International Journal of *Geo-Information*

MDPI

Article

Fuzzy GML Modeling Based on Vague Soft Sets

Bo Wei [1,2,*], Qingqing Xie [1,2], Yuanyuan Meng [1,2] and Yao Zou [1,2]

[1] Guangxi Key Laboratory of Spatial Information and Geomatics, Guilin University of Technology, 12, Jiangan Road, Guilin 541004, China; xieqq@glut.edu.cn (Q.X.); mengyy@glut.edu.cn (Y.M.); zyao@glut.edu.cn (Y.Z.)

[2] College of Geomatics and Geoinformation, Guilin University of Technology, 12, Jiangan Road, Guilin 541004, China

* Correspondence: superweibo@glut.edu.cn; Tel.: +86-773-589-5911

Academic Editors: Zhao-Liang Li, Jose A. Sobrino and Wolfgang Kainz

Received: 18 October 2016; Accepted: 5 January 2017; Published: 11 January 2017

Abstract: The Open Geospatial Consortium (OGC) Geography Markup Language (GML) explicitly represents geographical spatial knowledge in text mode. All kinds of fuzzy problems will inevitably be encountered in spatial knowledge expression. Especially for those expressions in text mode, this fuzziness will be broader. Describing and representing fuzziness in GML seems necessary. Three kinds of fuzziness in GML can be found: element fuzziness, chain fuzziness, and attribute fuzziness. Both element fuzziness and chain fuzziness belong to the reflection of the fuzziness between GML elements and, then, the representation of chain fuzziness can be replaced by the representation of element fuzziness in GML. On the basis of vague soft set theory, two kinds of modeling, vague soft set GML Document Type Definition (DTD) modeling and vague soft set GML schema modeling, are proposed for fuzzy modeling in GML DTD and GML schema, respectively. Five elements or pairs, associated with vague soft sets, are introduced. Then, the DTDs and the schemas of the five elements are correspondingly designed and presented according to their different chains and different fuzzy data types. While the introduction of the five elements or pairs is the basis of vague soft set GML modeling, the corresponding DTD and schema modifications are key for implementation of modeling. The establishment of vague soft set GML enables GML to represent fuzziness and solves the problem of lack of fuzzy information expression in GML.

Keywords: Geography Markup Language (GML); Document Type Definition (DTD); schema; vague soft set; fuzzy modeling

1. Introduction

All kinds of fuzzy problems will inevitably be encountered because many natural phenomena have fuzzy characteristics in the expression of spatial knowledge [1]. Especially for expressions based on text, this fuzziness will be broader. The OpenGIS Geography Markup Language (GML) is a type of text encoding spatial information, based on Extensible Markup Language (XML) grammar, and is used for spatial data modeling, storage, and transmission. Due to its explicit expressions of geographic spatial knowledge, GML has become an important tool to deal with geographic spatial information, and is a standard for spatial data representation and exchange over the Web [2].

Olfat proposed a new synchronization approach, based on GML, to automatically update metadata elements [3]. GML shape grammar can be used for modeling, including semantically enriched 3D building models [4], modeling transit networks [5], GML-based 3D spatial data model for geoscience information in coalmines [6], and a new storage schema model for GML documents, including spatial and non-spatial information [7]. Hao introduced Scalable Vector Graphics (SVG)-based load-balancing spatial analysis, and then designed and implemented two case studies [8]. As information services and their corresponding management of mobile devices have increased significantly, a GML-based mobile device trace monitoring system [9] and GML map visualization on mobile devices were studied [10] through a case study to show how the general-purpose GML standard could be leveraged in order to describe the most comprehensive geographic datasets [11]. Hu [12] implemented a program that visualizes the poorly-readable verification conditions of GML files. As it is very costly to store and transfer GML documents, a new and effective approach for GML documents [13] and an approach for efficient compression transmission of the GML schema, called GML Data Stream Compression (GDSC) were proposed [14]. GML is a new language that is still in development, but it has become a more efficient medium for geospatial applications [15]. How to retrieve the information resources in the distributed heterogeneous GIS systems, and how to integrate these multi-source data by using GML to solve multi-source, multi-level, and multi-dimensional geospatial information were presented in References [16–18]. Wu [19] proposed an approach to transform an Industry Foundation Class (IFC) data model to a GML data model, including methodology and tool development. Lake [20] introduced an application of GML to the geological sciences through some simple geological case studies. Gao [21] presented the design and implementation of essential algorithms for parsing GML schema. Chen [22] defined GXQuery, based on XQuery, and presented its applicability through typical examples. These studies discussed GML from its modeling, parsing, storage, transmission, and visualization to its applications. However, it should be noted that all these are based on a crisp representation method for GML. For instance, using a set of crisp coordinates, (−1776.6145, 436.55563, 0.0, −1176.6145, 436.55563, 0.0, −1176.6145, 1036.55563, 0.0, −1776.6145, 1036.55563, 0.0, −1776.6145, 436.55563, 0.0), to represent a surface for a 3D column object [19]. In this case, either the surface or its vertexes is crisply represented. In fact, uncertainty, including fuzziness, often appears as imperfect knowledge in modeling of natural phenomena [1]. Sometimes, for example, in a strange city, it is hard to clearly express a position because of this imperfect knowledge. In this regard, or to derive better results, and for a better understanding of the real world [2], a fuzzy representation method for GML should be developed. Otherwise, some imperfect knowledge would be lost in GML.

In the mathematical tools, a typical representation of expressions of fuzziness is the fuzzy set theory introduced by Zadeh in 1965 [23]. Based on the fuzzy set theory, Mukherjee and Ghosh [2] presented a fuzzy GML fragment that is used in spatial web services. A Val element, <Val Poss = fuzzy value>, including a Poss attribute, was defined for representing the "degree of membership" of the fuzzy set theory. In the given GML fragment, the nearness, represented by the Val element, of the supposed paddy fields with fuzzy boundary is represented in fuzzy GML developed based on fuzzy GML schema. This fuzzy boundary means that the boundary has a smooth transition rather than is crisp. However, the literature mainly put emphasis on discussing how to develop a fuzzy logic framework for integration and sharing of heterogeneous geospatial information among distributed data sources [2]. The details of how to develop the Val element are not discussed, and a fuzzy GML modeling for DTD is not presented. In addition, for the fuzzy set theory, one limitation is that a fuzzy set only takes a value between zero and one to represent the "degree of membership". In this regard and to extend the fuzzy set theory, Gau and Buehrer [24] proposed the theory of vague sets in 1993, in which a vague set is defined by a truth-membership function and a false-membership function, or takes two values between zero and one to represent a "degree of truth-membership" and a "degree of false-membership", respectively. Both theories, fuzzy set theory or vague set theory, have their own difficulties. One of the major difficulties may be due to the inadequacy of the parameterization tools for these theories [25]. To overcome this difficulty, Xu et al. [26] introduced the notion of vague soft sets, based on soft set theory [27] and vague set theory. A vague soft set, not only represents fuzzy information more exquisitely when compared to a fuzzy set, but can also represent the fuzziness of the associated parameters of a vague set.

The main objective of this paper is to develop a fuzzy GML model to represent fuzziness in GML based on the vague soft set theory, which includes a vague soft set GML Document Type Definition (DTD) model and a vague soft set GML schema model. The rest of this paper is organized as follows.

Section 2 presents the concept of vague soft sets, followed by the concept of vague set theory and soft set theory, and focuses on fuzziness analysis that may exist in GML. In Section 3, vague soft set GML modeling is discussed in detail. Section 4 presents some discussion. Some concluding comments are provided in Section 5.

2. Methodology

2.1. Vague Soft Sets

The concept of vague set theory was originally proposed by Gau and Buehrer [24] in order to extend the fuzzy set theory introduced by Zadeh [23]. A vague set, A, in universe $U = \{x_1, x_2, \ldots, x_n\}$ can be expressed by the following notion: $A = \{(x_i, [t_A(x_i), 1 - f_A(x_i)])|x_i \in U\}$, i.e., $A(x_i) = [t_A(x_i), 1 - f_A(x_i)]$ and the condition $0 \leq t_A(x_i) \leq 1 - f_A(x_i)$ should hold for any $x_i \in U$, where $t_A(x_i)$ is the membership degree (truth-membership) of element x_i to vague set A, while $f_A(x_i)$ is the degree of non-membership (false-membership) of element x_i to set A [24].

When universe U is continuous, vague set A can be written as:

$$A = \int_U [t_A(x), 1 - f_A(x)]/x; x \in U. \tag{1}$$

When universe U is discrete, vague set A can be written as:

$$A = \sum_{i=1}^{n} [t_A(x_i), 1 - f_A(x_i)]/x_i; x_i \in U. \tag{2}$$

Molodtsov [27] introduced soft set theory in 1999. A soft set is a parameterized family of subsets of the universal set. Let U be an initial universe set, and $P(U)$ the power set of U, E a set of parameters and $A \subseteq E$. A pair (F, A) is called a soft set over U, where F is mapping given by $F : A \rightarrow P(U)$ [27].

By combining vague set theory with soft set theory, the notion of vague soft sets was introduced by Xu et al. [26]. A vague soft set over U is a parameterized family of the vague set of universe U. Let U be an initial universe set, $V(U)$ is the set of all vague sets in U, and E a set of parameters and $A \subseteq E$. A pair (F, A) is called a vague soft set in U, where F is mapping given by $F : A \rightarrow V(U)$ [26]. An example of a vague soft set regarding landmarks follows:

Example 1. *Consider a vague soft set (F, E), where U is a set of three landmarks, which is denoted by $U = \{u_1, u_2, u_3\}$, and E is a parameter set, where $E = \{e_1, e_2\}$ = {visibility, cultural importance}. The vague soft set (F, E) describes the significance of the landmarks.*

Let:

$$\begin{aligned} F(e_1) &= \left(\frac{[t_{F(e_1)}(u_1), 1-f_{F(e_1)}(u_1)]}{u_1}, \frac{[t_{F(e_1)}(u_2), 1-f_{F(e_1)}(u_2)]}{u_2}, \frac{[t_{F(e_1)}(u_3), 1-f_{F(e_1)}(u_3)]}{u_3} \right), \\ F(e_2) &= \left(\frac{[t_{F(e_2)}(u_1), 1-f_{F(e_2)}(u_1)]}{u_1}, \frac{[t_{F(e_2)}(u_2), 1-f_{F(e_2)}(u_2)]}{u_2}, \frac{[t_{F(e_2)}(u_3), 1-f_{F(e_2)}(u_3)]}{u_3} \right), \end{aligned} \tag{3}$$

then the parameterized family $\{F(e_i) \mid i = 1, 2\}$ of the vague sets in U is a vague soft set (F, E).

2.2. The Fuzziness in GML

GML consists of elements and attributes, in which the elements are used to describe data and the attributes are used to describe the element that they belong to. A typical GML fragment is shown as follows:

Example 2. *A GML fragment of a landmark.*

```
<gml:Featuretype Name="landmark">
<gml:description>city landmarks</gml:description>
<gml:name>Graben_29A</gml:name>
<gml:geometricPropertytype Name="point">
<gml:Point>
<gml:coord>
<gml:X>100</gml:X>
<gml:Y>50</gml:Y>
</gml:coord>
</gml:Point>
</gml:geometricProperty>
</gml:Feature>
```

This fragment describes some spatial information of a landmark. The gml:Feature element and the gml:geometricProperty element have the same attribute name, typeName, but they are different because they belong to different elements. While the elements gml:description, gml:name, gml:X, and gml:Y directly contain their data, the elements gml:Feature, gml:geometricProperty, gml:Point, and gml:coord contain their own child elements. For example, the elementsgml:X and gml:Y are two child elements of the gml:coord element, and the gml:coord element is also a child element of the gml:Point element. The relationships between these elements reflect a kind of chain of GML elements.

2.2.1. Representation of Fuzziness Using Vague Soft Sets

Spatial information is often fuzzy, and so the data used to describe the spatial information represented in GML are often fuzzy as well. In Example 2, pair <gml:name> and </gml:name> describe a crisp name of a landmark and is Graben_29A. However, a toponym is often fuzzy because it may be affected by language, culture, environment, and so on. This fuzziness represents a degree of identity for the toponym and may manifest as the "degree of membership" if using fuzzy set theory. For instance, assume that landmark Graben_29A may have three names, Graben_1, Graben_2, and Graben_3, corresponding to 80%, 60%, and 50% identity, respectively. Then, the fuzziness, represented by fuzzy set theory may be 0.8, 0.6, and 0.5 in sequence. Similarly, this fuzziness, represented by vague set theory may be [0.8, 0.9], [0.6, 0.8], and [0.5, 0.7], which means that the votes for the names Graben_1, Graben_2, and Graben_3 are "8 in favor, 1 against, and 1 abstention", "6 in favor, 2 against, and 2 abstentions", and "5 in favor, 3 against, and 2 abstentions", respectively. Furthermore, the names Graben_1, Graben_2, and Graben_3 can be used to construct a parameter set, E, where $E = \{e_1, e_2, e_3\}$ = {Graben_1, Graben_2, Graben_3}. If considering toponym investigation in different ways, such as online surveys and field questionnaire surveys, a universe, U, can also be constructed, where U is like $U = \{u_1, u_2\}$ = {online survey, field questionnaire survey}. The vague set, parameter set, and the universe above consist exactly of a vague soft set and so the fuzziness can be represented by vague soft sets.

2.2.2. The Fuzziness in GML

Three kinds of fuzziness from the composition of GML and the relationship between GML elements can be found in GML, which are element fuzziness, chain fuzziness, and attribute fuzziness. Element fuzziness is the fuzziness in elements, which refers to the degree in which a child element belongs to a parent element. In fuzzy set theory, this degree refers to the "degree of membership". For instance, in Example 2, the pair of coordinates, 100 and 50, contained by the gml:coord element is crisp. However, if the spatial position is fuzzy, the fuzzy degree of the coordinates needs to be expressed, which is the degree to which the child element gml:coord belongs to its parent element gml:Point. In fact, element fuzziness is only a type of fuzzy relationship between two levels of elements, which are parent and child.

The second fuzziness, chain fuzziness, is an extension of element fuzziness, which represents the fuzziness among at least three elements. For instance, in Example 2, consider a chain gml:geometricProperty → gml:Point → gml:coord from the root element gml:geometricProperty. Assume that the degree of the child element gml:coord, belonging to its parent element gml:Point, is a vague value $[t_{coord}, 1 - f_{coord}]$, and the degree of the child element gml:Point, belonging to its parent element gml:geometricProperty, is a vague value $[t_{Point}, 1 - f_{Point}]$. Then, the degree of the gml:coordelement, belonging to the gml:geometricProperty element, a vague value $[t_{coord\text{-}geom}, 1 - f_{coord\text{-}geom}]$, can be represented as follows [24]:

$$t_{coord\text{-}geom} = \vee(t_{coord} \wedge t_{point}), 1 - f_{coord\text{-}geom} = \vee((1 - f_{coord}) \wedge (1 - f_{point})). \quad (4)$$

For more complicated situations, such as chain gml:A → gml:B → gml:D and chain gml:A → gml:C → gml:D, there are two chains between the gml:A element and the gml:D element. In this case, the degree of the gml:D element, belonging to the gml:A element, a vague value $[t_{A\text{-}D}, 1–f_{A\text{-}D}]$, has two values and a max operation can be used to acquire a final result:

$$t_{A\text{-}D} = \max(t_{c1}, t_{c2}), 1 - f_{A\text{-}D} = \max((1 - f_{c1}), (1 - f_{c2})) \quad (5)$$

where C1 and $C2$ represent the values of t and f obtained from chain gml:A → gml:B → gml:D and chain gml:A → gml:C → gml:D, respectively.

The last fuzziness, attribute fuzziness, refers to the fuzziness of a value belonging to an attribute. Traditionally, GML, as with XML, restricts attributes in order to have a unique single value [2,28]. An attribute value may not only be fuzzy, but also may have two types of possibility distributions, i.e., disjunctive and conjunctive possibility distributions [2,28]. A disjunctive possibility distribution refers to the case where some data items are known to have a single unique value, but where such a value is, thus far, unknown. For instance, in Example 2, if the coordinate X (gml:X) is unknown, a disjunctive possibility distribution may be represented as {[0.8, 0.9]/98, [0.9, 0.9]/99, [0.9, 1.0]/100, [0.8, 1.0]/101}. In contrast, a conjunctive possibility distribution refers to the case where an attribute simultaneously has several available values, but such values do not have complete knowledge regarding the attribute. For instance, in Example 2, if landmark Graben_29A simultaneously has three names Graben_1, Graben_2, and Graben_3, a conjunctive possibility distribution may be described as Graben_1 with possibility [0.8, 0.9], Graben_2 with possibility [0.6, 0.8], and Graben_3 with possibility [0.5, 0.7].

Obviously, element fuzziness is a special case of chain fuzziness, and the representation of chain fuzziness in GML is the same as that of element fuzziness as element fuzziness is the degradation of chain fuzziness when a chain only has two levels of elements. Furthermore, the computation of chain fuzziness does not need to be represented in GML. Thus, for the three types of fuzziness, only element fuzziness and attribute fuzziness need to be considered in order to express it in GML. Using these two kinds of fuzziness, the next section presents vague soft set GML DTD modeling and vague soft set GML schema modeling, based on vague soft sets.

Due to using vague soft sets to represent fuzziness, the following five elements, or five pairs, associated with vague soft sets have been introduced.

1. Pair <VagueSoftSets> and </VagueSoftSets>, which is the start and end of a vague soft set.
2. Pair <Field> and </Field>, which is the start and end of a universe.
3. Pair <SoftSet> and </SoftSet>, which is the start and end of a soft set.
4. Pair <VagueSet> and </VagueSet>, which is the start and end of a vague set.
5. Pair <Distribution> and </Distribution>, which is the start and end of a possibility distribution.

In these five elements, the VagueSoftSets element is a root node and the Field element is a child node of the VagueSoftSets element. When there is no possibility distribution, the SoftSet element is a child node of the Field element. Otherwise, the Distribution element is a child node of the Field element. In general, the VagueSet element is a child node of the SoftSet element.

3. Results

3.1. Vague Soft Set GML DTD Modeling

GML DTD is used to define GML in GML 1.0. To express fuzziness in GML 1.0, some custom elements need to be introduced, and the DTDs of these custom elements should be, correspondingly, modified, in order to accommodate these custom elements. A GML fragment that introduces the five elements mentioned above is shown as follows:

Example 3. *A GML fragment with fuzzy data.*

```
<landmarkModel>
<city>Guilin</city>
<landmarkMembers>
<VagueSoftSets>
<Field FName="f1">
<SoftSet SName="e1">
<VagueSet TrueMembership="0.8" FalseMembership="0.1">
<landmarkMember>
<landmarkName>Elephant Trunk Hill</landmarkName>
<district>Binjiang Road</district>
<description>The Symbol of Guilin</description>
<locationVSS>
<PointVSS>
<VagueSoftSets>
<Field FName="f1">
<Distribution Type="disjunctive">
<SoftSet SName="e1">
<VagueSet TrueMembership="0.9" FalseMembership="0.0">
<coordinates>100,200</coordinates>
</VagueSet>
</SoftSet>
<SoftSet SName="e2">
<VagueSet TrueMembership="0.9" FalseMembership="0.1">
<coordinates>101,200</coordinates>
</VagueSet>
</SoftSet>
<SoftSet SName="e3">
<VagueSet TrueMembership="0.8" FalseMembership="0.1">
<coordinates>100,201</coordinates>
</VagueSet>
</SoftSet>
</Distribution>
</Field>
</VagueSoftSets>
</PointVSS>
</locationVSS>
<salience>
<VagueSoftSets>
<Field FName="f1">
<Distribution Type="conjunctive">
<SoftSet SName="e1">
```

```
42. <VagueSet TrueMembership="0.6" FalseMembership="0.3">facade size</VagueSet>
43. </SoftSet>
44. <SoftSet SName="e2">
45. <VagueSet TrueMembership="0.8" FalseMembership="0.1">shape factor</VagueSet>
46. </SoftSet>
47. <SoftSet SName="e3">
48. <VagueSet TrueMembership="0.7" FalseMembership="0.2">shape deviation</VagueSet>
49. </SoftSet>
50. <SoftSet SName="e4">
51. <VagueSet TrueMembership="0.9" FalseMembership="0.0">color (RGB)</VagueSet>
52. </SoftSet>
53. <SoftSet SName="e5">
54. <VagueSet TrueMembership="0.6" FalseMembership="0.2">color (HSB)</VagueSet>
55. </SoftSet>
56. <SoftSet SName="e6">
57. <VagueSet TrueMembership="0.7" FalseMembership="0.1">visibility</VagueSet>
58. </SoftSet>
59. <SoftSet SName="e7">
60. <VagueSet TrueMembership="0.8" FalseMembership="0.1">cultural importance</VagueSet>
61. </SoftSet>
62. <SoftSet SName="e8">
63. <VagueSet TrueMembership="0.9" FalseMembership="0.0">identifiability</VagueSet>
64. </SoftSet>
65. </Distribution>
66. </Field>
67. </VagueSoftSets>
68. </salience>
69. </landmarkMember>
70. </VagueSet>
71. </SoftSet>
72. </Field>
73. </VagueSoftSets>
74. </landmarkMembers>
75. </landmarkModel>
```

Example 3 describes the situation of landmarks in a city. Pair <landmarkMembers> and </landmarkMembers> is used to describe all landmarks, and pair <landmarkMember> and </landmarkMember> focuses on the situation of a landmark. In lines 4–7, the fuzzy data represented by a vague soft set are introduced between the landmarkMembers element and the landmarkMember element in order to express the degree of identity of the Elephant Trunk Hilllandmark, where TrueMembership and FalseMembership are two attributes belonging to the VagueSet element. These two attributes represent the truth-membership and false-membership of a vague set, respectively. The TrueMembership attribute is equal to 0.8 and the FalseMembership attribute is equal to 0.1, which means that the vote for the Elephant Trunk Hilllandmark, as one of the landmarks of GUILIN city, is "8 in favor, 1 against, and 1 abstention". The SoftSet element has a SName attribute to represent the parameter name of a parameter set. Similarly, the Field element has an FName attribute to represent the universe name of a universe. Again, in lines 16–32 and lines 40–65, pair <Distribution> and </Distribution> is used to illustrate the types of possible distributions of fuzzy data. The Distribution element has a Type attribute to represent a conjunction or disjunction operation, as the attribute value of Type is equal to "conjunctive" or "disjunctive". In lines 16–32, using a vague soft set, a disjunctive possibility distribution is used to illustrate that the coordinates of the landmark are, thus far, fuzzy. Vague values [0.9, 1.0], [0.9, 0.9], and [0.8, 0.9] represent the possibility of coordinates (100, 200), (101, 200), and (100, 201) for the landmark, respectively. In lines 40–65, the fuzzy data within pair <Salience> and </Salience>, represented by a vague soft set, express the significance features of a landmark, such as facade size, shape factor, shape deviation, RGB color, Hue Saturate Bright (HSB) color, visibility, cultural importance, identifiability, and so on [29]. Because the effect of each significance feature on landmark significance is different, pair <VagueSet> and </VagueSet> is used to illustrate these influences. Therefore, in this case, landmark significance requires all eight types of significance features for a comprehensive evaluation, and, thus, a conjunction operation of the possibility distribution fuzzy data will be executed.

In order to accommodate the five elements mentioned above, it is clear that the DTDs of the five elements should be modified accordingly. The next part will focus on DTD modification for vague soft set GML DTD modeling.

As shown in Example 3, the five elements VagueSoftSets, Field, SoftSet, VagueSet, and Distribution can, not only be a parent or child element of other GML elements, but can also contain text data and have parent–child relationships existing within them. If "VE" is used to represent the five elements, and "GE" is used to represent a given element existing in GML or in a GML document, then the DTD of "VE" is shown as follows:

```
<!ELEMENT VE (#PCDATA|GE|VE)*>
<!ATTLIST VE VAN VAT VVT>
```

where VAN is the name of an attribute denoted by VAN = {FName, type, SName, TrueMembership, FalseMembership} and VAT is the type of attribute denoted by VAT = {CDATA, ID, IDREF, IDREFS, ENUM} and VVT is the type of attribute value denoted by VVT = {#REQUIRED, #IMPLIED, #FIXED, conjunctive, disjunctive}.

When the chain of "VE" is VagueSoftSets → Field → SoftSet → VagueSet, the DTDs of each element in this chain are as follows:

```
<!ELEMENT VagueSoftSets (Field+)>
<!ELEMENT Field (SoftSet+)>
<!ATTLIST Field FName CDATA #REQUIRED>
<!ELEMENT SoftSet (VagueSet+)>
<!ATTLIST SoftSet SName CDATA #REQUIRED>
<!ELEMENT VagueSet (#PCDATA|GE)*>
<!ATTLIST VagueSet TrueMembership CDATA "1.0" FalseMembership CDATA "0.0">
```

When the chain of "VE" is VagueSoftSets → Field → Distribution → SoftSet → VagueSet, the DTDs of each element in this chain are follows:

```
<!ELEMENT VagueSoftSets (Field+)>
<!ELEMENT Field (Distribution*)>
<!ATTLIST Field FName CDATA #REQUIRED>
<!ELEMENT Distribution (SoftSet+)>
<!ATTLIST Distribution Type (disjunctive|conjunctive) "disjunctive">
<!ELEMENT SoftSet (VagueSet+)>
<!ATTLIST SoftSet SName CDATA #REQUIRED>
<!ELEMENT VagueSet (#PCDATA|GE)*>
<!ATTLIST VagueSet TrueMembership CDATA "1.0" FalseMembership CDATA "0.0">
```

Then, the last DTDs of "VE" are obtained by combining these two types of DTD (shown above) as follows:

```
<!ELEMENT VagueSoftSets (Field+)>
```

```
<!ELEMENT Field (SoftSet+|Distribution*)>
<!ATTLIST Field FName CDATA #REQUIRED>
<!ELEMENT Distribution (SoftSet+)>
<!ATTLIST Distribution Type (disjunctive|conjunctive) "disjunctive">
<!ELEMENT SoftSet (VagueSet+)>
<!ATTLIST SoftSet SName CDATA #REQUIRED>
<!ELEMENT VagueSet (#PCDATA|GE)*>
<!ATTLIST VagueSet TrueMembership CDATA "1.0" FalseMembership CDATA "0.0">
```

Now, the entire DTD of the GML fragment (Example 3) is shown as follows:

```
<!ELEMENT landmarkModel (city,landmarkMembers)>
<!ELEMENT city (#PCDATA)>
<!ELEMENT landmarkMembers (VagueSoftSets)>
<!ELEMENT VagueSoftSets (Field+)>
<!ELEMENT Field (SoftSet+|Distribution*)>
<!ATTLIST Field FName CDATA #REQUIRED>
<!ELEMENT SoftSet (VagueSet+)>
<!ATTLIST SoftSet SName CDATA #REQUIRED>
<!ELEMENT VagueSet (#PCDATA|landmarkMember|coordinates)*>
<!ATTLIST VagueSet TrueMembership CDATA "1.0" FalseMembership CDATA "0.0">
<!ELEMENT landmarkMember (landmarkName?, district?, description?, locationVSS?, salience?)>
<!ELEMENT landmarkName (#PCDATA)>
<!ELEMENT district (#PCDATA)>
<!ELEMENT Distribution (SoftSet+)>
<!ATTLIST Distribution Type (disjunctive|conjunctive) "disjunctive">
<!ELEMENT salience (VagueSoftSets)>
<!ELEMENT locationVSS (PointVSS)>
<!ELEMENT PointVSS (coordinates|VagueSoftSets*)>
```

where the elements "description" and "coordinates" in Example 2 have been defined in the files gmlfeature.dtd and gmlgeometry.dtd, provided by GML 1.0. Because the file gmlfeature.dtd is included in gmlgeometry.dtd, a simple introduction of gmlfeature.dtd can be as follows:

```
<!ENTITY % GMLFEATUREDTD SYSTEM "gmlfeature.dtd">
%GMLFEATUREDTD;
```

In addition, the elements locationVSS and PointVSS are two custom elements and are not the elements "location" and "Point" provided by GML 1.0. The reason for this is that the DTD of the "Point" element only has a child element "coordinates" and, thus, it needs to be extended in order to contain the VagueSoftSets element so as to represent the fuzzy data in it. Because the element name "Point" cannot be redefined, a new element name, PointCSS, is used and defined. Similarly, the "location" element is redefined as the locationVSS element.

3.2. Vague Soft Set GML Schema Modeling

As of GML 2.0 and later, DTD was replaced by schema. Vague soft set GML schema modeling is based on the file feature.xsd, provided by GML 2.0 or later. As it is in the same namespace, the file feature.xsd can be included as follows:

```
<include schemaLocation="feature.xsd"/>
```

In vague soft set GML schema modeling, the five elements VagueSoftSets, Field, SoftSet, VagueSet, and Distribution above are still used. When the chain of "VE" is VagueSoftSets → Field → SoftSet → VagueSet, the following schemas of each element in this chain can be obtained.

First, the schema of the VagueSoftSets element, using a complex type VagueSoftSetsType, is defined as follows:

```
<complexType name="VagueSoftSetsType">
<complexContent>
<extension base="gml:AbstractFeatureType">
<sequence maxOccurs="unbounded">
<element name="Field" type="ex:FieldType"/>
</sequence>
</extension>
</complexContent>
</complexType>
```

Then, the schema of the Field element, using a complex type FieldType with an FName attribute, is defined as follows:

```
<complexType name="FieldType">
<complexContent>
<extension base="gml:AbstractFeatureType">
<choice maxOccurs="unbounded">
<element name="SoftSet" type="ex:SoftSetType"/>
</choice>
<attribute name="FName" type="string" use="required"/>
</extension>
</complexContent>
</complexType>
```

Now, the schema of the SoftSet element, using a complex type SoftSetType with a SName attribute, is defined as follows:

```
<complexType name="SoftSetType">
<complexContent>
<extension base="gml:AbstractFeatureType">
<choice maxOccurs="unbounded">
<element name="VagueSet" type="ex:VagueSetType"/>
</choice>
<attribute name="SName" type="string" use="required"/>
</extension>
</complexContent>
</complexType>
```

The last schema of the VagueSet element, using a complex type VagueSetType with two attributes, TrueMembership and FalseMembership, is defined as follows:

```
<complexType name="VagueSetType" mixed="true">
<complexContent>
<extension base="ex:exAbstractFeatureType">
<choice minOccurs="0" maxOccurs="1">
<element name="GE" type="ex:GEType"/>
</choice>
```

```
<attribute name="TrueMembership" type="ex:TrueMembershipType" default="1.0"/>
<attribute name="FalseMembership" type="ex:FalseMembershipType" default="0.0"/>
</extension>
</complexContent>
</complexType>
<simpleType name="TrueMembershipType">
<restriction base="decimal">
<minInclusive value="0"/>
<maxInclusive value="1"/>
</restriction>
</simpleType>
<simpleType name="FalseMembershipType">
<restriction base="ex:TrueMembershipType">
</restriction>
</simpleType>
```

When the chain of "VE" is VagueSoftSets → Field → Distribution → SoftSet → VagueSet, the schema of the Distribution element, using a complex type DistributionType with a Type attribute, needs to be added as follows:

```
<complexType name="DistributionType">
<complexContent>
<extension base="gml:AbstractFeatureType">
<sequence maxOccurs="unbounded">
<element name="SoftSet" type="ex:SoftSetType"/>
</sequence>
<attribute name="Type" type="ex:TypeType" default="disjunctive"/>
</extension>
</complexContent>
</complexType>
<simpleType name="TypeType">
<restriction base="string">
<pattern value="disjunctive|conjunctive"/>
</restriction>
</simpleType>
```

Simultaneously, the schema of the Field element, using a complex type FieldType, needs to be modified accordingly, where the Distribution element has been added into this schema as a child element of the Field element, as follows:

```
<complexType name="FieldType">
<complexContent>
<extension base="gml:AbstractFeatureType">
<choice maxOccurs="unbounded">
<element name="SoftSet" type="ex:SoftSetType"/>
<element name="Distribution" type="ex:DistributionType"/>
</choice>
<attribute name="FName" type="string" use="required"/>
</extension>
</complexContent>
</complexType>
```

In the schema of the VagueSet element above, it is noted that the base class of the VagueSet element is the class ex:exAbstractFeatureType rather than the class gml:AbstractFeatureType provided by GML 2.0 or later. The reason for this is that the VagueSet element, not only needs to contain its child elements, but also needs to contain text; however, the class gml:AbstractFeatureType does not support these kinds of mixed-data models. Thus, the class gml:AbstractFeatureType is replaced by the following custom class ex:exAbstractFeatureType:

```
<complexType name="exAbstractFeatureType" abstract="true" mixed="true">
<sequence>
<element ref="gml:description" minOccurs="0"/>
<element ref="gml:name" minOccurs="0"/>
<element ref="gml:boundedBy" minOccurs="0"/>
</sequence>
<attribute name="fid" type="ID" use="optional"/>
</complexType>
```

The only difference between the class ex:exAbstractFeatureType and the class gml:AbstractFeatureType is that the value of the "mixed" attribute is equal to "true" instead of "false" in the class ex:exAbstractFeatureType, in which "false" is a default value in the class gml:AbstractFeatureType. This change makes the class ex:exAbstractFeatureType contain a mixed-data model such as Example 3.

Now, a general schema of "VE" can be defined as follows:

```
<element name="VE" type="ex:VEType"/>
<complexType name="VEType" mixed="TF">
<complexContent>
<extension base="baseType">
<Order Occurrence>
<element name="VE" type="ex:VEType"/>
<element name="GE" type="ex:GEType"/>
</Order>
<attribute name="VSAN" type="VSAT" VSVT/>
</extension>
</complexContent>
</complexType>
```

where VEType and GEType represent the types "VE" and "GE", respectively, and:

```
baseType={ex:exAbstractFeatureTyp, gml:AbstractFeatureType},
TF={true},if baseType={ex:exAbstractFeatureTyp},
TF={false},if baseType={gml:AbstractFeatureType},
Order={sequence, choice},
Occurrence={minOccurs, maxOccurs},
attribute name VSAN={FName, SName, type, TrueMembership, FalseMembership},
attribute type VSAT={string, ex:typeType, ex:TrueMembershipType, ex:FalseMembershipType},
attribute VSVT={use, default}.
```

In addition, as in the DTD above, the elements gml:location and gml:Point, provided by GML 2.0 or later, should be modified to the elements locationVSS and PointVSS. Their schemas are defined based on those provided by GML 2.0 or later, where the locationVSS element uses a complex type exPointPropertyType and the PointVSS element uses a complex type exPointType, as follows:

```
<complexType name="exPointPropertyType">
```

```
<complexContent>
<extension base="gml:GeometryAssociationType">
<choice>
<element ref="ex:PointVSS"/>
</choice>
</extension>
</complexContent>
</complexType>
<complexType name="exPointType">
<complexContent>
<extension base="gml:AbstractGeometryType">
<sequence>
<choice>
<element ref="gml:coord"/>
<element ref="gml:coordinates"/>
<element ref="ex:VagueSoftSets"/>
</choice>
</sequence>
</extension>
</complexContent>
</complexType>
```

4. Discussion

In vague soft set GML DTD modeling, <!ELEMENT VE (#PCDATA|GE|VE)*> is given as a general DTD example of mixed element for VE. In fact, in XML DTD specification, an element definition has several forms according to its different contents. The element contents can be ANY, EMPTY, #PCDATA, child element, mixed element, and so on. Consequently, there are other general forms for VE to define DTD, such as <!ELEMENT VE ANY>, <!ELEMENT VE EMPTY>, and <!ELEMENT VE (#PCDATA)>. In vague soft set GML schema modeling, although only the schemas, including a general schema, of VE are given, it is still very convenient to use them in GML on the basis of GML and XML schema specification. Take Example 3 above as an example. In Example 3, the VagueSoftSets element (line 4) is a child element of the landmarkMembers element (line 3). A schema of the <landmarkMembers> can be defined as follows:

```
<element name="landmarkMembers" type="ex:landmarkMembersType"/>
<complexType name="landmarkMembersType">
<complexContent>
<extension base="gml:AbstractFeatureType">
<sequence>
<element ref="ex:VagueSoftSets"/>
</sequence>
</extension>
</complexContent>
</complexType>
```

<element ref="ex:VagueSoftSets"/> indicates that it contains a vague soft set. However, according to GML and XML schema specification, there are also other forms, including general forms, for VE to define schemas. In this sense, both in DTD modeling and in schema modeling, the forms and the general forms for defining VE given above are only two types of basic forms, especially for Example 3, and can be as a reference to obtain other forms on the basis of different element contents in GML.

In modeling of natural phenomena, vagueness in boundary zones, ambiguities in linguistic terms, fuzziness in semantics of spatial objects, and a mix of these need to be considered [1]. Spatial object with uncertain boundaries, or fiat object [30,31], can be represented in vague soft set GML modeling. A GML fragment of a river with uncertain boundaries is as follows:

```
1. <River>
2. <gml:name>The Li River</gml:name>
3. <gml:description>a very beautiful river in Guilin</gml:description>
4. <uncertainBoundaries>
5. <VagueSoftSets>
6. <Field FName="f1">
7. <Distribution Type="disjunctive">
8. <SoftSet SName="Inner">
9. <VagueSet TrueMembership="0.8" FalseMembership="0.1">
10. <distance>100</distance >
11. </VagueSet>
12. </SoftSet>
13. <SoftSet SName="Median">
14. <VagueSet TrueMembership="0.5" FalseMembership="0.3">
15. <distance>200</distance >
16. </VagueSet>
17. </SoftSet>
18. <SoftSet SName="Outer">
19. <VagueSet TrueMembership="0.2" FalseMembership="0.6">
20. <distance>300</distance >
21. </VagueSet>
22. </SoftSet>
23. </Distribution>
24. </Field>
25. </VagueSoftSets>
26. </uncertainBoundaries>
27. </River>
```

This GML fragment represents three uncertain boundaries at distances 100, 200, and 300 m from the Li River, respectively. In this case, each uncertain boundary is a ring composed of an inner boundary and an outer boundary rather than a single boundary. Take the "Inner" ring, lines 8–12, as an example. The truth-membership value is 0.8 and the false-membership value is 0.1, which means that the membership value for inner boundary and outer boundary are 0.8 and 0.9, respectively, where $0.9 = 1 - 0.1$.

However, GML is only a markup language. It is limited in expressing complex semantic fuzziness and qualitative description. Perhaps, adverbs of degree are the most suitable for representing fuzziness in GML. Take three words, "fairly", "rather", "very", as an example. A GML fragment of these adverbs of degree is as follows:

```
<VagueSoftSets>
<Field FName="f1">
<Distribution Type="disjunctive">
<SoftSet SName="fairly">
<VagueSet TrueMembership="0.6" FalseMembership="0.3">
<distance>400</distance >
</VagueSet>
```

```
</SoftSet>
<SoftSet SName="rather">
<VagueSet TrueMembership="0.7" FalseMembership="0.2">
<distance>300</distance >
</VagueSet>
</SoftSet>
<SoftSet SName="very">
<VagueSet TrueMembership="0.9" FalseMembership="0.05">
<distance>100</distance >
</VagueSet>
</SoftSet>
</Distribution>
</Field>
</VagueSoftSets>
```

Suppose the distance between a paddy and a river is within 1000 m. Qualitative descriptions "Paddy P is fairly close to river R", "Paddy P is rather close to river R", and "Paddy P is very close to river R" are different in describing the distance from paddy P to river R. Vague values [0.6, 0.7], [0.7, 0.8], and [0.9, 0.95] represent a fuzziness degree for the distance. Obviously, for the distance fuzziness, [0.6, 0.7] is the first and [0.9, 0.95] is the last. Compared with the representation of "fairly close", "very close" is closer, and their corresponding distances might be 400 m and 100 m, respectively.

GML is used for spatial data modeling, storage, transmission, etc., [3–22]; however, GML itself is not use for spatial data processing. Compared with artificial intelligence methods that can derive qualitative representations of geographical data and processes by using linguistic descriptions [32], data represented in GML are "static", which means data are only data in GML, and cannot derive more data or information unless other processing methods are used. Like above example, "Paddy P", "river R", distance fuzziness, and the corresponding distances can be represented in GML, however, qualitative descriptions such as "Paddy P is fairly close to river R", "Paddy P is rather close to river R", and "Paddy P is very close to river R" would not be obtained. In fact, GML is use for data representing phase, and artificial intelligence methods is use for data processing phase. These two phases would be connective if the data represented in GML can be use for artificial intelligence methods. For example, a GML fragment representing a matrix of the landscape states among U, F, A, S, B, and O, where U, F, A, S, B, and O represent urban land use, forest land use, agricultural land use, shrublands and pastures, bare ground areas, and other land uses, respectively [32], is as follows:

```
<U><F> null </F><A> null </A><S> null </S><B> null </B><O> null </O></U>
<F><U> t15 </U><A> t9 </A><S> t7 </S><B> t10 </B><O> t13 </O></F>
<A><U> t1 </U><F> t5 </F><S> t2 </S><B> t3 </B><O> t4 </O></A>
<S><U> t12 </U><F> t16 </F><A> t6 </A><B> t11 </B><O> t14 </O></S>
<B><U> t18 </U><F> t19 </F><A> t8 </A><S> t17 </S><O> null </O></B>
<O><U> null </U><F> null </F><A> null </A><S> null </S><B> null </B></O>
```

Similarly, other data for landscape transformations, for instance, parameters of the landscape transformation model, can also be represented in GML, and then through GML parsing [21] and data transmission to artificial intelligence methods, the output, consisting of linguistic descriptions, along with quantitative descriptions, can be obtained [32].

Traditionally, geographic information system (GIS) and geographic education oriented the needs of professionals. This was difficult to use GIS for the public because of its professionalism. However, with the emergence of Wikimapia, OpenStreetMap, Google Earth, Google Map, or neogeography [33,34], this situation was improved in recent 10 years. It is important that the public gradually understands and becomes familiar with GIS, as GIS is becoming a popular development trend. An important feature of this change is the public's active participation. This feature emphasizes that the user is ordinary people rather than GIS and mapping professionals. The user not only is pure geographic information consumers in traditional GIS application, but also is likely to be the provider of the geographic information. In the face of such change, geographical education should vary in response to these developments [33], and a geospatially enabled Web 3.0 (the Semantic Web) would be to build in order to entail geospatial semantics (linguistic descriptions) [34]. As mentioned previously, although GML or fuzzy GML has limitation in representing geospatial semantics or linguistic descriptions, one important contribution of them is they have a high application potential in both mobile environments and GIS web services [15]. This contribute would make GML or fuzzy GML become an important tool to build the Geospatial Web [33,34] for geographical education.

5. Conclusions

Element fuzziness, chain fuzziness, and attribute fuzziness are the three types of fuzziness in GML, where element fuzziness is a special case of chain fuzziness. Vague soft set GML modeling only needs to consider element fuzziness and attribute fuzziness because the representation of chain fuzziness can be replaced by the representation of element fuzziness in GML. This paper introduced five elements, or five pairs, associated with vague soft sets that enable GML to represent fuzziness and implement vague soft set GML modeling, which solves the problem of lack of fuzzy information expression in GML. The following conclusions were reached:

(1) The introduction of the five elements associated with vague soft sets, VagueSoftSets, Field, SoftSet, VagueSet, and Distribution, is the basis of vague soft set GML modeling.
(2) In order to accommodate the five introduced elements, corresponding DTD and schema modifications are key for implementing vague soft set GML modeling. Different chains impact different definitions of DTD and schema for the introduced five elements.
(3) In general, the class gml:AbstractFeatureType, provided by GML 2.0 or later, is the base class for vague soft set GML schema modeling. However, a new custom base class needs to be defined by the user when the class gml:AbstractFeatureType does not meet the needs of practical modeling.

Acknowledgments: This research was jointly supported by the National Natural Science Foundation of China (41461085), the Natural Science Foundation of Guangxi Province (2016GXNSFAA380035 and 2014GXNSFDA118032), the Science and Technology Development Program of Guangxi Province (1598019-4), the "BaGui Scholars" Special Funds of Guangxi Province (2013-3), and the Doctoral Foundation of the Guilin University of Technology (GUT1996015).

Author Contributions: Bo Wei and Qingqing Xie conceived of and designed the modeling procedures; Yuanyuan Meng and Yao Zou performed the validation of the modeling and performed data analyses; and Bo Wei and Qingqing Xie wrote the paper. All authors drafted and revised the article collectively. All authors read and approved of the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jadidi, A.; Mostafavi, M.A.; Bédard, Y.; Shahriari, K. Spatial representation of coastal risk: A fuzzy approach to deal with uncertainty. *ISPRS Int. J. Geo-Inf.* **2014**, *3*, 1077–1100. [CrossRef]
2. Mukherjee, I.; Ghosh, S.K. Fuzzy spatial web services for integrating Geo-Spatial information from heterogeneous repositories. In Proceedings of the 2nd International Conference on Computer Technology and Development (ICCTD 2010), Cairo, Egypt, 2–4 November 2010; Volume 4, pp. 597–602.
3. Olfat, H.; Kalantari, M.; Rajabifard, A.; Senot, H.; Williamson, I.P. A GML-based approach to automate spatial metadata updating. *Int. J. Geogr. Inf. Sci.* **2013**, *27*, 231–250. [CrossRef]
4. Hohmann, B.; Havemann, S.; Krispel, U.; Fellner, D. A GML shape grammar for semantically enriched 3D building models. *Comput. Graph.* **2010**, *34*, 322–334. [CrossRef]
5. Huang, R. Modeling transit networks by GML for distributed transit trip planners. *J. Spat. Sci.* **2008**, *53*, 1–15. [CrossRef]

6. Wang, Z.G.; Gao, W.J.; Qu, H.G.; Wu, Z.X. GML-based 3D spatial data model for geoscience information in coal mines. In Proceedings of the 21st International Conference on Geoinformatics, Kaifeng, China, 20–22 June 2013; pp. 1–4.
7. Kim, Y.K.; Yoo, H.K.; Chang, J.W. New GML storage schema models for spatial and non-spatial information. In Proceedings of the 10th International Conference on Computer and Information Technology, Bradford, UK, 29 June–1 July 2010; pp. 620–626.
8. Hao, S.H.; Yan, L.; Gartner, G.; Wang, Y.P. An SVG-based method to support spatial analysis in XML/GML/SVG-based WebGIS. *Int. J. Geogr. Inf. Sci.* **2011**, *25*, 1561–1574.
9. Song, E.H.; Han, S.K.; Yang, L.T.; Guo, M.Y.; Jeong, Y.S. A GML-based mobile device traces monitoring system. *Embed. Ubiquitous Comput. Workshops* **2006**, *4097*, 234–243.
10. Song, E.H.; Jeong, Y.S. GML map visualization on mobile devices. *J. Inf. Process. Syst.* **2010**, *6*, 33–42. [CrossRef]
11. Guo, L.L. Pioneering GML deployment for NSDI—Case study of US TIGER/GML. *ISPRS Int. J. Geo-Inf.* **2013**, *2*, 82–93. [CrossRef]
12. Hu, H.L.; Kim, J.; Park, J.; Yoo, W. Visualization of verification condition by GML file. *J. Korea Soc. Comput. Inf.* **2012**, *17*, 23–32. [CrossRef]
13. Wei, Q.T.; Guan, J.H.; Zhou, S.G.; Wang, X. A new and effective approach to GML documents compression. *Comput. J.* **2014**, *57*, 1723–1740. [CrossRef]
14. Shen, Y.; Feng, J.; Zhu, H.T. An approach to efficient compression transmission schema of GML. In Proceedings of the 2010 IEEE Youth Conference on Information Computing and Telecommunications, Beijing, China, 28–30 November 2010; pp. 41–44.
15. Lu, C.T.; Dos Santos, R.F.; Sripada, L.N.; Kou, Y.F. Advances in GML for geospatial applications. *GeoInformatica* **2007**, *11*, 131–157. [CrossRef]
16. Huang, C.H.; Chuang, T.R.; Deng, D.P.; Lee, H.M. Building GML-native web-based geographic information systems. *Comput. Geosci.* **2009**, *35*, 1802–1816. [CrossRef]
17. Zhu, F.B.; Yang, J.M.; Guo, Q.Q. Emergency GIS system based on GML and multi-source spatial data. In Proceedings of the 2011 IEEE 3rd International Conference on Communication Software and Network, Xi'an, China, 27–29 May 2011; pp. 86–90.
18. Xi, Y.T.; Wu, J.G. Application of GML and SVG in the development of WebGIS. *J. China Univ. Min. Technol.* **2008**, *18*, 140–143. [CrossRef]
19. Wu, I.C.; Hsieh, S.H. Transformation from IFC data model to GML data model: Methodology and tool development. *J. Chin. Inst. Eng.* **2007**, *30*, 1085–1090. [CrossRef]
20. Lake, R. The application of geography markup language (GML) to the geological sciences. *Comput. Geosci.* **2005**, *31*, 1081–1094. [CrossRef]
21. Gao, X.L.; Cui, Z.C.; Jia, N.B.; Xiao, H.; Zhang, S.L. Design and implementation of essential algorithms for parsing GML schemas. In Proceedings of the Sixth International Conference on Intelligent Human-Machine Systems and Cybernetics, Hangzhou, China, 26–27 August 2014; Volume 2, pp. 284–287.
22. Chen, J.H.; He, B.B.; Wang, W.H. GXQuery: A GML spatial data query language. In Proceedings of the 2nd International Conference on Information Management and Engineering, Xian, China, 16–18 April 2010; pp. 271–275.
23. Zadeh, L.A. Fuzzy set. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
24. Gau, W.L.; Buehrer, D.J. Vague sets. *IEEE Trans. Syst. Man Cybern.* **1993**, *23*, 610–614. [CrossRef]
25. Wang, C.; Qu, A.J. Entropy, similarity measure and distance measure of vague soft sets and their relations. *Inf. Sci.* **2013**, *244*, 92–106. [CrossRef]
26. Xu, W.; Ma, J.; Wang, S.; Hao, G. Vague soft sets and their properties. *Comput. Math. Appl.* **2010**, *59*, 787–794. [CrossRef]
27. Molodtsov, D. Soft set theory—Firstresults. *Comput. Math. Appl.* **1999**, *37*, 19–31. [CrossRef]
28. Ma, Z.M.; Yan, L. Fuzzy XML data modeling with the UML and relational data models. *Data Knowl. Eng.* **2007**, *63*, 972–996. [CrossRef]
29. Nothegger, C.; Winter, S.; Raubal, M. Computation of the salience of features. *Spat. Cognit. Comput.* **2004**, *4*, 113–136.
30. Smith, B.; Varzi, A.C. Fiat and bona fide boundaries. *Philos. Phenomenol. Res.* **2000**, *60*, 401. [CrossRef]
31. Smith, B.; Mark, D.D.M. Do mountains exist? Towards an ontology of landforms. *Environ. Plan. BPlan. Des.* **2003**, *30*, 411–427. [CrossRef]

32. Papadimitriou, F. Artificial intelligence in modelling the complexity of Mediterranean landscape transformations. *Comput. Electron. Agric.* **2012**, *81*, 87–96. [CrossRef]
33. Papadimitriou, F. A "Neogeographical Education"? The Geospatial Web, GIS and digital art in adult education. *Int. Res. Geogr. Environ. Educ.* **2010**, *19*, 71–74. [CrossRef]
34. Papadimitriou, F. Introduction to the complex Geospatial Web in geographical education. *Int. Res. Geogr. Environ. Educ.* **2010**, *19*, 53–56. [CrossRef]