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A new land-cover classification approach in UAV-based Remote Sensing for solution ecological tasks

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SUMMARY

Nowadays application of UAVs gives a possibility to achieve data with a very high accuracy for solution of different ecological and agricultural problems. The classification of incomplete and high conflicting sources is one of the most important and difficult procedures in Remote Sensing. It has been proposed the new classification approach to applying Dezert-Smarandache Theory in UAV-based remote sensing problems. The classical Dezert-Smarandache fusion rule has been considered in this work. It has been noted, that this theory processes the contradictory information an deals with exhaustive and not mutually exclusive hypotheses. The numerical example has been considered in this work too. The proposed approach to applying the Dezert-Smarandache Theory in land-cover classification can be applied in numerous agricultural tasks, pest control in forestry, prevention of natural disasters, such as forest fires.

Introduction

Nowadays UAV-based Remote Sensing gives a new opportunities for conducting scientific research in a much more detail way at sufficiently low cost. Application of UAVs gives a possibility to achieve images with a very high resolution. UAVs can reveal many ecological and agricultural tasks, such as environment monitoring, forestry, plant health assessment, prevention and analysis of natural disasters (forest fires, floods, etc.) and assessment of property damage *(Alpert, 2022; Popov et al., 2017)*.

UAVs allow to see forests and agricultural fields from a height. Drone-based images help to solve numerous modern ecological tasks. Flying over large territories, UAVs show the differences between healthy and unhealthy plants. With computer technologies constantly improving, imaging of the forests and fields will need to improve as well. Classification is one of the most important procedures in Remote Sensing tasks. This procedure can be applied in forest classification, determing of soil types, pest control in forestry and agriculture. Classification of incomplete, vague and high conflicting information has always been and still remains the one of most difficult tasks of remote sensing. In this paper the new classification approach to applying Dezert-Smarandache Theory in UAV-based remote sensing problems is proposed. This theory can deal with imprecise and highly conflicting information. Dezert-Smarandache Theory deals with exhaustive and not mutually exclusive hypotheses, because exhaustive hypotheses can potentially overlap and can not properly identified. Dezert-Smarandache Theory deals with all hypotheses, all unions and intersections of these hypotheses. Proposed theory considers only exhaustive elements which can change with time with new information. Dezert-Smarandache Theory offers a flexibility on the structure of the model one has to deal with. When the free Dezert-Smarandache model holds, the conjunctive consensus is used. It is also described classical Dezert-Smarandache fusion rule in this paper. The illustrative example is given throughout this work to show the interest of this theory. The proposed approach to applying the Dezert-Smarandache Theory in land-cover classification can be applied in different agricultural, ecological and practical tasks *(Smets, 2007; Smarandache and Dezert, 2005)*.

Figure 1 *Most important ecological and agricultural tasks, that can apply proposed classification approach, based on Dezert-Smarandache Theory: pest control in forestry and agriculture, detection and prevention of forest fires*

Main concepts of Dezert-Smarandache Theory

Let $\Omega = \{e_1, ..., e_n\}$ be a finite set (frame) of n exhaustive elements.

Hyper-power set D^Ω is defined as:

1) $\varnothing,\ e_1, ..., e_n \in D^\Omega$;

2) if $X, Y \subset D^\Omega$, then $X \cap Y \subset D^\Omega$ and $X \cup Y \subset D^\Omega$;

3) no other elements belong to D^Ω, except those obtained by using items 1 or 2.

$\Omega = \{e_1, ..., e_n\}$ denotes the finite set of hypotheses characterizing the fusion problem. D^Ω constitutes the free Dezert-Smarandache model and allows to work with fuzzy concepts.
From a general frame Ω, we define a map $m: D^\Omega \to [0,1]$ associated to a given body of evidence as

$$\begin{cases} m(\varnothing) = 0, \\ \sum_{A_i \subset D^\Omega} m(A) = 1. \end{cases} \quad (1)$$

$m(A)$ is the generalized basic belief assignment (mass) of A.
Let's note, that belief and plausibility functions are defined as:

$$Bel(A) = \sum_{\substack{B \subset A \\ B \subset D^\Omega}} m(B); \quad (2)$$

$$Pl(A) = \sum_{\substack{B \cap A \neq \varnothing \\ B \subset D^\Omega}} m(B). \quad (3)$$

Dezert-Smarandache fusion rule

When the free Dezert-Smarandache model holds the conjunctive consensus, called Dezert-Smarandache classic rule, is performed on D^Ω. Let's note, that Dezert-Smarandache classic rule of two independent sources associated with two generalized basic belief assignments (masses) *(Smarandache and Dezert, 2006; Popov et al., 2021; Smarandache and Dezert, 2004).*
Dezert-Smarandache classic rule is defined as:

$$m_{DS}(X) = \sum_{\substack{X_1, X_2 \subset D^\Omega \\ X_1 \cap X_2 = X}} m_1(X_1) m_2(X_2), \quad (4)$$

where D^Ω consists of two elements X_1 and X_2.
For the general case Dezert-Smarandache classic rule is defined as:

$$m_{DS}(X) = \sum_{\substack{X_1, ..., X_m \subset D^\Omega \\ X_1 \cap ... \cap X_m = X}} \prod_{i=1}^{m} m_i(X_i), \quad (5)$$

where D^Ω consists of m elements $X_1, X_2, ..., X_m$.
The Dezert-Smarandache classic rule is commutative and associative and can be used for the combination of sources of data involving fuzzy concepts. This rule can be easily extended for the combination of $k>2$ independent sources of information.

Example

Consider an example, where we conduct procedure of classification, applying Dezert-Smarandache classic rule.
Suppose, that frame is $\Omega = \{A, B\}$,
where hypothesis "*A*" means that sample belongs to class "Deciduous forest";
hypothesis "*B*" means that sample belongs to class "Coniferous forest".
Suppose, we have two spectral bands (sources of information). The sensors provide two bodies of evidence m_1 and m_2, respectively:

$m_1(A) = 0,3;\ \ m_1(B) = 0,4;\ \ m_1(A \cap B) = 0,2;\ \ m_1(A \cup B) = 0,1;$

$m_2(A) = 0,1;\ \ m_2(B) = 0,4;\ \ m_2(A \cap B) = 0,2;\ \ m_2(A \cup B) = 0,3.$

Then we should combine these generalized basic belief assignments (masses), applying Dezert-Smarandache classic rule (4).
Let's note, that the free Dezert-Smarandache model for this example will be defined as:

1) The $m_2(A)$ alternately multiply by the following masses: $m_1(A)$, $m_1(B)$, $m_1(A \cap B)$, $m_1(A \cup B)$. Next, we find the sum of the obtained four products. In this way, we get combined mass for the hypothesis *A*.

2) In a similar way $m_2(B)$ alternately multiply by the following masses: $m_1(A)$, $m_1(B)$, $m_1(A \cap B)$, $m_1(A \cup B)$. Then we find the sum of the obtained four products. In this way, we get a combined mass for the hypothesis *B*.

3) Then generalized basic belief assignment $m_2(A \cap B)$ alternately multiply by the following masses: $m_1(A)$, $m_1(B)$, $m_1(A \cap B)$, $m_1(A \cup B)$. Next, we find the sum of the obtained four products and get a combined mass for the hypothesis $m(A \cap B)$.

4) In a similar way $m_2(A \cup B)$ alternately multiply by the following masses: $m_1(A)$, $m_1(B)$, $m_1(A \cap B)$, $m_1(A \cup B)$. Next, we find the sum of the obtained four products and get a combined mass for the hypothesis $m(A \cup B)$.

Then define combined generalized basic belief assignments (combined masses):

$$m(A) = m_1(A) \cdot m_2(A) + m_1(B) \cdot m_2(A) + m_1(A \cap B) \cdot m_2(A) + m_1(A \cup B) \cdot m_2(A) =$$
$$= 0,3 \cdot 0,1 + 0,4 \cdot 0,1 + 0,2 \cdot 0,1 + 0,1 \cdot 0,1 = 0,03 + 0,04 + 0,02 + 0,01 = 0,1;$$
$$m(B) = m_2(B) \cdot m_1(A) + m_2(B) \cdot m_1(B) + m_1(A \cap B) \cdot m_2(B) + m_1(A \cup B) \cdot m_2(B) =$$
$$= 0,4 \cdot 0,3 + 0,4 \cdot 0,4 + 0,2 \cdot 0,4 + 0,1 \cdot 0,4 = 0,12 + 0,16 + 0,08 + 0,04 = 0,4;$$
$$m(A \cap B) = m_2(A \cap B) \cdot m_1(A) + m_1(B) \cdot m_2(A \cap B) + m_2(A \cap B) \cdot m_1(A \cap B) + m_2(A \cap B) \cdot m_1(A \cup B) =$$
$$= 0,2 \cdot 0,3 + 0,2 \cdot 0,4 + 0,2 \cdot 0,2 + 0,2 \cdot 0,1 = 0,06 + 0,08 + 0,04 + 0,02 = 0,2;$$
$$m(A \cup B) = m_2(A \cup B) \cdot m_1(A) + m_2(A \cup B) \cdot m_1(B) + m_2(A \cup B) \cdot m_1(A \cap B) + m_2(A \cup B) \cdot m_1(A \cup B) =$$
$$= 0,3 \cdot 0,3 + 0,3 \cdot 0,4 + 0,3 \cdot 0,2 + 0,3 \cdot 0,1 = 0,09 + 0,12 + 0,06 + 0,03 = 0,3.$$

Let's note, that the sum of the obtained combined generalized basic belief assignments (combined masses) is equal to "1":

$$m(A) + m(B) + m(A \cap B) + m(A \cup B) = 0,1 + 0,4 + 0,2 + 0,3 = 1.$$

So, we can make a conclusion, that the sample most likely belongs to the class "Coniferous forest".

Conclusions

Application of UAVs gives a possibility to achieve information with a very high accuracy for solution of different ecological and agricultural tasks. It was also noted, that classification is one of the most important procedures in Remote Sensing tasks. But classification of incomplete, imprecise and potentially high conflicting sources is one of most important problems of remote sensing. *(Popov et al., 2020; Alpert, 2021).*
In this paper the new classification approach to applying Dezert-Smarandache Theory in UAV-based remote sensing problems was proposed. It was noted, that Dezert-Smarandache Theory can process contradictory data. This theory deals with exhaustive and not mutually exclusive hypotheses. Dezert-Smarandache Theory deals with all hypotheses, all unions and intersections of these hypotheses. The classical Dezert-Smarandache fusion rule was considered in this work. It also was described and analyzed a free Dezert-Smarandache model. The numerical example was considered in this work too. The proposed approach to applying the Dezert-Smarandache Theory in land-cover classification can be applied in environment monitoring, pest control in forestry, numerous agricultural tasks, prevention of natural disasters, such as forest fires, and assessment of property damage *(Alpert, 2021; Alpert and Onyshchenko, 2022).*

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