交互界面设计等方面[1]。通常, 空间关系分为拓扑关系、距离关系和方向关系[2]。在空间对象拓扑关系描述方面, 目前已有一些学者建立了一些形式化描述模型, 如基于空间逻辑的RCC模型[2], 空间代数模型[3], 四元组模型[4], 九元组模型[5], V9I模型[6]和四交差模型[7]等。这些模型在一定分类层次上具有相同的区分能力, 它们大都能区分简单面区域间的8种拓扑关系, 但对于带空洞的面区域间拓扑关系, 这些模型大多则显的无能为力。然而在现实世界中, 带孔的面域较为常见, 它们在GIS空间数据库存储表达时已被视为一种复杂的空间数据类型, 但对于这种复杂空间数据类型的设计、定义以及拓扑关系描述和运算的研究, 现有的成果则相对较少[8-9], 其原因主要是由于带孔面域间的拓扑关系要比简单面域间拓扑关系类型多, 并且复杂得多。

为此, 本文研究带孔面域间拓扑关系的描述和推理方法。文献[10]在四交差模型基础上探讨了带空洞面对象间拓扑关系的描述方法, 但其得到的拓扑关系不够完善, 还有很多拓扑关系没有得到, 存在一定的不足。文献[11]讨论了文献[8]中对带孔面区域的定义中存在的不足, 进而对简单目标间拓扑关系的描述和区分方法进行了扩展, 层次地分析和区分简单面域和带孔洞面域间拓扑关系, 但是文献[11]未对两个带空洞面域间拓扑关系展开研究。本文在文献[11]的基础上, 根据点集拓扑学的理论, 对带孔面域进行了定义。在此定义基础上, 通过分析简单面域间拓扑关系演化过程, 提出一种能描述带孔面域间的空间拓扑关系的方法, 并由该方法得到两个带孔面域间有意义的拓扑关系。文中利用现有的判断拓扑关系模型(四元组模型, 九元组模型和四交差模型)进行实例判断, 证明该方法在理论上是可行的。

2 带孔洞面区域的定义

2.1 现有带孔面区域的定义及存在的问题

为了能够描述带孔面域间的拓扑关系, 文献[8]等给出了带孔洞面域的定义, 将一个带孔洞的面域被分解为一个由外边界圈定的简单面域和若

干个孔面域。假设 A 为一个带孔洞的面域, H_1^A, H_2^A, .., H_m^A 是落在 A 内的 m 个孔, 根据文献[8]的方法, 则有

$$A^* = A \cup (\bigcup_{i=1}^{m} H_i^A) \quad (1)$$

式中, A^* 即为面域 A 和它包含的孔组成的一个简单面域。如图 1 所示, 面域 A 包含有两个孔, 记为 H_1^A 和 H_2^A。按照文献[8]中的方法, 将面域 A 分解为三个简单面域, 即 A^*、H_1^A 和 H_2^A, 在描述两个带孔面域间拓扑关系时, 则利用 A 分解得到的简单面域分别与 B 分解得到的简单面域间的拓扑关系来描述, 最终可以得到拓扑关系的个数为: $\mu = (m+n+1)^2$ (m、n 分别是面区域 A、B 内孔的个数)。但考虑到带孔面域分解后得到的简单面域之间存在一些关系约束, 例如, 同一个面域的孔之间满足相离关系, 总区域 A^* 与 A 的各个孔洞之间是包含关系, 从而两个带孔面域间的拓扑关系在这些约束条件下可以简化为 μ 个组合关系[8], 即 $\mu = mn+m+n+1$ (m、n 分别是面域 A、B 内孔的个数)。

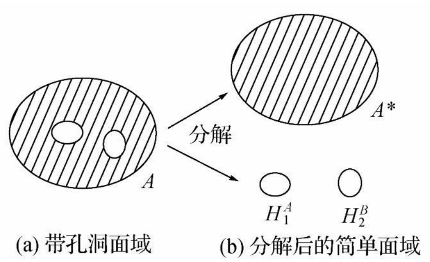

图 1　带孔洞面目标的现有描述方法

Fig. 1　Existing method for description of area object with holes

按照文献[8]对带孔面域的定义, 在对带孔区域的分解后, 改变了其拓扑性质[11]。如在图 1(a)中面目标 A 的 Euler 示性数为 -1, 而分解后图 1(b)中的三个简单区域 A^*、H_1^A 和 H_2^A 的 Euler示性数都为 1, 计算方法见文献[12]。

2.2　本文对带孔面域的定义

对于一个带孔的面域, 从空间构成上来看, 整个空间仍可粗分为两个部分, 即目标集和目标外部集。为了更好地描述带孔面域间拓扑关系, 给出其相关概念及定义。

根据点集拓扑学理论[13], 给出以下定义。

定义 1　如果一个集合 $\boldsymbol{X}$ 的子集簇 A 满足以下三个条件: ①空集和 $\boldsymbol{X}$ 属于 A; ②A 中任意两个元素的交仍为 A 的元素; ③A 中任意两个元素的并仍为 A 的元素, 则 $(\boldsymbol{X}, A)$ 称为拓扑空间, 记为 $X°A$ 中的元素称为 $\boldsymbol{X}$ 中的开集, 它们在 $\boldsymbol{X}$ 中的余集称为闭集。

定义 2　设 $\boldsymbol{X}$ 是一个连通的拓扑空间, $\boldsymbol{X}$ 中的一个空间面域 A 是满足如下两个条件的非空的集合: ①A 的内部是连通的; ②A 等于 A 的内部的闭包$\overline{A}$。这时 A 的外部 $A^- = \boldsymbol{X} - A$。

在上述定义的基础上, 给出带孔面域的定义。如图 2 所示, 面域 A 包含一个孔, 它的内边界记为∂A°, 外边界记为∂A^-, 则面域 A 即为∂A^-与∂A°中间的区域(如图 2 所示), 那么二维空间中的面域 A 即为: $A = \partial A^- - \partial A^\circ$。按照文献[8]中对面域中孔的约定, 同一个面域的孔之间满足相离关系, 则按照上述的定义, 含有两个或两个以上孔的面域也可以用以上方法定义。

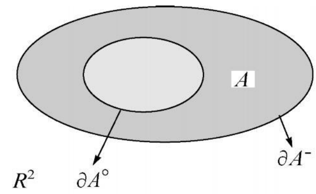

图 2　带一个孔的面域

Fig. 2　An area with a hole

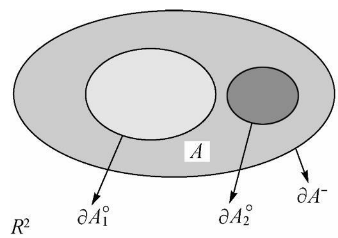

图 3　带两个孔的面域

Fig. 3　An area with two holes

本文为了描述两个带孔的面域 A、B 间的拓扑关系, 提出一种通过判断∂A°、∂A^-与∂B°、∂B^-间的关系, 来确定 A、B 两面域间拓扑关系的一种方法。同时由上述定义可知, 当$\partial A^\circ = \phi$时, A 即为简单一区域, 即该方法能将简单面域和带孔的面域统一起来定义, 简单面域是带孔面域当$\partial A^\circ = \phi$的一个特例。因此简单面域和带孔面域间的拓扑关系可统一描述, 它们之间的空间拓扑关系都包含在以下三种情况中:

(1) 当$\partial A^\circ = \phi$和$\partial B^\circ = \phi$时, A、B 都为简单面域, 则 A、B 间的拓扑关系用 $R(A, B)$ 来描述;

(2) 当$\partial A^\circ = \phi$或$\partial B^\circ = \phi$时, 即 A、B 中有一个为简单面对象, 一个为带孔的面域时, 假设 A

为带孔面域(带一个孔), B 为简单面域, 则 A、B 间的拓扑关系用 $R(\partial A^{-}, B)$、$R(\partial A^{\circ}, B)$ 来描述;

(3) 当 $\partial A^{\circ} \neq \phi$ 和 $\partial B^{\circ} \neq \phi$ 时, 即 A, B 都为带孔面域(带一个孔), 它们之间的拓扑关系可由 $R(\partial A^{-}, \partial B^{-})$、$R(\partial A^{-}, \partial B^{\circ})$、$R(\partial A^{\circ}, \partial B^{-})$、$R(\partial A^{\circ}, \partial B^{\circ})$ 来描述;

上述的三种情况中, 用来判断拓扑关系的表达式 $R(A, B)$, 可以采用文献[2-7]中任何一种拓扑关系模型。

3　带孔面域间空间拓扑关系的描述方法

3.1　简单面域间空间拓扑关系的演化过程

对于两个简单面域 A、B 间拓扑关系的研究, 主要的模型如文献[2-7]所述。这些模型中的任一种方法都可以得到 A、B 之间有意义的 8 种拓扑关系, 即"相离(disjoint)"、"相接(meet)"、"相交(overlap)"、"覆盖"、"包含(contains)"、"覆盖于(coveredby)"、"包含于(inside)"和"相等(equal)"。考虑到包含与包含于、覆盖与覆盖于具有对称性, 这里讨论以下六种拓扑关系: 相离、相接、相交、覆盖、包含和相等。若以对象 A 为参照物, 则发现这六种拓扑关系表现为对象 B 逐渐向 A 靠拢, 并最终与 A 重合, 图 4 即为两对象间六种拓扑关系演化示意图。

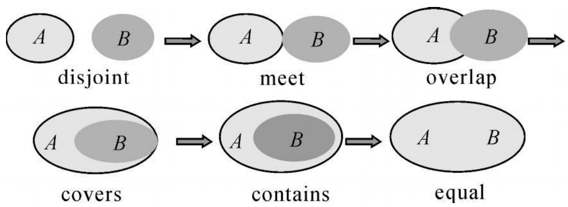

图 4　拓扑关系演化图

Fig. 4　Evolution chart of topological relations

根据图 4 的演化过程, 不难发现, 若用 $R(\partial A^{-}, \partial B^{-})$、$R(\partial A^{-}, \partial B^{\circ})$、$R(\partial A^{\circ}, \partial B^{-})$、$R(\partial A^{\circ}, \partial B^{\circ})$ 四个表达式描述两个带孔面域间拓扑关系时, 为提高判断效率, 可以采用一种逐级推理的方法, 先判断 $R(\partial A^{-}, \partial B^{-})$, 然后依次判断 $R(\partial A^{-}, \partial B^{\circ})$、$R(\partial A^{\circ}, \partial B^{-})$ 和 $R(\partial A^{\circ}, \partial B^{\circ})$。先判断 $R(\partial A^{-}, \partial B^{-})$ 的关系, 相当于对两个带孔面域首先进行粗判断, 在这种关系确定后再讨论其他几种关系的取值情况。下面将具体讨论用该方法来判断两带孔面域间的拓扑关系。

3.2　两个带孔面区域间空间拓扑关系的具体描述

根据拓扑关系演化图, 在描述两个带孔面域间的空间拓扑关系时, 先计算式 $R(\partial A^{-}, \partial B^{-})$, 然后依次讨论式 $R(\partial A^{-}, \partial B^{\circ})$、$R(\partial A^{\circ}, \partial B^{-})$ 和 $R(\partial A^{\circ}, \partial B^{\circ})$ 的取值。由于包含与包含于、覆盖与覆盖于具有对称性, 对于 $R(\partial A^{-}, \partial B^{-})$ 式的取值只讨论以下六种关系, 即: 相离(disjoint)、相接(meet)、相交(overlap)、覆盖(covers)、包含(contains)、相等(equal)。以 A 为参考对象, 详细讨论 A、B 间的拓扑关系方法如下:

(1) 当 $R(\partial A^{-}, \partial B^{-})$ = disjoint, 则 $R(\partial A^{-}, \partial B^{\circ}) = R(\partial A^{\circ}, \partial B^{-}) = R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint;

(2) 当 $R(\partial A^{-}, \partial B^{-})$ = meet 时, 则 $R(\partial A^{-}, \partial B^{\circ}) = R(\partial A^{\circ}, \partial B^{-}) = R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint;

(3) 当 $R(\partial A^{-}, \partial B^{-})$ = overlap、$R(\partial A^{-}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains} 时, $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside};

(4) 当 $R(\partial A^{-}, \partial B^{-})$ = overlap、$R(\partial A^{-}, \partial B^{\circ})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside}; 而 $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint;

(5) 当 $R(\partial A^{-}, \partial B^{-})$ = overlap、$R(\partial A^{-}, \partial B^{\circ})$ = meet 时, $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside}; 而 $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint;

(6) 当 $R(\partial A^{-}, \partial B^{-})$ = overlap、$R(\partial A^{-}, \partial B^{\circ})$ = overlap 时, 则 $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = coveredby 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = inside 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside};

(7) 当 $R(\partial A^{-}, \partial B^{-})$ = overlap、$R(\partial A^{-}, \partial B^{\circ})$ = covers 时, 则 $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside}; 此时, 当 $R(\partial A^{\circ}, \partial B^{-})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covered-

by, inside}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = coveredby 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = inside 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside};

(8) 当 $R(\partial A^{-}, \partial B^{-})$ = overlap、$R(\partial A^{-}, \partial B^{\circ})$ = contains 时, 则 $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside}; 此时, 当 $R(\partial A^{\circ}, \partial B^{-})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = coveredby 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = inside 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains, coveredby, inside, equal};

(9) 当 $R(\partial A^{-}, \partial B^{-})$ = covers 时, 则 $R(\partial A^{-}, \partial B^{\circ})$ = contains, $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, coveredby, inside}; 此时, 当 $R(\partial A^{\circ}, \partial B^{-})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = coveredby 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = inside 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains, coveredby, inside, equal};

(10) 当 $R(\partial A^{-}, \partial B^{-})$ = coveredby 时, 则 $R(\partial A^{-}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}, 而 $R(\partial A^{\circ}, \partial B^{-})$ = inside; 此时, 当 $R(\partial A^{-}, \partial B^{\circ})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{-}, \partial B^{\circ})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{-}, \partial B^{\circ})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside}; 当 $R(\partial A^{-}, \partial B^{\circ})$ = covers 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside}; 当 $R(\partial A^{-}, \partial B^{\circ})$ = contains 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains, coveredby, inside, equal};

(11) 当 $R(\partial A^{-}, \partial B^{-})$ = contains 时, 则 $R(\partial A^{-}, \partial B^{\circ})$ = contains, $R(\partial A^{\circ}, \partial B^{-})$ = {disjoint, meet, overlap, covers, coveredby, contains, inside, equal}; 此时, 当 $R(\partial A^{\circ}, \partial B^{-})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{\circ}, \partial B^{-})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; $R(\partial A^{\circ}, \partial B^{-})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}; $R(\partial A^{\circ}, \partial B^{-})$ = covers 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = contains; 当 $R(\partial A^{\circ}, \partial B^{-})$ = coveredby 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = contains 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = contains; 当 $R(\partial A^{\circ}, \partial B^{-})$ = inside 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains, coveredby, inside, equal}; 当 $R(\partial A^{\circ}, \partial B^{-})$ = equal时, $R(\partial A^{\circ}, \partial B^{\circ})$ = contains;

(12) 当 $R(\partial A^{-}, \partial B^{-})$ = inside 时, 则 $R(\partial A^{\circ}, \partial B^{-})$ = inside, $R(\partial A^{-}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, coveredby, contains, inside, equal}; 此时, 当 $R(\partial A^{-}, \partial B^{\circ})$ = disjoint 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{-}, \partial B^{\circ})$ = meet 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = disjoint; 当 $R(\partial A^{-}, \partial B^{\circ})$ = overlap 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside}; 当 $R(\partial A^{-}, \partial B^{\circ})$ = covers 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, coveredby, inside}; 当 $R(\partial A^{-}, \partial B^{\circ})$ = contains 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains, coveredby, inside, equal}; 当 $R(\partial A^{-}, \partial B^{\circ})$ = coveredby 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = inside; 当 $R(\partial A^{-}, \partial B^{\circ})$ = inside 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = inside; 当 $R(\partial A^{-}, \partial B^{\circ})$ = equal 时, $R(\partial A^{\circ}, \partial B^{\circ})$ = inside;

(13) 当 $R(\partial A^{-}, \partial B^{-})$ = equal 时, 则 $R(\partial A^{-}, \partial B^{\circ})$ = $R(\partial A^{\circ}, \partial B^{-})$ = contains, $R(\partial A^{\circ}, \partial B^{\circ})$ = {disjoint, meet, overlap, covers, contains, coveredby, inside, equal}。

通过上面的推理判断, 可以得到两个带孔面域间多种有意义的拓扑关系。同理, 以 B 为参考对象也可得到上述相同的结果。

4 应用实例

按照上述的定义, 将带孔面域进行定义, 最后采用一个逐级推理的方式来判断它们之间的拓扑关系。在判断过程中, 对于 A、B 之间的拓扑关系 $R(A, B)$ 采用文献[2-7]中任一中模型都可以进行计算。例如, 对于图 5 中两种情况, 分别采用四元组模型[4]、九元组模型[5]和四交差模型[7]得到

的结果是一致的。

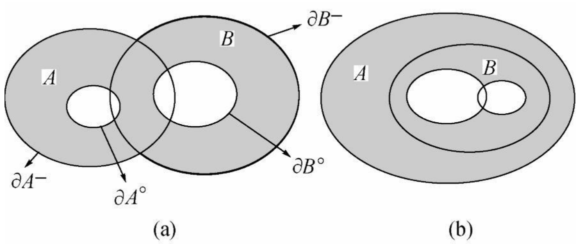

图5 带一孔面域A和B间的拓扑关系

Fig.5 Topological relations between an area A and B with a hole

对于图5(a),采用四元组模型进行判断,结果如下:

$R(\partial A^-,\partial B^-)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$, $R(\partial A^-,\partial B^\circ)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^-)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^\circ)=\begin{bmatrix}0&0\\0&0\end{bmatrix}$。即:$R(\partial A^-,\partial B^-)=$ overlap、$R(\partial A^-,\partial B^\circ)=$ overlap、$R(\partial A^\circ,\partial B^-)=$ overlap、$R(\partial A^\circ,\partial B^\circ)=$ disjoint;

采用九元组模型进行判断,结果如下:

$R(\partial A^-,\partial B^-)=\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}$, $R(\partial A^-,\partial B^\circ)=\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^-)=\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^\circ)=\begin{bmatrix}0&0&1\\0&0&1\\1&1&1\end{bmatrix}$。即:$R(\partial A^-,\partial B^-)=$ overlap、$R(\partial A^-,\partial B^\circ)=$ overlap、$R(\partial A^\circ,\partial B^-)=$ overlap、$R(\partial A^\circ,\partial B^\circ)=$ disjoint;

采用四交差模型进行判断,结果如下:

$R(\partial A^-,\partial B^-)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$, $R(\partial A^-,\partial B^\circ)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^-)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^\circ)=\begin{bmatrix}0&1\\1&0\end{bmatrix}$。即:$R(\partial A^-,\partial B^-)=$ overlap、$R(\partial A^-,\partial B^\circ)=$ overlap、$R(\partial A^\circ,\partial B^-)=$ overlap、$R(\partial A^\circ,\partial B^\circ)=$ disjoint;

对于图5(b),采用四元组模型进行判断,结果如下:

$R(\partial A^-,\partial B^-)=\begin{bmatrix}0&0\\1&1\end{bmatrix}$, $R(\partial A^-,\partial B^\circ)=\begin{bmatrix}0&0\\1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^-)=\begin{bmatrix}0&1\\0&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^\circ)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$。即:$R(\partial A^-,\partial B^-)=$ contains、$R(\partial A^-,\partial B^\circ)=$ contains、$R(\partial A^\circ,\partial B^-)=$ inside、$R(\partial A^\circ,\partial B^\circ)=$ overlap;

采用九元组模型进行判断,结果如下:

$R(\partial A^-,\partial B^-)=\begin{bmatrix}1&1&1\\0&0&1\\0&0&1\end{bmatrix}$, $R(\partial A^-,\partial B^\circ)=\begin{bmatrix}1&1&1\\0&0&1\\0&0&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^-)=\begin{bmatrix}1&0&0\\1&0&0\\1&1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^\circ)=\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}$。即:$R(\partial A^-,\partial B^-)=$ contains、$R(\partial A^-,\partial B^\circ)=$ contains、$R(\partial A^\circ,\partial B^-)=$ inside、$R(\partial A^\circ,\partial B^\circ)=$ overlap;

采用四交差模型进行判断,结果如下:

$R(\partial A^-,\partial B^-)=\begin{bmatrix}0&0\\1&1\end{bmatrix}$, $R(\partial A^-,\partial B^\circ)=\begin{bmatrix}0&0\\1&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^-)=\begin{bmatrix}0&1\\0&1\end{bmatrix}$, $R(\partial A^\circ,\partial B^\circ)=\begin{bmatrix}1&1\\1&1\end{bmatrix}$。即:$R(\partial A^-,\partial B^-)=$ contains、$R(\partial A^-,\partial B^\circ)=$ contains、$R(\partial A^\circ,\partial B^-)=$ inside、$R(\partial A^\circ,\partial B^\circ)=$ overlap。

通过上述的例子可以看出,本文所提出的判断两带孔面域间拓扑关系的方法适合现有的一些模型,若要用将该方法加入到现有GIS系统中全面地描述空间对象间拓扑关系,该方法则为提高GIS对现实世界的建模、分析和描述能力提供了一定的理论依据。

5 结 论

空间对象的边界和内部区分是描述空间对象间拓扑关系的基础,本文在文献[11]的基础上,根据点集拓扑学理论,给出了能将简单面域和带孔的面域的定义统一起来表达的一种方法,通过分析简单面域间拓扑关系的一个演化过程,提出了两个带孔面域(带一个孔)间的拓扑关系的逐级层次推理方法,并由该方法得到两个带孔面域间有

意义的拓扑关系。通过试验证明, 采用现有描述简单面域间拓扑关系模型中的任意一种来对两带孔面域间拓扑关系进行判断, 都能得到相同结果, 则证明该方法在理论上是可行的, 有利于完备地描述带一个孔的面域间拓扑关系, 为提高 GIS 对现实世界的描述能力提供了一定的理论依据。

尽管该方法区分了两带一个孔面域间的拓扑关系, 但该方法仅仅局限于带一个孔的情形, 对于含两个和两个以上孔的复杂情况用该方法是否合适还有待进一步研究, 这也将是作者进一步的研究工作。

参考文献:

[1] BURROUGH P A, MCDONNELL R A. Principles of Geographical Information Systems[M]. Oxford: Oxford University Press, 1998.

[2] COHN A G, GOTTS N M. The "Egg-Yolk" Representation of Regions with Indeterminate Boundaries[C] // Proceedings of GISDATA-Specialist Meeting on Special Objects with Indeterminate Boundaries. London: Taylor & Francis, 1996: 171-187.

[3] LI Zhilin, ZHAO Renliang, CHEN Jun. An Algebra Model for Spatial Relations[C] // Proceedings of the 3RD ISPRS Workshop on Dynamic and Multi-dimensional GIS. Bangkok: [s. n.], 2001: 170-177.

[4] EGENHOFER M, FRANZOSA R. Point-set Topological Spatial Relations[J]. International Journal of Geographical Information Systems, 1991, 5(2): 161-174.

[5] EGENHOFER M, HERRING J. Categoring Binary Topological Relationships between Regions, Lines, Points in Geographic Databases[R]. Oronoi: University of Maine, 1991.

[6] CHEN Jun, LI Chengming, LI Zhilin, et al. A Voronoi-based 9-intersection Model for Spatial Relations[J]. International Journal of Geographical Information Science, 2001, 15(3): 201-220.

[7] DENG Min, LIU Wenbao, FENG Xuezhi. Generic Model of Topological Relations between Spatial Regions in GIS[J]. Acta Geodaetica et Cartographica Sinica, 2005, 34(1): 85-90. (邓敏, 刘文宝, 冯学智. GIS 面目标间拓扑关系的形式化模型[J]. 测绘学报, 2005, 34(1): 85-90.)

[8] EGENHOFER M, CLEMENTINI E, DI FELICE P. Topological Relations between Regions with Holes[J]. International Journal of Geographical Information Science, 1994, 8(2): 129-144.

[9] SCHNEIDER M, BEHR T. Topological Relationships between Complex Spatial Objects[J]. ACM Transations on Database Systems, 2006, 31(1): 39-81.

[10] LIU Bo, LI Dajun, RUAN Jian, et al. Formal Description of Regions with Hole's Topological Relations[J]. Geomatics and Information Science of Wuhan University, 2009, 34(1): 68-71. (刘波, 李大军, 阮见, 等. 带空洞面对象间拓扑关系形式化描述[J]. 武汉大学学报: 信息科学版, 2009, 34(1): 68-71.)

[11] DENG Min, LI Zhilin, LI Guangqiang. A Hierarchical Approach to Topological Relations between a Simple Area and an Area with Holes[J]. Acta Geodaetica et Cartographica Sinica, 2008, 37(3): 330-337. (邓敏, 李志林, 李光强. 简单面目标与带孔洞面目标间拓扑关系的层次表达方法[J]. 测绘学报, 2008, 37(3): 330-337.)

[12] DENG Min. Extended Models on Topological Relations in Vector GISs: Theories and Methods[D]. Wuhan: Wuhan University, 2003. (邓敏. 矢量 GIS 中拓扑关系的扩展模型理论与方法[D]. 武汉: 武汉大学, 2003.)

[13] ARMSTRONG M A. Basic Topology[M]. SUN Yifeng, Translated. Beijing: Peking University Press, 1983. (ARMSTRONG M A. 基础拓扑学[M]. 孙以丰, 译. 北京: 北京大学出版社, 1983.)

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