Cellular automata applied in remote sensing to implement contextual pseudo-fuzzy classification

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INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

Introduction

• Remote sensing is the most relevant science that allows us the acquisition of information about the surface of the land and environmental information values without having actual contact with the area being observed.

• The classification algorithms are one of the most important techniques used in remote sensing that help developers to interpret the information contained in the satellite images. The aim of satellite images classification is to divide image pixels into discrete classes (spectral classes). The resulting classified image is essentially a thematic map of the original image.

Introduction

• In spite of the great number of classifiers that exist, there are several researchers studying new classification methods because there is not a 100% eficient classifier. These algorithms have reached a great advance in the last years. The analysts use the classification algorithms to interpret the information contained in the satellite images.

• In this paper we propose a new procedure for the classification of satellite images. The new classification Algorithm based on Cellular Automata (ACA) uses this technique for the assignment of the satellite image pixels to the diferent spectral classes.

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

INDEX

- Introduction
- **Spectral and Contextual Classification of Satellite Images**
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

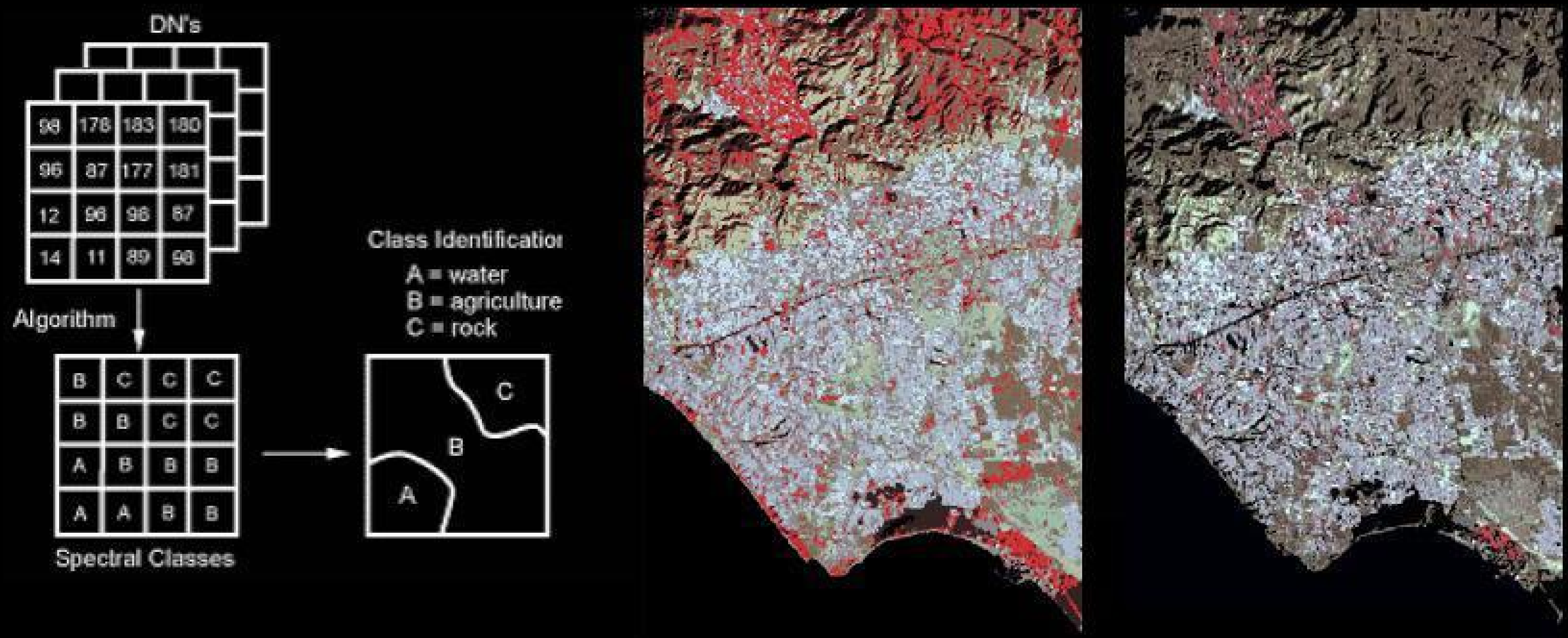
Spectral and Contextual Classification of Satellite Images

• Common classification procedures can be broken down into two divisions based on the method used: supervised and unsupervised classification, whose classification methods are based on the spectral properties of the satellite image pixels.

• In an unsupervised classification algorithm, the analyst only species the number of classes, and the algorithm groups the satellite image pixels based solely on the numerical information of the data. In these algorithms, the analyst has not to know the zone to study.

• In a supervised classification, the analyst selects samples of the diferent elements to identify the pixels in the image. In this method the analyst knowledge of the study area determines the quality of the training set.

Spectral and Contextual Classification of Satellite Images



(a) (b) (c)

Spectral and Contextual Classification of Satellite Images

- These spectral supervised and unsupervised classification algorithms works well in non-noisy images and if the spectral properties of the pixels determine the classes suficiently well.

- However, if noise or substantial variations in class pixel properties are present, the resulting image classification may have many small (often one-pixel) regions which are misclassified. Several standard approaches can be applied to avoid this misclassification, like using contextual information in addition to spectral data. There are several contextual classification algorithms that use mean values, variances or texture description from a pixel neighbourhood to improve that pixel spectral classification.

INDEX

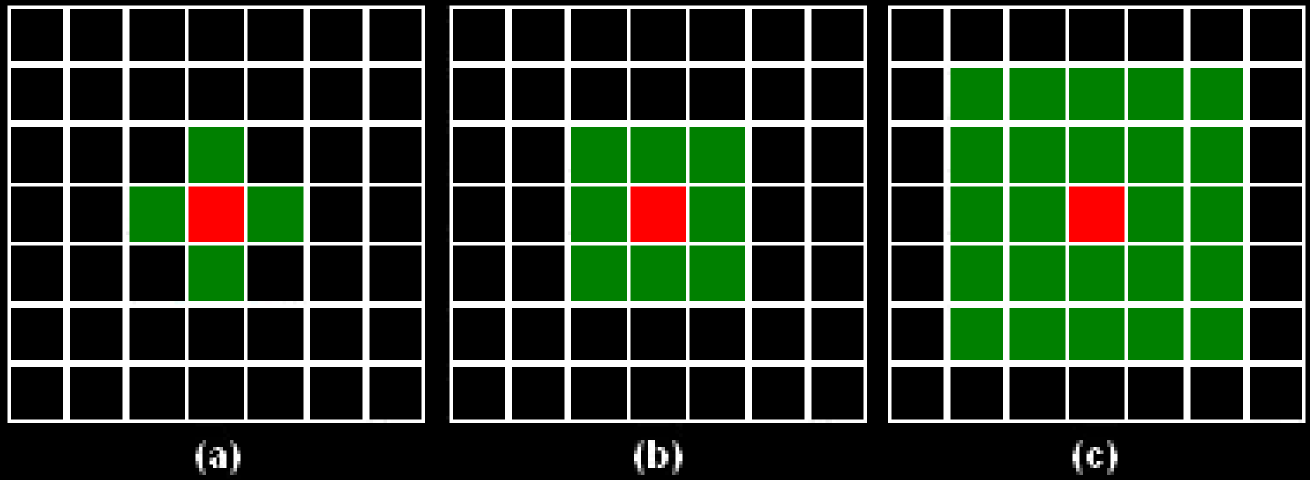
- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

Classical applications of CA in Remote Sensing

• When we work with satellite images, we consider each pixel of the image as a cell of the cellular automaton and we normally take the 8 around pixels as neighbourhood (Moore Neighborhood), although we can take the 4 around pixels (von Neumann Neighborhood) or even the 24 around pixels (Extended Moore Neighborhood).



Classical applications of CA in Remote Sensing

• Cellular automata have been used in applications that experiment a time evolution like environmental simulations, complex social phenomena modelling, images treatment in articial vision, criptography of digital information and articial intelligence in mathematical games.

• So far cellular automata have been applied on satellite images mainly to simulate processes. In the next section we propose an important and novel alternative: cellular automata applied in remote sensing to implement contextual classification algorithms of satellite images.

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

INDEX

Classification of Satellite Images with CA (ACA)

• The application of cellular automata in satellite image classification processes is a new field of investigation. In this paper we propose a methodology to implement a new satellite image classification Algorithm with Cellular Automata (ACA) that classifies the pixels based on mixed spectral and contextual information, and thus improves the classification results obtained by another classical classification algorithms.

• ACA has been implemented with Visual C++ and Erdas Imagine 9.1 Toolkit, and is a new classification algorithm based on a multistate cellular automaton that allows the user to enter new states and rules to the cellular automata in order to customize as much as possible the satellite images classification process.

Classification of Satellite Images with CA (ACA)

In order to implement ACA we must take into account the following correspondences between a cellular automaton and the basic elements of a generic process of satellite image classification:

- Each cell of the grid corresponds to a pixel of the image.
- Each state of cellular automaton will represent a dierent class of the final classification.
- The neighbourhood of each cell will consist of the 8 nearest cells (Moore neighbourhood).
- The transition function f must correctly classify each pixel of the image based on the features of the current cell and its neighbourhood, using mixed spectral and contextual data.

Classification of Satellite Images with CA (ACA)

- In order to customize the classification process, the satellite image expert analyst has to set the desired behavior of ACA through introducing the states and rules of the cellular automaton that denes the results wanted. For example, we have implemented a version of ACA that try to get 3 objectives. Primarily to improve the results obtained by supervised classification classical algorithms (eg minimun distance) using contextual information. Secondly to get a pseudo-fuzzy classification based on spectral proximity hierarchies, where in each iteration of cellular automata only those pixels that are within a spectral distance of the center of its class are classified (this distance is increased in each iteration). And thirdly, to obtain a detailed list of the noisy and uncertain pixels, and classes edges detection.

Classification of Satellite Images with CA (ACA)

So we have assigned 3 states for each of the cells: [class][quality][type], where each state can take the following values:

- [class]=training set classes, noiseClass (noisy pixels) or emptyClass (pixels not classified yet).

- [quality]= 1..numIterations (number of iterations of CA)

- [type]= focus (not border pixels), edge (border pixels), uncertain (caotic pixels) and noisy (noise detection).

Classification of Satellite Images with CA (ACA)

- If the number of spectral classification classes is 1, and the neighbourhood class states are emptyClass or the same as actual pixel: [class][quality][type] = spectralClass, CAiteration, *focus*

- If the number of spectral classification classes is 1, and the neighbourhood class states are dierent than actual pixel class: [class][quality][type] = spectralClass, CAiteration, *edge*

- If the number of spectral classification classes is 1 and the spectralClass is noiseClass: [class][quality][type] = majority class of the neighbourhood, CAiteration, *noisy*

- If the number of spectral classification classes is bigger than 1: [class][quality][type] = majority class of the neighbourhood among the dubious classes, CAiteration, *uncertain*

INDEX

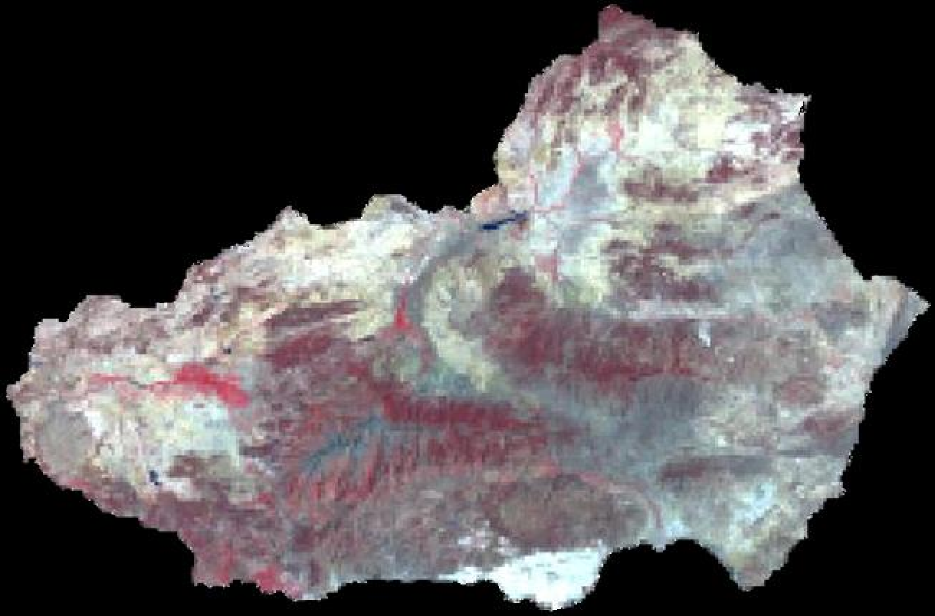
- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

Results and conclusions

• In this section we analyze the results obtained with this version of ACA algorithm. Tests have been carried out on a multispectral Landsat image with 7 layers, with a total resolution of 301x301 pixels (90,601 total pixels). The spatial resolution of each pixel is 30x30 meters.



Results and conclusions

a) **Improving the quality of the pixels classification using contextual information**. ACA improves the results obtained by another supervised classification algorithms, because in the classification process of each image pixel it uses the around pixels as neighbourhood in the transition function f, and this relationship among the image pixels offers an optimal final classification.

The number of well classified pixels in each algorithm is obtained by adding the values in the main diagonal of the table. In the case of the minimum distance algorithm there are a total of 72.974 well classified pixels (80% well classified), and in the ACA algorithm there are a total of 75.899 well classified pixels (84% well classified). Therefore the quality of the final classification has improved by 4%,

Results and conclusions

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Class 1	**0**	0	0	0	0	0	0	0
Class 2	789	**6080**	355	0	0	0	0	0
Class 3	1247	0	**9447**	532	0	0	0	0
Class 4	1547	0	2	**11998**	242	0	0	0
Class 5	1555	0	0	52	**12827**	3	27	0
Class 6	1027	0	0	47	281	**8330**	35	1
Class 7	1513	0	0	0	250	12	**13050**	0
Class 8	1396	0	0	0	0	66	381	**11242**

Table 1. Confusion matrix of the minimum distance algorithm

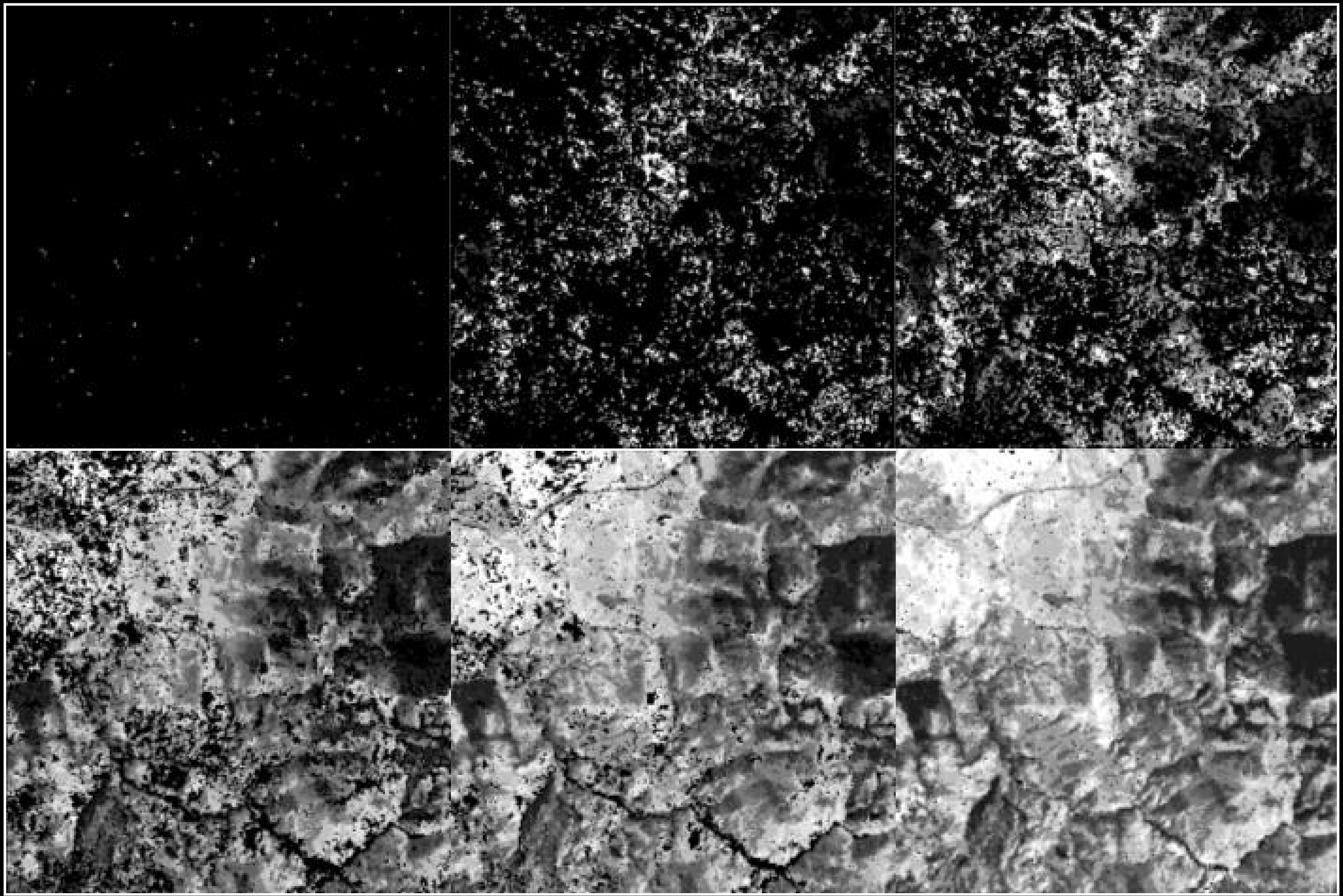
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Class 1	**0**	0	0	0	0	0	0	0
Class 2	123	**6326**	611	54	62	11	18	14
Class 3	179	0	**9648**	963	240	74	73	37
Class 4	205	0	5	**12282**	777	252	174	73
Class 5	194	0	1	58	**13254**	88	713	135
Class 6	123	0	0	47	291	**8699**	161	330
Class 7	130	0	0	1	254	16	**13724**	661
Class 8	217	0	0	0	0	68	407	**11966**

Table 2. Confusion matrix of the ACA algorithm

Results and conclusions

b) **Obtaining a pseudo-fuzzy classification based on spectral proximity hierarchies in feature space**. With ACA we can obtain a hierarchical classification based on spectral proximity in feature space, so that in each iteration of cellular automaton only those pixels in the image that are within a distance from the center of its class are classified, and this distance is increasing at each iteration. Thus, the pixels classified in a particular iteration are more reliable than those that fall in the next iteration, and so on.

Results and conclusions



Results and conclusions

c) Boundary, uncertain and noisy pixel detection. In addition, the ACA algorithm also provides the expert with a list of border pixels of each class represented in the image as well as uncertain and noisy pixels, in order to have more additional information related to the classification process to improve the subsequent analysis of results obtained. Thus, the ACA algorithm incorporates aspects of pre-sorting tasks (detection and elimination of image noise), classification (enhanced in our case) and postclassification (correction uncertain pixel) satellite imagery.

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- Acknowledgment

Future Work

Some possible future work are shown below:

- Implementing new versions of the ACA algorithm based on new states and rules of cellular automaton to further customize the classification process.

- Using software agents to reduce the computational cost, touring various regions of the image in parallel.

- Creating a Erdas Imagine pluggin that allows a custom classification based on cellular automtata.

INDEX

INDEX

- Introduction
- Spectral and Contextual Classification of Satellite Images
- Classical aplications of Cellular Automata in Remote Sensing
- Classification of Satellite Images with Cellular Automata (ACA)
- Results and Conclusions
- Future Work
- **Acknowledgment**

Acknowledgments

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