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Evaluating supervised classification methods in urban environments using UAV images

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A B S T R A C T

The use, commerce and technological development of Unmanned Aerial Vehicles (UAV's) is advancing every year with different proposals and applications in different fields of Science. Not too many years ago, aerial studies depended exclusively on images taken from airplanes and images derived from satellites, which usually represent high cost. Image classification allows the production of thematic maps and also allows the user to create an image with well distinguished classes with a good level of accuracy. In the 00's this process was mainly used in satellite images, but with the expansion of the UAV, new processes and techniques are starting to develop along. This article had the purpose of testing the accuracy of classification through kappa and tau statistics using different classifiers (Maxver, Maxver-ICM and Euclidean Distance) in aerial images, two with a short number of details and better distinguished classes and an orthophoto containing a high number of features.

Keywords: UAV, Image Processing, Supervised classification

Avaliação de processos de métodos de classificação supervisionada em ambientes urbanos usando imagens de UAV

R E S U M O

O uso, o comércio e o desenvolvimento tecnológico dos Veículos Aéreos Não Tripulados (VANTs) estão avançando a cada ano com diferentes propostas e aplicações em diferentes campos da Ciência. Não há muitos anos, os estudos aéreos dependiam exclusivamente de imagens tiradas de aviões e imagens derivadas de satélites, que costumam representar alto custo. A classificação de imagens permite a produção de mapas temáticos e também permite ao usuário criar uma imagem com classes bem diferenciadas e com bom nível de precisão. Nos anos 2000, esse processo era usado principalmente em imagens de satélite, mas com a expansão do UAV, novos processos e técnicas estão começando a se desenvolver. Este artigo teve como objetivo testar a acurácia da classificação por meio da estatística kappa e tau utilizando diferentes classificadores (Maxver, Maxver-ICM e Distância Euclidiana) em imagens aéreas, dois com número reduzido de detalhes e classes mais bem diferenciadas e uma ortofoto contendo um alto número de recursos.

Palavras-chave: UAV, Processamento de Imagens, Classificação Supervisionada

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1. Introduction

UAVs' use, uncrewed aerial vehicles became, especially in the last decade, a potent tool to many kinds of land studies, including soil, vegetation, urban development, geology, and environmental evaluations. For a time, aerial images' use for scientific purposes are ultimately based on orbital images or photographs taken from airplanes, which represented a high cost, a long process, and a severe project plan because of the need to repeat the process. With the development and accessibility of computers and cameras, UAV's commercialization started to impact studies that before needed an expensive plan significantly.

Through photogrammetry, defined by Chodoronek (2015), Douglass et al. (2015) as the art of deriving tridimensional images using photos taken from different perspectives, UAV's can cover areas of interest at an attractive price, high quality, and accuracy, making the digital image processing possible and creating different types of products. According to Silva (2014), digital imaging processing's principal function is to give useful tools to facilitate the identification and information extraction from images for interpretation. Classification is the task of assigning pixels in the image to categories or classes of interest, for example, bare soil, vegetation, built-up areas and Kaira et al. (2013) present the image classification as an essential part of the image analysis.

According to Wojtaszek et al. (2012), urban growth, land cover, and land use data play an important role in ecological and environmental research. The Federal University of Pernambuco, located in the city of Recife, Brazilian northeast, is one of the most important universities of the Northeast of Brazil, housing many natural resources, including different types of natural vegetation, corresponding to a large portion of the terrain, and artificial features, with a significant number of buildings, paving and general urban infrastructure.

It is a very well-known fact that satellite images can provide concrete products regarding spatial identification of objects and areas, providing identification of land cover through classes, as seen in Silva (2014), Abburu and Golla (2015), Campos et al. (2016), especially after image treatment proceedings. However, with the recent expansion of UAV's use in land studies and the constant need for land monitoring and evaluation, there has been some necessity of taking advantage of all resources and possible exploitation of UAV images and image processing software. In this article, three questions were asked: How effective are UAV images to create classification maps? Does the number of contents matter to create those maps? Is there a better classification method? However, this work aimed to use digital image processing through UAV images to verify and compare statistically, by Kappa, TAU, and other statistic features, the behavior of aerial photographs containing only a short number of contents and more well-distinguished classes (vegetation, soil and edification and the orthophoto produced of the area of interest, containing a close number of classes, but a larger number of objects and details and a smaller scale, through an orthophoto.

2. Materials and methods

2.1 Digital image processing and image classification

Digital image processing is understood as manipulating images through a computer utilizing and receiving images as a product. By this process, it becomes possible to improve the visual aspect of structural features of the image, giving the analyst a source to photo interpretation and creating products used in other processes in the future (Câmara et al., 2013). The umage classification refers to extracting information from images by detecting, identifying, and classifying the existing features in the images in terms of the type of class these features should represent on the field (Kalra et al., 2013).

To Körting et al. (2014), traditionally, image classification algorithms are mainly divided into supervised and unsupervised paradigms, and in supervised classification, design algorithms to estimate the classes' distribution in the feature space automatically.

There are many image classifications, supervised or non-supervised, by regions or pixel by pixel, parametric or non-parametric, spectral, and spatial, and they use different methods and algorithms for the classifications. In the supervised classification process, the analyst chooses the areas of interest in collecting samples of features previously known (Mather, 1987).

Maxver, as a pixel-by-pixel classifier, is a supervised method that uses only the spectral information of each pixel to find similar regions. This method considers the distances between media of the classes' digital levels through statistical parameters associating classes considering individual points. In the first phase, the image is classified by the algorithm MAXVER attributing classes to the pixels, taking into consideration the digital level values, and in the next phase, the attributed class depends on two things, the value derived from the pixel as a single unit and the classes from the neighbors. MAXVER-ICM, Iterated Conditional Modes, also considers the spatial dependence in the classification.

The classification using euclidean distance is a supervised classification proceeding that uses this distance to associate a specific class pixel. In this process, each pixel incorporated a group through an analysis of similarity of euclidean distance, given by the equation:

$$D(x,m) = (x^2 - m^2)^{\wedge}0,5 \qquad (1)$$

where "x" is the tested pixel and "m" is the group media (Borges et al., 2007).

2.2 Materials

For the image acquiring process, a Phantom Pro 4 uses a UAV model equipped with a 20MP camera. The aerial images processed in a microcomputer, and to obtain means of comparison, an orthophoto are produced. The other two aerial photographs chosen with the purpose of Kappa and TAU comparison.

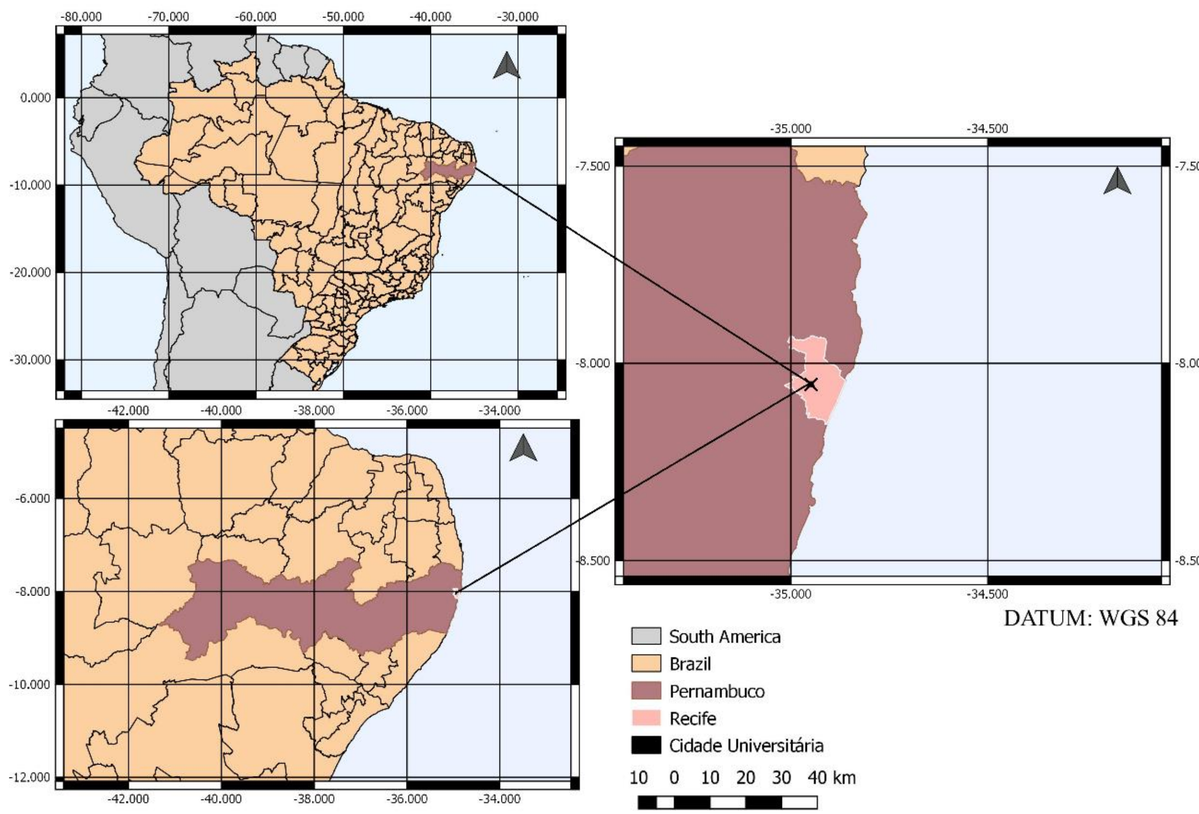
2.3 Methods

The present methodology evolved the study area's choice, followed by the photograph acquisition, the photograph selection, orthophoto production, and the image classification through MAXVER, MAXVER-ICM, and Euclidean Distance.

2.4 Study area

The Federal University of Pernambuco area are chosen due to the number of natural and artificial elements inside and near the campus, for example, a considerable amount of vegetation, numerous buildings, paving, and the existence of bare soil, which represents well the urbanization in the Cidade Universitária district, in the city of Recife. Figure 1 shows the location map of the study area.

Figure 1 - Location map of the study area.



Fonte: authors (2020).

2.5 Photograph selection and orthophoto production

Through the UAV equipment, 190 images are obtained. The equipment worked on lines to cover the whole terrain. After that, two photos are chosen according to how classes would differ from each other, for example, a nitid distinction from vegetation to paving, in a way that classes would look very distinct because of the shape, texture, and colors.

Then, the orthophoto production step started with the intent of creating a raster file. This process resulted in a 1,6 GSD, Ground Sample Distance, representing the medium size, in terrain units, representing a pixel in the image resolution.

2.6 Image Classification

The two aerial photos and the orthophoto are classified through 3 supervised processes: Maxver, Maxver-ICM, and Euclidean Distance. The threshold of 99,9% was chosen because it would represent a higher accuracy, which tries to classify all the objects regardless of assurance. All the images were open in RGB pattern to make the photo interpretation easier, and in each, samples are taken and used in all the classification processes.

Classes are created to represent the classified field, and the same ones were used in all images, vegetation, represented by green, human constructions, represented by the color gray, and bare soil, represented by brown. To statistically analyze, two aspects were considered relevant: The kappa statistic (Khat) and the overall performance based on Fonseca's (2000) classification, presented in Table 1:

Table 1. Values for Kappa coeficient.

< 0 Non Acceptable
0 < k ≤ 0,2 Poor
0,2 < k ≤ 0,4 Average
0,4 < k ≤ 0,6 Good
0,6 < k ≤ 0,8 Very Good
0,8 < k ≤ 1,0 Excellent

Fonte: Fonseca (2000).

3. Results and Discussion

3.1 Classifiers

Three classifiers were used, MaxVER, MaxVER-ICM, and Euclidean Distance resulting in classification images shown on the images represented on images 2, 3, and 4:

Figure 2 - Classifications through Maxver.

Fonte: authors (2020).

Figure 3 - Classifications through Maxver-ICM.

Fonte: authors (2020).

Figure 4 - Classifications through Euclidean Distance.

Fonte: authors (2020).

White spots shown in all the classified images are the objects or areas that the classifier could not associate with any of the classes. Through the sample analysis, it was possible to obtain the statistic parameters of all classifiers in the chosen images (Table 2):

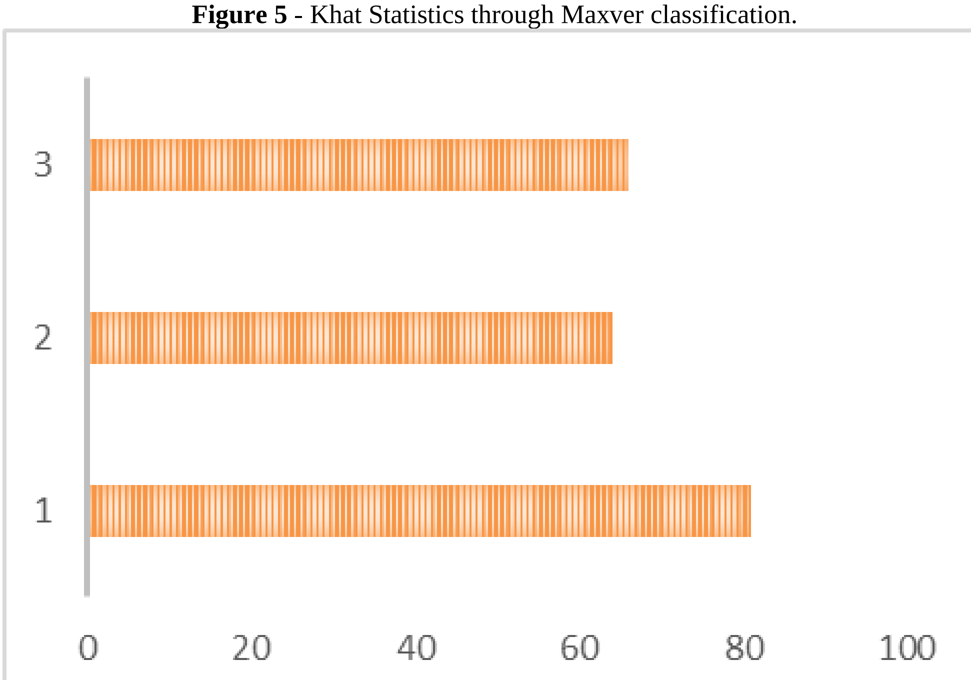
Table 2 – Statistic parameters through the chosen classifiers.

	Classification: MaxVER			**Classification: MaxVER-ICM**			**Classification: Euclidian Distance**		
	Aerial Photograph 1 (%)	Aerial Photograph 2 (%)	Orthophoto (%)	Aerial Photograph 1 (%)	Aerial Photograph 2 (%)	Orthophoto (%)	Aerial Photograph 1 (%)	Aerial Photograph 2 (%)	Orthophoto (%)
Overall Performance	95,28	98,44	97,30	94,54	98,03	98,32	88,63	98,44	80,69
Average Error	4,72	1,56	%	4,65	1,85	1,68	11,37	1,56	19,31
Average Abstention	0,00	0,00	1,09%	0,81	0,12	0,00	0,00	0,00	0,00
KHAT statistic	91,78	73,78	94,48	90,61	69,34	96,48	80,60	73,78	66,38
THAU Statistic	92,92	97,66	95,96	91,81	97,04	97,47	82,94	97,66	71,04

Fonte: authors (2020).

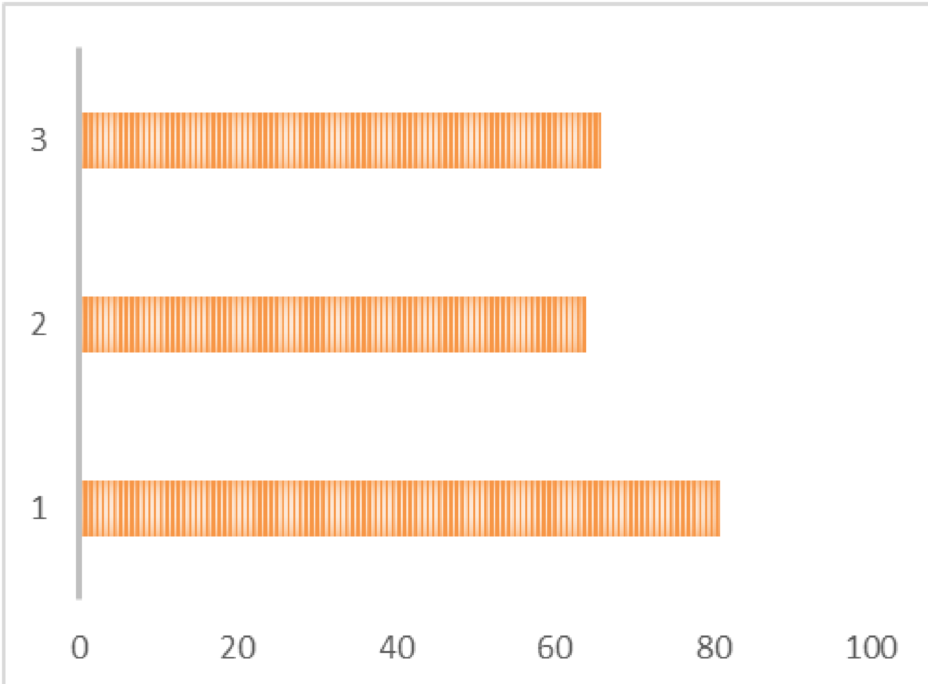
The charts below show the representation of the khat statistics according to the classifiers. 1, 2, and 3 represent aerial photo 1, aerial photo 2, and the orthophoto, respectively.

Figure 5 - Khat Statistics through Maxver classification.



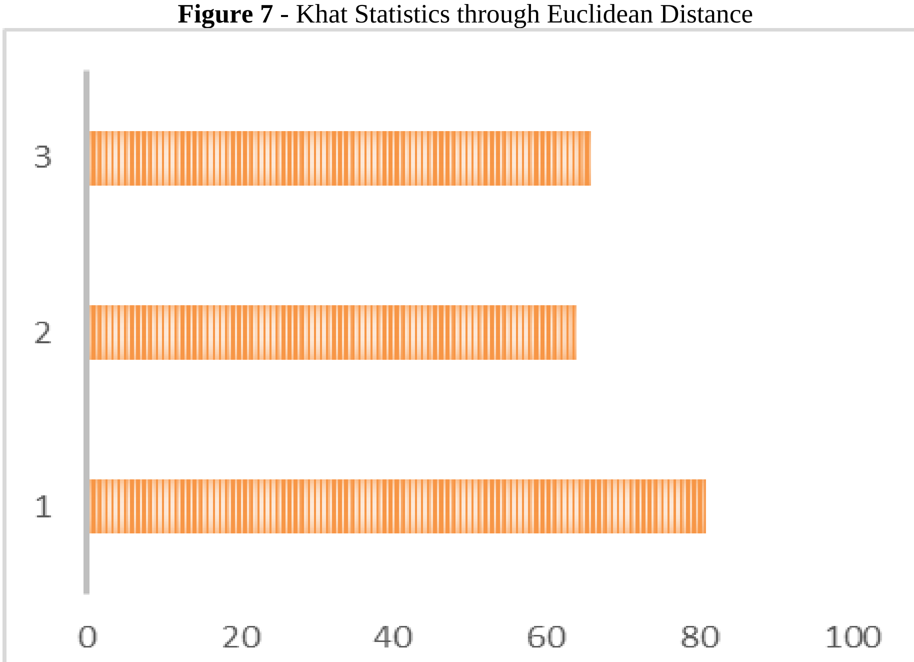
Fonte: authors (2020).

Figure 6 - Khat Statistics through Maxver-ICM.



Fonte: authors (2020).

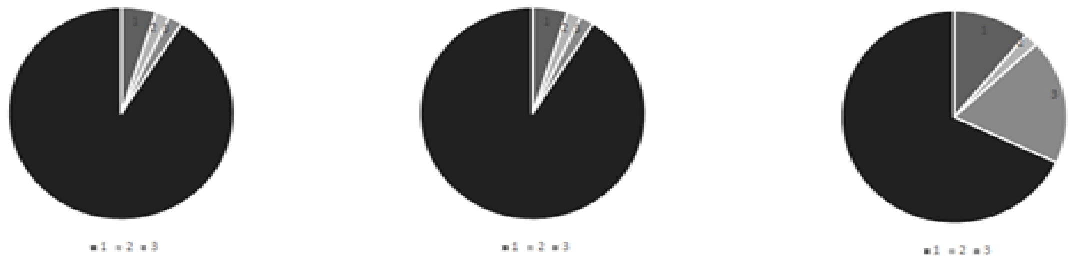
Figure 7 - Khat Statistics through Euclidean Distance



Fonte: authors (2020).

The Figure 8 shows the chart of the average error considering each method:

Figura 8 - Khat Statistics through Euclidean Distance Average classification error according to every classification method used: Maxver, Maxver-ICM and Euclidean Distance, respectively.



Fonte: authors (2020).

4. Conclusion

The overall performance among all the classifiers was not lower than 80%, being the least successful using the euclidean distance algorithm on the orthophoto. MaxVER presented a higher rate of overall performance in all the images. Regarding the kappa statistic, in the first aerial photo, kappa was considered excellent in all the classifiers, while it was considered only useful in the second aerial photo. The orthophoto presented excellent indices to kappa statistics in all classifiers except for the euclidean distance classifier that also presented the higher average error (19.31 and 11.37%).

With this study, it became clear that image classification using UAV images instead of typical satellite images is also possible with good results no matter the scale is if the classes can look very distinct from each other. Also, RGB patterns and high-quality images dismiss the need for some processing steps commonly used in satellite images, especially images derived from Landsat, such as contrast operations and IHS transformations. The results showed that none of the classifiers presented bad or non-acceptable results.

MaxVER and MaxVER-ICM presented very similar results, but overall, MaxVER proved to be the best classifier for UAV images.

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