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Computing the Fuzzy Topological Relations of Countries Affected by Congenital Disease

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A B S T R A C T

There are many studies have emerged to develop a descriptive concept of the topological relationship between spatial data. In this paper, a definition based on the interior operator and the closure operator for a fuzzy computational topology was used. The concept of the basic idea is that for each element there is an interior, exterior (complement), and boundary. The interior, the exterior and the boundary of the sample of countries affected by the congenital disease based on UNICEF database were computed.

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1. Introduction

In geographic information system (GIS) with positional and attribute information, topological relations' information can be used for quality control, analyses, queries in spatial data and others. Topological relations are important in many tasks of object recognition, scene description and spatial reasoning. Topological relations' information play a fundamental role in GIS modeling. It is an important matter is to understand the relationships between spatial features. When a topology deals with the geometric object it deals with its structural and spatial properties regardless of their type, extension or geometric shape. Topological relationships between objects are a type of topological properties that remain invariant when any continuous deformation occurs in space [26]. Topological relationships between objects are a type of topological properties that remains invariant when continuous deformation occurs in space [26]. Many approaches have been suggested for defining the topological relations between crisp spatial objects; in 1979, Corbett present the algebraic topological structure of map modeling [7]. In 1983, Allen described a method of representing the relationships between temporal intervals [1]. In 1991-1995, after the submitted of 4-intersection and 9-intersections by Egenhofer and Franzosa, significant progress occurred on the topological relations between spatial objects [8-9]. After that, a lot of studies have been done in this field for example [6, 10, 20, 24, 28]. The topological relationship between spatial data can be used to describe the inaccuracy

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of data in GIS and the fuzzy sets were used as a useful tool in this area. There are many possible relationships in spatial data which many important for the analysis in GIS, Where many studies used the relationships in spatial data [5, 21-23, 25, 27]. In this paper, we compute the interior, the exterior and the boundary of spatial data for an optional set of countries to derive the topological relations between the spatial data by using data from UNICEF database [29]. In this paper, description of the study field (a congenital disease in each country) and the basic definitions of fuzzy topological space and definitions of topological relations in this space are mentioned, then the data topological relationships are computed according to the fuzzy topological model.

2. Study Field (Congenital Disease in each Country)

A congenital disorder or a birth defect is a condition existent during childbirth regardless of why. A congenital disorder may produce in disabled handicaps that might be developmental, intellectual, or physical [4, 11, 30]. There are two fundamental types of congenital disorders: If there is a problem with the functioning of a certain part of the body then it is called functional disorder. While, when there is a problem in the state of a particular part of the body then it is called structural disorder. Some congenital disorders incorporate both functional and structural disorders [12]. Congenital disorders may consequence for hereditary or chromosomal disorders, exposure to chemicals or specific drugs, or certain contagions through pregnancy [2, 3, 13]. Risk elements incorporate folate inadequacy, drinking liquor or smoking through this phase, diabetes and parent's age. Furthermore there are different factors, for example, poisonous substances, prescriptions and enhancements, harmful substances, diseases, absence of supplements, physical limitation, hereditary qualities, economics, radiation, there are likewise obscure causes [14, 15]. Many are accepted to include numerous factors [15]. Congenital disorders might be noticeable during childbirth or analyzed by screening tests. Various imperfections can be distinguished before birth by various prenatal tests [17]. Treatment differs relying upon the imperfection being referred to. This may incorporate treatment, medicine, medical procedure, or assistive technology [16]. Birth defects influence around 96 million individuals in 2015 [19]. Congenital heart disease tops the list in terms of annual deaths by 303,000, followed by neural tube defects (65,000) [18]. Topological relationships were computed for data obtained from the UNICEF global databases of deaths of newborns for each country due to congenital disease. [29].

3. Fuzzy Sets and Fuzzy Topology

3.1 Fuzzy Sets

Definition 3.1 A fuzzy subset μ in a universe X (a fuzzy set) is defined as a map $\mu: X \to [0,1]$. Where, $\mu(x)$ for every $x \in X$ "stands for the grade of membership of x in fuzzy set μ" [31].

Definition 3.2 Let the set $X \neq \emptyset$ and $\Im(X)$ be the family of all fuzzy set in X. Then
(1) For any $G, H \in \Im(X)$, $G \leq H$ if and only if $G(x) \leq H(x); \forall x \in X$;
(2) For any $\{G_i : i \in I\} \subseteq \Im(X)$,
$(\bigcup_{i\in I} G_i)(x) = \bigvee_{i\in I} G_i(x) = \max_{i\in I} \{G_i(x)\}, \forall x \in X$;
(3) For any $\{G_i : i \in I\} \subseteq \Im(X)$,
$(\bigcap_{i\in I} G_i)(x) = \bigwedge_{i\in I} G_i(x) = \min_{i\in I} \{G_i(x)\}, \forall x \in X$;
(4) The complement $\neg G \in \Im(X)$ of $G \in \Im(X)$ is defined as
$(\neg G)(x) = 1 - G(x)$, for every $x \in X$ [31].

3.2 Fuzzy Topological Space

Definition 3.3 Let $X \neq \emptyset$ and let $\tau \subset I^X$, where $I = [0,1]$, if τ satisfy the following conditions:
(1) $0, 1 \in \tau$;
(2) for any $G, H \in \tau$, $G \wedge H \in \tau$;
(3) for any $\{G_i : i \in I\} \subset \tau$, $\bigvee_{i\in I} G_i \in \tau$;
Then τ is called a I-fuzzy topology and (I^X, τ) called I-fuzzy topological space [21].

Definition 3.4 The family of fuzzy closed sets is denoted by $\mathcal{F} \subset I^X$, and defined as $G \in \mathcal{F} = X \sim G \in \tau$, where $X \sim G$ is the complement of G [21].

Definition 3.5 The fuzzy interior of $G \in \Im(X)$; denoted by $int(G) \in \Im(X)$; is defined as :
$int(G) = \vee \{H \in \tau;\ H \leq G\}$ [21].

Definition 3.6 The fuzzy closure of $G \in \Im(X)$, denoted by $cl(G) \in \Im(X)$, is defined as :
$cl(G) = \wedge \{H \in \mathcal{F} :\ H \geq G\}$ [21].

Definition 3.7 The fuzzy exterior of $G \in \Im(X)$, denoted by $ext(G) \in \Im(X)$, is defined as :
$ext(G) = X{\sim}cl(G)$ [21].

Definition 3.8 The fuzzy boundary of $G \in \Im(X)$, denoted by $b(G) \in \Im(X)$, is defined as :
$b(G) = cl(G) \wedge cl(X{\sim}G)$ [21].

4. Fuzzy Topology Induced by the Interior and Closure Operators

In general, when interior and closure operators are defined, each of them will define a fuzzy topology separately [21]. The coherent between these two topologies may not exist. Following are the definitions for two operators, interior and closure defined coherent two fuzzy topologies.

Definition 4.1 The fuzzy interior operator of the fuzzy set $G \subset I^X$ is defined as $G \overset{\alpha}{\rightarrow} G_\alpha \in I^X$, where
$G_\alpha(X) = \begin{cases} G(X) & if \quad G(X) > \alpha \\ 0 & if \quad G(X) \leq \alpha \end{cases}$, for any fixed $\alpha \in [0,1]$ [22].

Definition 4.2 The fuzzy closure operator of a fuzzy set $G \subset I^X$ is defined as $G \overset{\overline{\alpha}}{\rightarrow} G^\alpha \in I^X$, where
$G^\alpha(X) = \begin{cases} 1 & if \quad G(X) \geq \alpha \\ G(X) & if \quad G(X) < \alpha \end{cases}$, for any fixed $\alpha \in [0,1]$ [22].

5. Case Study

The mortality rate of congenital disease in each country was marked by a rate within the interval [0,1] [5]. We try to determine the interior, exterior and boundary for the sample set of countries, to determine the countries most affected by congenital diseases for different value of α. The effect in the countries will be low if the closure value is close to zero. While, it will be high if the interior value is close to 1. This is evident from Table (1), compared to the percentage of deaths from this disease.

6. The New Fuzzy Topology Model

Table 1 - The fuzzy value of interior, exterior and boundary with different values of α

ID	Country Name	Congenital Real Value [29] %100	Congenital Fuzzy Value	α = 0.15			α = 0.25			α = 0.35		
				Interior	Boundary	Exterior	Interior	Boundary	Exterior	Interior	Boundary	Exterior
1	Central African Republic	5.5	0.055	0	0.055	0.945	0	0.055	0.945	0	0.055	0.945
2	Mali	5.5	0.055	0	0.055	0.945	0	0.055	0.945	0	0.055	0.945
3	Chad	5.8	0.058	0	0.058	0.942	0	0.058	0.942	0	0.058	0.942
4	Mauritania	5.9	0.059	0	0.059	0.941	0	0.059	0.941	0	0.059	0.941
5	Niger	6.1	0.061	0	0.061	0.939	0	0.061	0.939	0	0.061	0.939
6	Pakistan	6.2	0.062	0	0.062	0.938	0	0.062	0.938	0	0.062	0.938
7	Nigeria	6.5	0.065	0	0.065	0.935	0	0.065	0.935	0	0.065	0.935
8	Somalia	6.6	0.066	0	0.066	0.934	0	0.066	0.934	0	0.066	0.934
9	Congo	7.4	0.074	0	0.074	0.926	0	0.074	0.926	0	0.074	0.926
10	South Sudan	7.7	0.077	0	0.077	0.923	0	0.077	0.923	0	0.077	0.923
11	Sudan	7.8	0.078	0	0.078	0.922	0	0.078	0.922	0	0.078	0.922
12	Afghanistan	8.1	0.081	0	0.081	0.919	0	0.081	0.919	0	0.081	0.919

13	Haiti	8.1	0.081	0	0.081	0.919	0	0.081	0.919	0	0.081	0.919
14	Mozambique	8.3	0.083	0	0.083	0.917	0	0.083	0.917	0	0.083	0.917
15	Cameroon	8.5	0.085	0	0.085	0.915	0	0.085	0.915	0	0.085	0.915
16	Togo	8.8	0.088	0	0.088	0.912	0	0.088	0.912	0	0.088	0.912
17	Liberia	8.9	0.089	0	0.089	0.911	0	0.089	0.911	0	0.089	0.911
18	Gambia	9.5	0.095	0	0.095	0.905	0	0.095	0.905	0	0.095	0.905
19	Yemen	9.6	0.096	0	0.096	0.904	0	0.096	0.904	0	0.096	0.904
20	Djibouti	9.8	0.098	0	0.098	0.902	0	0.098	0.902	0	0.098	0.902
21	South Africa	10.0	0.100	0	0.1	0.9	0	0.1	0.9	0	0.1	0.9
22	Ghana	10.4	0.104	0	0.104	0.896	0	0.104	0.896	0	0.104	0.896
23	Ethiopia	10.6	0.106	0	0.106	0.894	0	0.106	0.894	0	0.106	0.894
24	India	11.1	0.111	0	0.111	0.889	0	0.111	0.889	0	0.111	0.889
25	Zimbabwe	11.2	0.112	0	0.112	0.888	0	0.112	0.888	0	0.112	0.888
26	Senegal	11.4	0.114	0	0.114	0.886	0	0.114	0.886	0	0.114	0.886
27	Myanmar	11.5	0.115	0	0.115	0.885	0	0.115	0.885	0	0.115	0.885
28	Uganda	11.6	0.116	0	0.116	0.884	0	0.116	0.884	0	0.116	0.884
29	Gabon	12.5	0.125	0	0.125	0.875	0	0.125	0.875	0	0.125	0.875
30	Kenya	12.5	0.125	0	0.125	0.875	0	0.125	0.875	0	0.125	0.875
31	Namibia	12.6	0.126	0	0.126	0.874	0	0.126	0.874	0	0.126	0.874
32	Bangladesh	12.9	0.129	0	0.129	0.871	0	0.129	0.871	0	0.129	0.871
33	Nepal	13.1	0.131	0	0.131	0.869	0	0.131	0.869	0	0.131	0.869
34	Eritrea	13.2	0.132	0	0.132	0.868	0	0.132	0.868	0	0.132	0.868
35	Jamaica	13.2	0.132	0	0.132	0.868	0	0.132	0.868	0	0.132	0.868
36	Turkmenistan	13.6	0.136	0	0.136	0.864	0	0.136	0.864	0	0.136	0.864
37	Serbia	14.8	0.148	0	0.148	0.852	0	0.148	0.852	0	0.148	0.852
38	Rwanda	14.9	0.149	0	0.149	0.851	0	0.149	0.851	0	0.149	0.851
39	Morocco	15.3	0.153	0.153	0.847	0.847	0	0.153	0.847	0	0.153	0.847
40	Bolivia	15.5	0.155	0.155	0.845	0.845	0	0.155	0.845	0	0.155	0.845
41	Cambodia	15.5	0.155	0.155	0.845	0.845	0	0.155	0.845	0	0.155	0.845
42	Guatemala	16.5	0.165	0.165	0.835	0.835	0	0.165	0.835	0	0.165	0.835
43	Azerbaijan	16.8	0.168	0.168	0.832	0.832	0	0.168	0.832	0	0.168	0.832
44	Philippines	16.8	0.168	0.168	0.832	0.832	0	0.168	0.832	0	0.168	0.832
45	Iraq	17.1	0.171	0.171	0.829	0.829	0	0.171	0.829	0	0.171	0.829
46	Indonesia	17.5	0.175	0.175	0.825	0.825	0	0.175	0.825	0	0.175	0.825
47	Venezuela	17.5	0.175	0.175	0.825	0.825	0	0.175	0.825	0	0.175	0.825
48	China	18.0	0.180	0.18	0.82	0.82	0	0.18	0.82	0	0.18	0.82
49	Algeria	18.7	0.187	0.187	0.813	0.813	0	0.187	0.813	0	0.187	0.813
50	Cuba	19.6	0.196	0.196	0.804	0.804	0	0.196	0.804	0	0.196	0.804
51	Uzbekistan	19.9	0.199	0.199	0.801	0.801	0	0.199	0.801	0	0.199	0.801
52	Grenada	20.0	0.200	0.2	0.8	0.8	0	0.2	0.8	0	0.2	0.8
53	North Korea	20.1	0.201	0.201	0.799	0.799	0	0.201	0.799	0	0.201	0.799
54	Brazil	20.7	0.207	0.207	0.793	0.793	0	0.207	0.793	0	0.207	0.793
55	Iran	20.9	0.209	0.209	0.791	0.791	0	0.209	0.791	0	0.209	0.791
56	South Korea	20.9	0.209	0.209	0.791	0.791	0	0.209	0.791	0	0.209	0.791
57	Egypt	21.4	0.214	0.214	0.786	0.786	0	0.214	0.786	0	0.214	0.786

58	Canada	21.7	0.217	0.217	0.783	0.783	0	0.217	0.783	0	0.217	0.783
59	Portugal	22.2	0.222	0.222	0.778	0.778	0	0.222	0.778	0	0.222	0.778
60	Viet Nam	22.7	0.227	0.227	0.773	0.773	0	0.227	0.773	0	0.227	0.773
61	Italy	23.4	0.234	0.234	0.766	0.766	0	0.234	0.766	0	0.234	0.766
62	Jordan	23.8	0.238	0.238	0.762	0.762	0	0.238	0.762	0	0.238	0.762
63	Syria	23.9	0.239	0.239	0.761	0.761	0	0.239	0.761	0	0.239	0.761
64	United States	24.8	0.248	0.248	0.752	0.752	0	0.248	0.752	0	0.248	0.752
65	Spain	24.9	0.249	0.249	0.751	0.751	0	0.249	0.751	0	0.249	0.751
66	France	25.3	0.253	0.253	0.747	0.747	0.253	0.747	0.747	0	0.253	0.747
67	Tunisia	25.4	0.254	0.254	0.746	0.746	0.254	0.746	0.746	0	0.254	0.746
68	Mexico	25.6	0.256	0.256	0.744	0.744	0.256	0.744	0.744	0	0.256	0.744
69	Iceland	26.7	0.267	0.267	0.733	0.733	0.267	0.733	0.733	0	0.267	0.733
70	Libya	27.0	0.270	0.27	0.73	0.73	0.27	0.73	0.73	0	0.27	0.73
71	Malaysia	27.1	0.271	0.271	0.729	0.729	0.271	0.729	0.729	0	0.271	0.729
72	Colombia	27.3	0.273	0.273	0.727	0.727	0.273	0.727	0.727	0	0.273	0.727
73	Lebanon	27.4	0.274	0.274	0.726	0.726	0.274	0.726	0.726	0	0.274	0.726
74	Croatia	27.5	0.275	0.275	0.725	0.725	0.275	0.725	0.725	0	0.275	0.725
75	Saudi Arabia	27.6	0.276	0.276	0.724	0.724	0.276	0.724	0.724	0	0.276	0.724
76	Oman	27.8	0.278	0.278	0.722	0.722	0.278	0.722	0.722	0	0.278	0.722
77	Argentina	28.1	0.281	0.281	0.719	0.719	0.281	0.719	0.719	0	0.281	0.719
78	Sweden	28.5	0.285	0.285	0.715	0.715	0.285	0.715	0.715	0	0.285	0.715
79	Ukraine	28.9	0.289	0.289	0.711	0.711	0.289	0.711	0.711	0	0.289	0.711
80	Germany	29.5	0.295	0.295	0.705	0.705	0.295	0.705	0.705	0	0.295	0.705
81	Russia	29.6	0.296	0.296	0.704	0.704	0.296	0.704	0.704	0	0.296	0.704
82	Australia	29.7	0.297	0.297	0.703	0.703	0.297	0.703	0.703	0	0.297	0.703
83	United Kingdom	29.7	0.297	0.297	0.703	0.703	0.297	0.703	0.703	0	0.297	0.703
84	Qatar	30.0	0.300	0.3	0.7	0.7	0.3	0.7	0.7	0	0.3	0.7
85	Netherlands	30.1	0.301	0.301	0.699	0.699	0.301	0.699	0.699	0	0.301	0.699
86	New Zealand	30.3	0.303	0.303	0.697	0.697	0.303	0.697	0.697	0	0.303	0.697
87	United Arab Emirates	30.3	0.303	0.303	0.697	0.697	0.303	0.697	0.697	0	0.303	0.697
88	Singapore	30.4	0.304	0.304	0.696	0.696	0.304	0.696	0.696	0	0.304	0.696
89	Turkey	30.5	0.305	0.305	0.695	0.695	0.305	0.695	0.695	0	0.305	0.695
90	Norway	31.9	0.319	0.319	0.681	0.681	0.319	0.681	0.681	0	0.319	0.681
91	Switzerland	32.4	0.324	0.324	0.676	0.676	0.324	0.676	0.676	0	0.324	0.676
92	Poland	33.3	0.333	0.333	0.667	0.667	0.333	0.667	0.667	0	0.333	0.667
93	Belgium	33.5	0.335	0.335	0.665	0.665	0.335	0.665	0.665	0	0.335	0.665
94	Slovakia	33.8	0.338	0.338	0.662	0.662	0.338	0.662	0.662	0	0.338	0.662
95	Slovenia	34.4	0.344	0.344	0.656	0.656	0.344	0.656	0.656	0	0.344	0.656
96	Finland	36.0	0.360	0.36	0.64	0.64	0.36	0.64	0.64	0.36	0.64	0.64
97	Malta	36.0	0.360	0.36	0.64	0.64	0.36	0.64	0.64	0.36	0.64	0.64
98	Bahrain	38.0	0.380	0.38	0.62	0.62	0.38	0.62	0.62	0.38	0.62	0.62
99	Austria	39.0	0.390	0.39	0.61	0.61	0.39	0.61	0.61	0.39	0.61	0.61
100	Costa Rica	39.4	0.394	0.394	0.606	0.606	0.394	0.606	0.606	0.394	0.606	0.606
101	Lithuania	40.1	0.401	0.401	0.599	0.599	0.401	0.599	0.599	0.401	0.599	0.599
102	Antigua and Barbuda	40.2	0.402	0.402	0.598	0.598	0.402	0.598	0.598	0.402	0.598	0.598

103	Kuwait	41.9	0.419	0.419	0.581	0.581	0.419	0.581	0.581	0.419	0.581	0.581
104	Ireland	42.9	0.429	0.429	0.571	0.571	0.429	0.571	0.571	0.429	0.571	0.571
105	Japan	47.5	0.475	0.475	0.525	0.525	0.475	0.525	0.525	0.475	0.525	0.525

Table (1) shows that for different values of α, the fuzzy interior, closure, exterior and boundary are different. The table shows for the larger value of α, the interior value will be smaller. When α=0.15, the nonzero values for countries ID greater than 39. When α=0.25, the nonzero values for countries ID greater that 66. When α=0.35, the nonzero values for countries ID greater than 95. This shows that the relation between interior value and the closure value are proportional to each other, while the relation between exterior value and the interior value are inversely proportional.
Following are the graphs showing the values of the topological relationships which obtained in Table 2 for the different α values

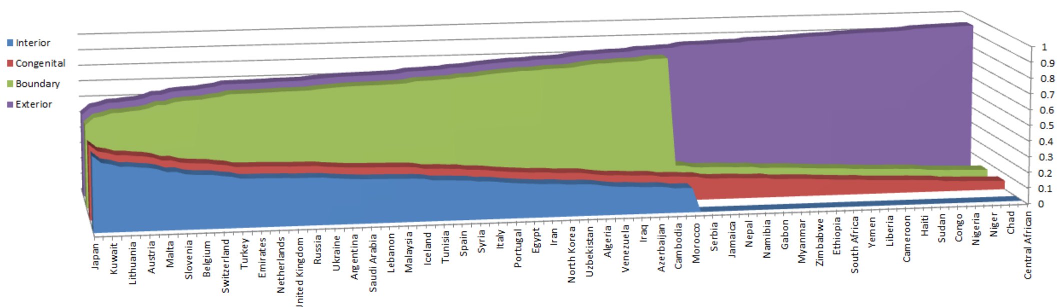

Fig. (1) The topological relations when α=0.15

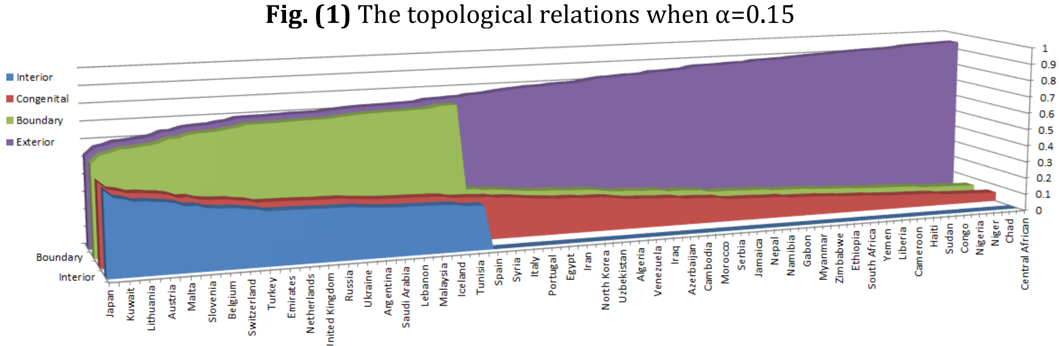

Fig. (2) The topological relations when α=0.25

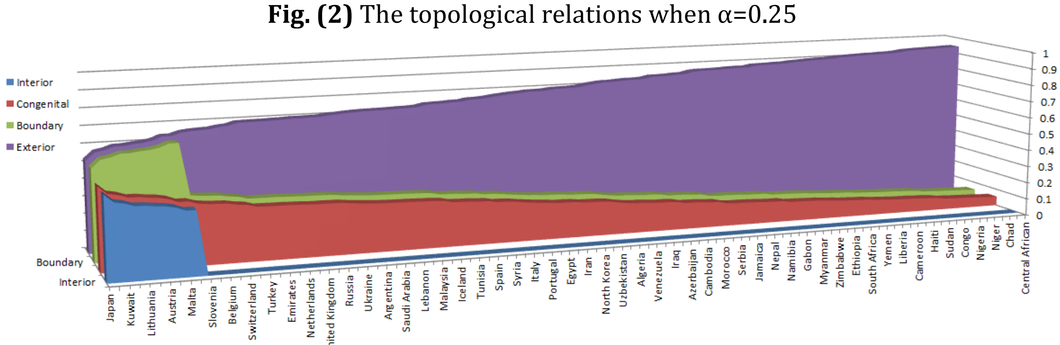

Fig. (3) The topological relations when α=0.35

6. Conclusion

The topological relationships were computed on the spatial objects of data from a geographic information system (GIS) for a particular geographical area to measure the extent of (for example) the impact of the flood on that region [5] or applied to land cover change [27]. In this research, data of a different type (death rate of congenital disease) were used for each country, then the topological relationships were found for those data. we were attempted to calculate the topological relationships between spatial data. We use the application of fuzzy topology to compute the interior, exterior, and boundary of fuzzy spatial data. A case study for classifying the fuzzy topology relations of the sample of countries affected by the congenital disease based on data from UNICEF database has been carried out. We have noted that countries with a high standard of living are the countries most affected by this disease, while those with a low economic level are the countries least affected by this disease. The same approach can be applied to other data or statistics for certain countries or regions.

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