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ELABORATION ON A NEW RGB-SPLIT METHOD TO ENHANCE BUILDING EXTRACTION IN SATELLITE IMAGES

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Summary. Image processing became necessary in various scientific applications and different research fields, especially satellite imaging. In the field of remote sensing, which is our area of interest, several researchers have developed classification and segmentation methods that are very useful. However, those applications are limited regarding the complexity and diversity of satellite images.

In this paper, we propose an original method for detecting buildings in RGB satellite images. The idea is to treat the three RGB matrices separately to accurately detect the pixel intensity variations, which provides better detection of building contours. Our method is mainly based on mathematical morphology operators. The method is a hybridization of two methods based on mathematical morphology which are the Hit or Miss Transform and the Top Hat, the Hit or Miss Transform detects all buildings because of its robust precision in detecting segments, after applying the HMT we apply the Top Hat to refine the segmentation result and finally detect clearly all building in the satellite image. We applied our method on several images from many datasets mainly Ikonos images, and Sentinel-2, the results of our method application gave great results with a Precision that exceeds 95%, Recall across 89%.

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I. Introduction

Computer vision is used in various domains as it facilitates the digital data acquisition and classification. The challenge for researchers in this field lies in choosing suitable segmentation and classification methods, particularly the thresholding method. The thresholding phase is crucial in all research domains using image processing.

In their study, Praveena and Kasmewara (2022) used image processing techniques to detect brain tumors. One of the challenges they faced was the unstructured shape of tumors. The authors employed integrated learning-based training for shape detection.

Khan et al. (2023) used image processing techniques for person identification through iris recognition. Despite the difficulty in achieving accurate contour detection, the authors employed three contour detection methods in their study.

Hedhli et al. (2018) used image processing for multi-resolution, multi-date, and potentially multi-sensor classification. The proposed method integrates pixel-level information at the same resolution to achieve their classification goals.

Babaali et al. (2022) used image processing techniques to extract roads. However, the accuracy of road extraction remains limited. To address this, the authors proposed an approach based on semantic segmentation and neural networks to improve the accuracy of road extraction.

Dal Poz (2014) combined LIDAR and photogrammetric images to effectively detect building roofs. However, the challenge of complex building shapes still persists in their study.

Dikmen and Halici (2014) usedshadows properties. They first detected shadow areas and then attempted to merge shadow parts belonging to the same building that were affected by over-segmentation. Based on the detected shadow zone, they reconstructed the building. This approach allowed them to effectively utilize shadow information for building reconstruction.

In their study, Liu et al. (2005) performed roof extraction of buildings using a multi-scale object-oriented classification approach. They then proceeded with shape reconstruction using probabilistic Hough transform.

On the other hand, Sellaouti et al. (2013) adopted an object-oriented approach for building extraction. They applied a watershed algorithm to divide the image into regions, which caused over-segmentation. In the second step, they applied fusion techniques to reconstruct the over-segmented buildings.

Other researchers have also focused on mathematical morphology, such as (Sheeren et al., 2007; Benediktsson et al., 2001; Peraresi and Benediktsson, 2001; Weber et al., 2006; Benblidia et al., 2006; Bres et al., 2003).

Previously, in our works (Benali et al., 2014a; 2014b; 2017), we used mathematical morphology to extract buildings from very high-resolution satellite images. We achieved satisfactory results; however, there is still room for improvement in these outcomes.

In this study, we once again employed mathematical morphology because this tool is well-suited for extracting geometric and spatial information from images. Additionally, its application is simple and fruitful.

II. Principle of developed method for the urban area detection RGB-split

The originality of our work lies in the separation of the three spectral components of the satellite image and the individual processing of each R, G, B component. Subsequently, we merge the final results from the three components to reconstruct a multi-spectral image that contains the extracted building information.

Our proposed method consists on the application of 8 steps as mentioned in the Fig. 1.

1. To begin, we apply a Top-Hat transform (TH) as follows:

a. Morphological closing on the original image.

b. Subtraction between the initial image and the result of the first phase.

$$I_f = I \bullet E = (I \oplus E) \ominus E \tag{1}$$

$$I_{chf} = I - I_f \tag{2}$$

With:

I_f : Resulting image from the morphological closing applied to the initial image (I).

$\oplus$: The dilation operator.

$\ominus$: Erosion operator.

I: The initial image.

E : The structuring element.

2. To eliminate non-important structures, we apply hysteresis thresholding.

$$I_{low} = \begin{cases} 1 \ \text{pour I} \geq \text{Slow} \\ 0 \ \text{pour I} < Slow \end{cases} \tag{3}$$

$$I_{high} = \begin{cases} 1 \ \text{pour I} \leq \text{Shigh} \\ 0 \ \text{pour I} > Shigh \end{cases} \tag{4}$$

$$It = Ilow * Ihigh \tag{5}$$

With:

I_low: The resulting image from the low threshold.

I_high: The resulting image from the high threshold.

It: The resulting image from the hysteresis thresholding.

3. For denoising and road removal, we used a sequential alternating filter.

Alternating filters are obtained by combinations of closing (•) and openings (∘):

$$\varphi_k(It) = (It \bullet B_k) \circ B_k \tag{6}$$

$$I_{f_K}(It) = \varphi_k \varphi_{k-1} \dots \varphi_1(It) \tag{7}$$

With:

B: Structuring element.

K: Filter size.

If: The resulting image of the sequential alternating median filtering.

4. The hole filling process consists of four steps

- Complementing the initial binary image.
- Labeling connected components to distinguish the objects of interest.
- Setting the pixel values of these regions to zero.
- Complementing to retrieve the refined result.

5. To finish the pre-processing we applied dilation, this step is applied to correct the gaps generated by the differents morphological operators that can distort the buildings or cause the loss of some useful information.

$$I_d = I \oplus E \tag{8}$$

With:

Id: The resulting image from the dilation.

$\oplus$: The dilation operator.

6. The extraction was carried out by the Hit or Miss Transform (HMT):

$$A \otimes (E, F) = (A \ominus E) \cap (A^c \ominus F) \tag{9}$$

With:

$\otimes$: The Hit or Miss transform operator.

$\ominus$: The erosion operator.

E, F: Structuring element.

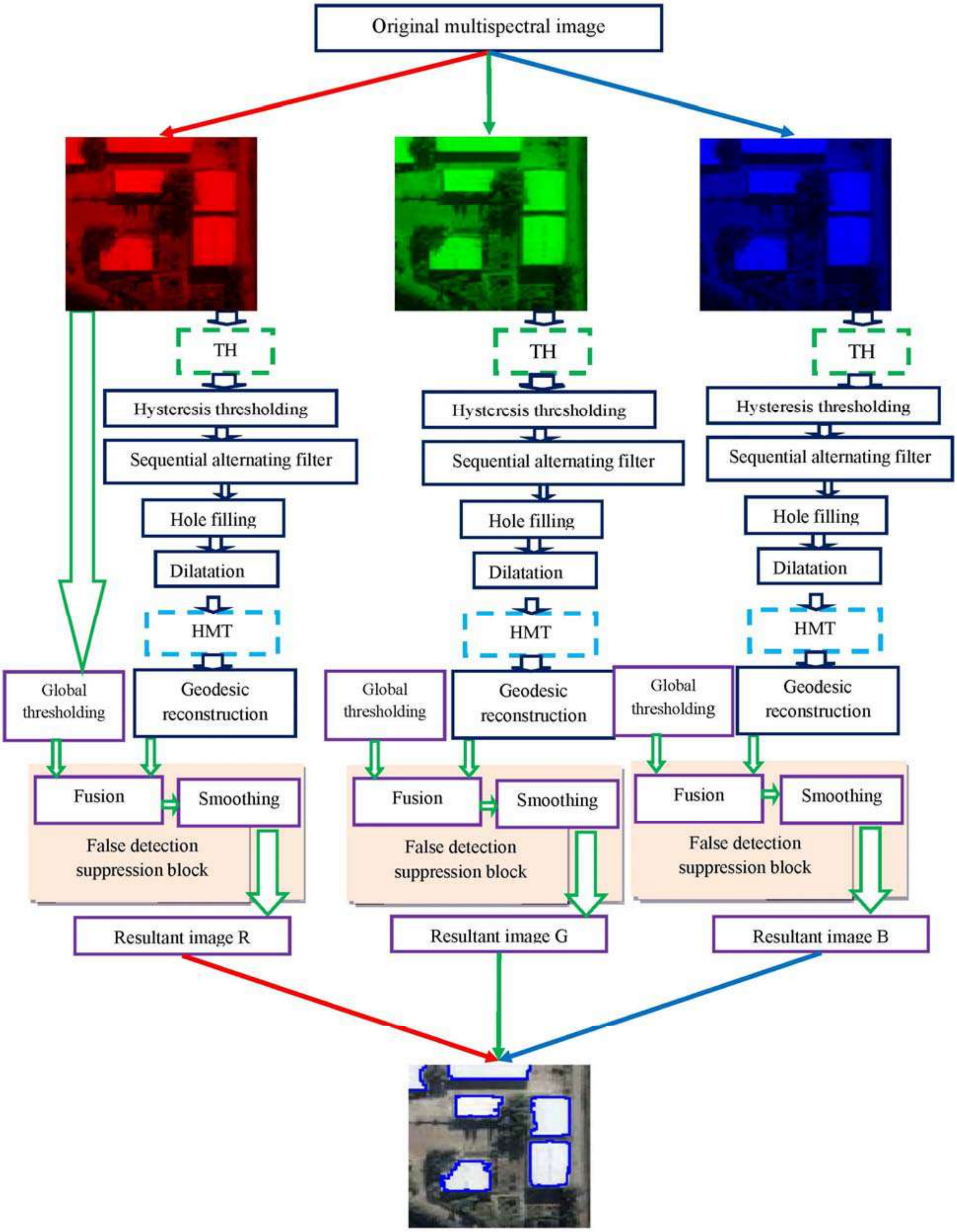

Fig. 1. Flowchart of the proposed RGB-SPLIT method

The transform consists in extracting all the objects with a size which is between the size of the structuring element E and that of F.

7. Restoration of the buildings shape by a geodesic reconstruction:

The buildings shapes deformation is clear after the application of HMT, which obliges us to apply a reconstruction step to restore the original buildings shapes.

The method requires a marker image which corresponds to the obtained HMT result, we apply a succession of dilation to this latter, the obtained result will be conditioned by a mask image resulting from the 4th phases because this one contains all the non-deformed objects of interest.

$$I_{rec} = (I_{hmt} \oplus_{I_{smo}} C_i)^{\infty} \quad (10)$$

With an application of the conditional dilation until invariance of the transformation defined by:

$$I_{hmt} \oplus_{I_{smo}} C_i = (I_{hmt} \oplus C_i) \cap I_{smo} \quad (11)$$

With :

I_rec : The reconstructed image.

I_hmt : The resulting image of the hit or miss transforms.

C_i: The structuring elements (1≤i≤3)

I_smo : The smoothed image.

8. False detection suppression block.

- Since we are using an unsupervised approach, we need to construct a reference image using global thresholding. Sheeren et al. (2007) The result of our approach will be conditioned by the reference image in order to reduce false detections.

After the conditioning phase, we apply morphological smoothing to remove any remaining false detections.

$$I_{fus} = I_{rec} \cap I_{seg} \quad (12)$$

With:

I_fus: Resulting image from fusion.

I_seg: Resulting image from global thresholding.

- Morphological smoothing

$$I\_smo = I\_fus \circ N = (I\_fus \ominus N) \oplus N \quad (13)$$

With :

I_{smo}: The result of applying smoothing to the conditioned image.

N: The structuring element.

III. Experimental results

To validate our method, we tested it on a dataset of images with varying complexity and variability in terms of color, size, and shapes

We will illustrate the results for three different images to demonstrate the advantages and limitations of our approach.

We present the results of applying our methods to the images we have chosen. Images A and I contain homogeneous rectangular buildings with areas of vegetation and shaded regions. Image E contains buildings with more complex structures, more roof details, vegetation, some areas affected by shadows, and relatively similar colors.

Since our method is unsupervised, it is important to visually inspect the images used in order to choose structuring elements of appropriate size, especially relative to the smallest building in the scene.

IV. Results evaluation

In Figures 2, 3 and 4 we can clearly observe an improvement in the results obtained with our method (RGB-SPLIT) compared to the other methods studied.

1. The first evaluation criterion is the Quantitative evaluation. It involves to calculating the number of buildings detected. To consider a building as correctly detected, at least 60% of its size must be detected.

Table 1

Quantitative evaluation

	Image 1	Image 2	Image 3
Original Image	5	16	7
HMT	5	13	8
TH	6	11	9
Hybridation method of Benali et al. (2017)	5	13	8
RGB SPLIT	5	14	8

The first image (1) (Table 1) contains 5 built-up areas with trees. The application of the TTR (Thresholding and Region Growing) algorithm allowed the extraction of all the buildings with some deformations caused by the morphological operators.

The application of the second method, CHF (High Hat Filtering), also resulted in the same number of buildings with an additional area. This is because the pixel intensities in this area are quite similar to those of the buildings.

The third method Hybridation of Benali et al. (2017) has helped correct some deformations compared to the first two methods.

Our approach has allowed for well-defined building boundaries and improved detection quality.

The image (2) contains more complex structures and heterogeneous building shapes, as well as more information compared to the previous image. This has resulted in the loss of several buildings after applying the TTR method.

The application of the CHF method also resulted in the loss of several buildings due to the complexity of the image and the operators used in the method, which are not well-suited to the shapes of the building areas in the image.

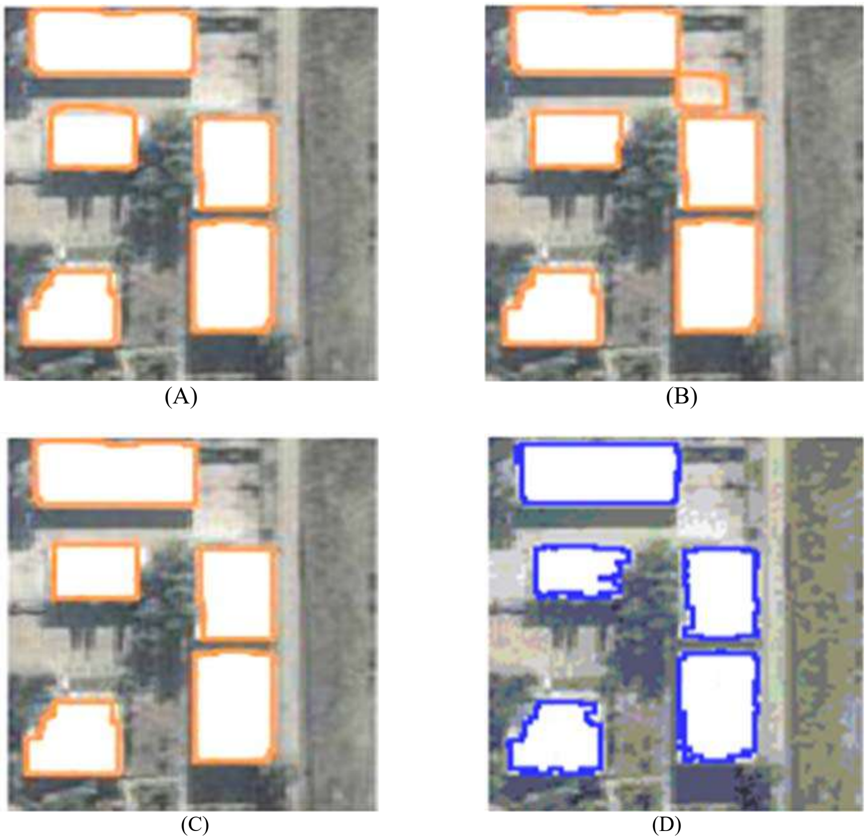

Fig. 2. (A). Resulting image of HMT, (B). Resulting image of TH, (C). Resulting image from hybridation method of Benali et al. (2017), (D). Proposed RGB-SPLIT

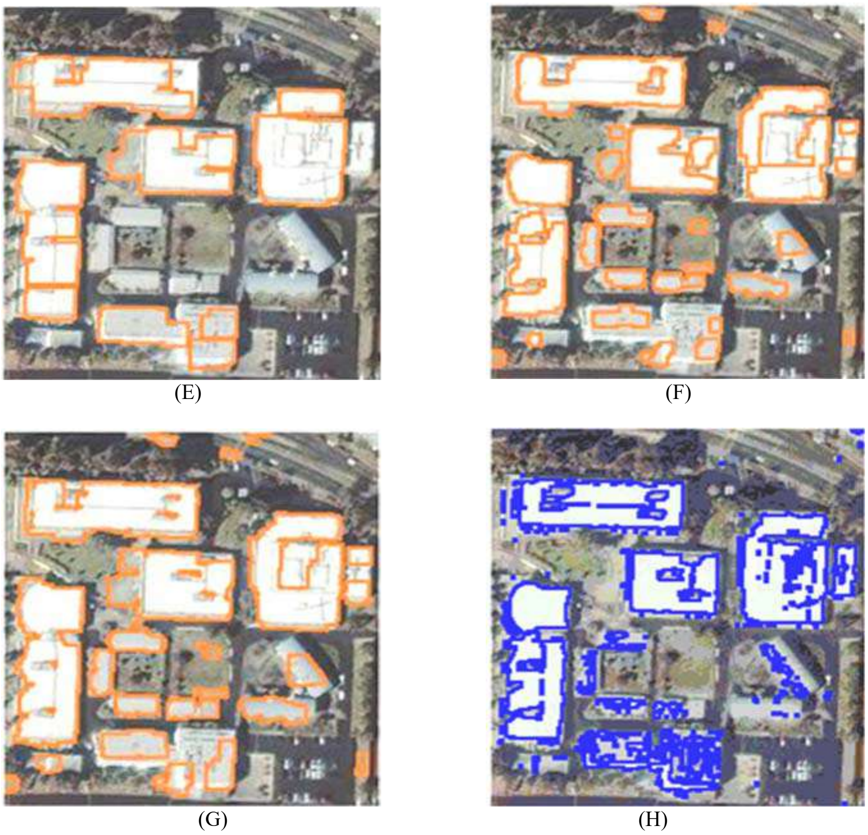

Fig. 3. (E). Resulting image of HMT, (F). Resulting image of TH, (G). Resulting image from hybridation method of Benali et al. (2017), (H). Proposed RGB-SPLIT

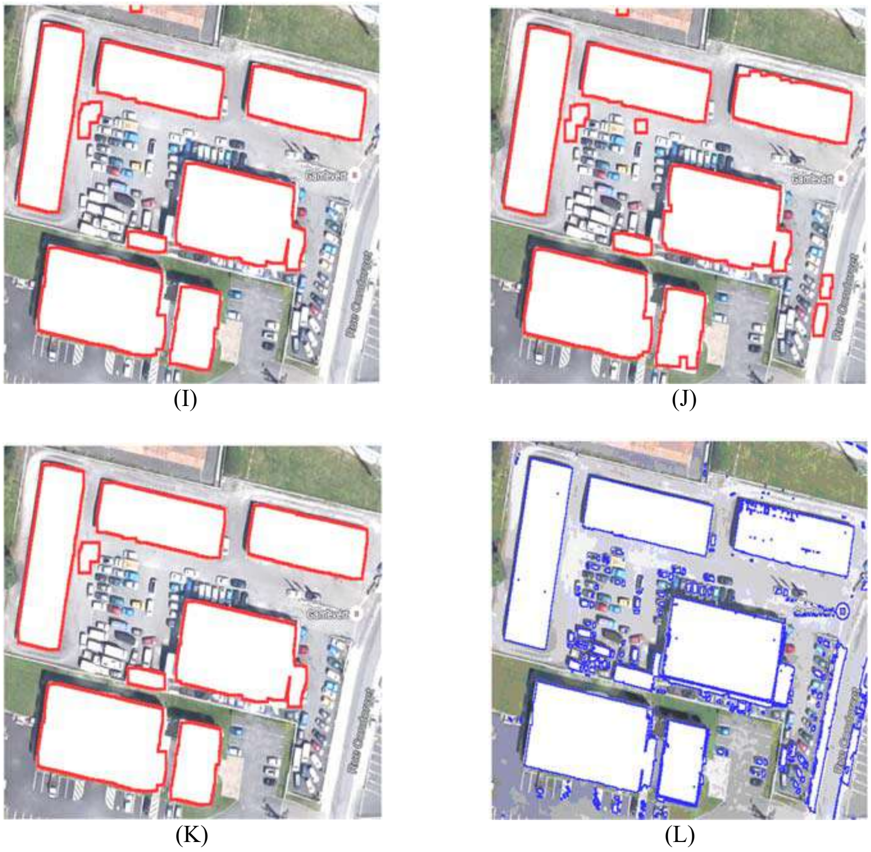

Fig. 4. (I). Resulting image of HMT, (J). Resulting image of TH, (K). Resulting image from the hybridation method of Benali et al. (2017), (L). Proposed RGB-SPLIT

The application of the Hybridation method of Benali et al. (2017) allowed us to reduce the number of false detections.

Our approach further allowed for a successful reconstruction of buildings and improved the detection quality.

The image (3) contains more buildings compared to the first image, along with a parking area with multiple cars of different shapes and colors. The high brightness of this image led to the detection of two additional areas, in addition to the existing buildings, after applying the TTR method.

An over-segmentation occurred after applying the CHF method, leading to an increase in false detections.

The application of the Hybridation method of Benali et al. (2017) did not allow for the suppression of false detections.

Our method allowed for the suppression of false detections, but it caused the detection of small vehicles as our method is sensitive to variations in pixel intensity.

To demonstrate the effectiveness of our approach, we applied our method to a carefully selected satellite image dataset, considering the complexity of structures and different shapes to distinguish the advantages and disadvantages of our approach. In the following, we present comparison graphs with multiple criteria for the four methods applied to our image dataset.

We observe (Fig. 5) that the result of applying our method is consistently closest to the number of buildings present in the original image.

2. The second evaluation criterion is the false rejection rate and the false acceptance rate.

The first image (1) (Table 2) contains very simple structures, which resulted in a similar false acceptance rate of around 2% after applying the four extraction methods.

The application of TTR resulted a false rejection rate of 1.7%, which is considered to be a very good detection rate. This rate increased to 2.42% after the application of CHF due to its complexity, causing deformation of the structures. The application of the third method reduced this rate to 0.5%, and finally, our contribution further reduced it to 0.28%, which is considered to be very good.

Image (E) contains more complex structures and condensed information, which increases the complexity and difficulty of extracting building zones.

The application of TTR resulted in a false acceptance rate of 13.18%, which is normal and acceptable for a complex image. This rate increased to 16.3% for CHF. The third method reduced this factor to 8.53%, and the RGB-SPLIT further reduced it to 5.8% because our method allows us distinguishing variations in each color spectrum separately.

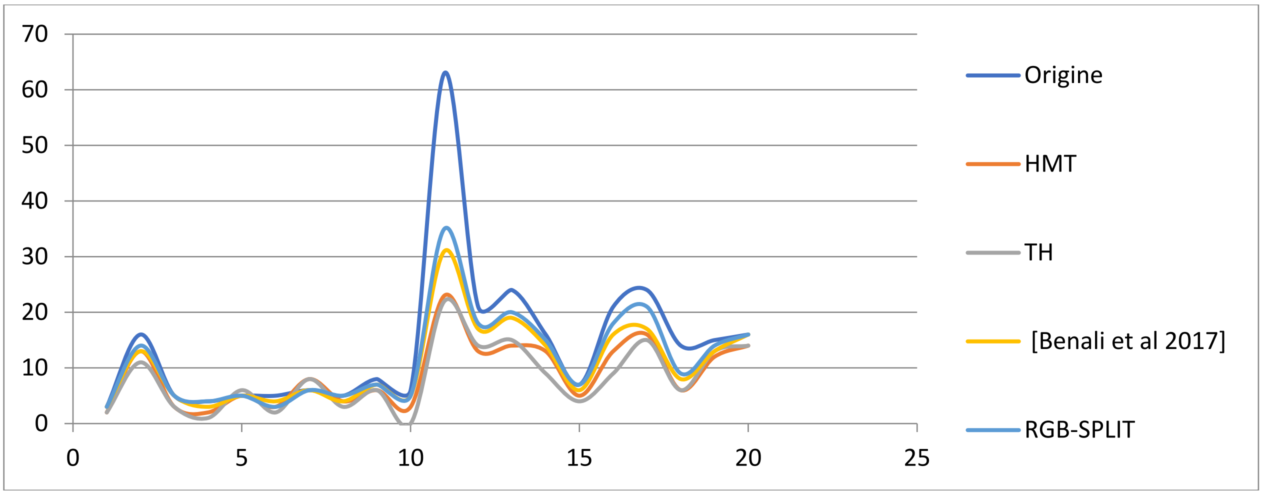

Fig. 5. Number of detected buildings

Table 2

Qualitative Evaluation TFA&TFR

		Image 1	Image 2	Image 3
HMT	TFA	2.47%	13.18%	2.62%
	TFR	1.7%	2.3%	11.23%
TH	TFA	2.6%	16.3%	3%
	TFR	2.42%	3.2%	9.93%
Hybridation of Benali et al. (2017)	TFA	2.7%	8.53%	2.87%
	TFR	0.5%	7.92%	9.65%
RGB SPLIT	TFA	1.64%	5.8%	3.41%
	TFR	0.28%	0.46%	0.32%

The false rejection rate obtained with TTR on image (2) is 2.3%, which is considered good. CHF still causes more deformations, resulting in an increase in this rate to 3.2%. The third method increased this rate to 7.92%, which is considered the detection limit for complex building areas. Our method was able to correct these deformations and reduce the rate to 0.46%, which demonstrates the robustness of our approach and its effectiveness in extracting the most complex zones.

For image (3), we have a nearly similar false acceptance rate after applying all four methods.

The false rejection rate is also nearly similar for the first three methods. However, the application of our proposed approach has significantly reduced this rate to 0.32%, demonstrating the effectiveness of our method.

3. To effectively demonstrate the efficiency of our approach, we have used a third evaluation criterion, which is the detection accuracy rate:

$$GDR = 1 - \frac{(FRA + FRR)}{2} \qquad (14)$$

We can clearly state (Table 3) that our method allows for the correction of detection errors and improves the detection accuracy rate.

Table 3

Good detection rate

	HMT	TH	Hybridation of Benali et al. (2017)	RGB-SPLIT
Image (1)	96.84%	97.11%	97.34%	99.04%
Image (2)	91.27%	95.36%	95.36%	96.87%
Image (3)	91.12%	94.09%	94.32%	98.14%

In the following, we present the results of applying the four methods to a dataset of 20 different images carefully chosen to study the advantages and disadvantages of our approach.

Regarding the false acceptance rate (Fig. 6), we can clearly see that the two methods that yield the best results are CHF and our method. Therefore, we can conclude that our approach effectively distinguishes non-relevant areas.

Regarding the false rejection rate (Fig. 7), we observe that the two methods that yield the best results are the third method and our method (RGB-SPLIT). Therefore, our method preserves the different shapes of building areas and effectively eliminates non-building structures.

In Fig. 8, we can observe that the rate of good detection obtained with our method is significantly better than that obtained with the other methods.

4. We will present a comparison of our results with previous works using the evaluation criterion called Precision and Recall.

$$P= \frac{TP}{TP+FP} \qquad R= \frac{TP}{TP+FN} \qquad (15)$$

TP: True Positive
FP: False Positive
FN: False Negative

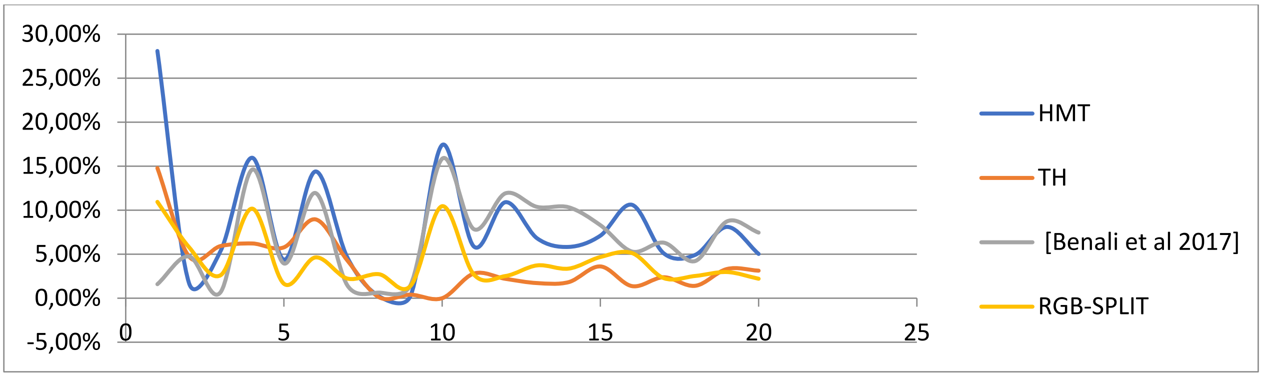

Fig. 6. False acceptation rate for database satellite images

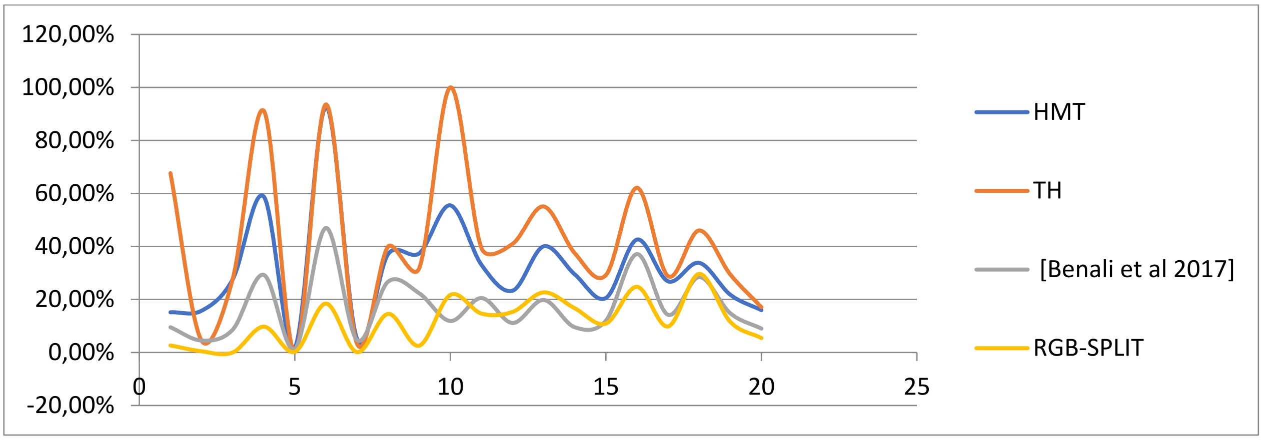

Fig. 7. False rejection rate for datasetsatellite images

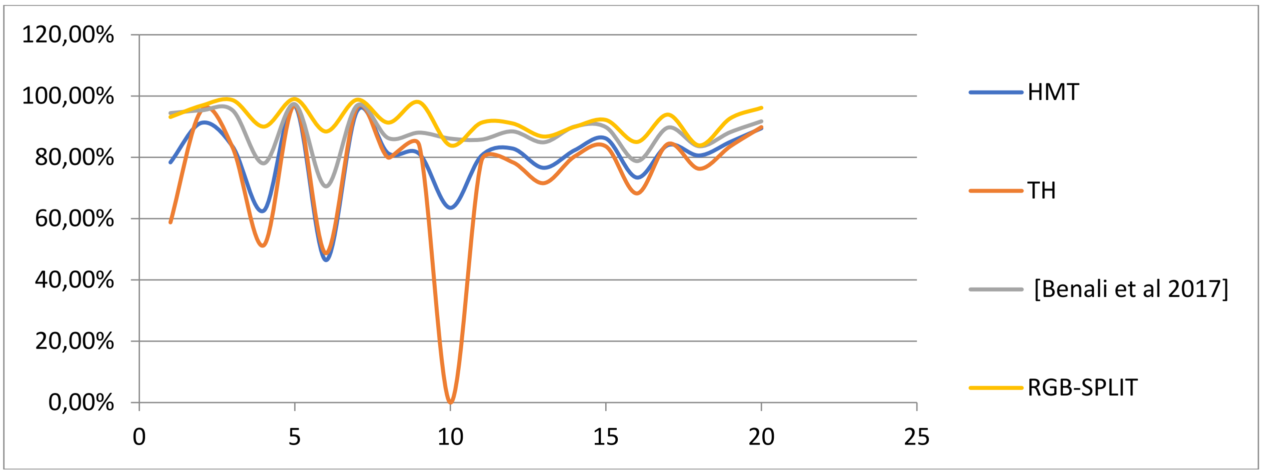

Fig. 8. The good detection rate for dataSET satellite images

Table 4

Comparative table illustrating Precision for different methods of detecting buildings

P									
HMT (Sheeren et al., 2007)	HMT (Benali et al., 2014)	HMT (Chandana et al., 2015)	TH (Benblidia et al., 2006)	TH (Benali et al., 2014)	(Hao et al., 2015)	(Qian et al., 2016)	(Dikmen and Halici, 2014)	(Benali et al., 2017)	RGB-SPLIT
91.00	91.86	94.46	92.00	93.25	92.76	93.00	65.94	93.1095	95,7625

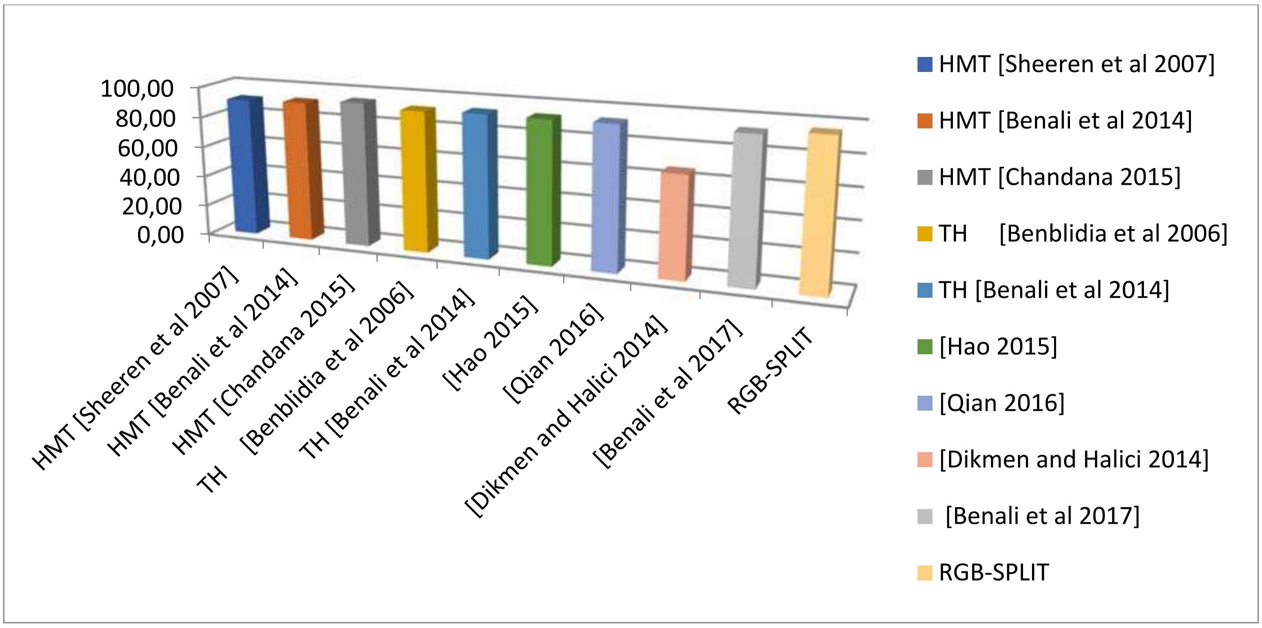

Fig. 9. Qualitative evaluation with: Précision

Table 5

Comparative table illustrating Recall for differents methods of detecting buildings

R									
HMT (Sheeren et al., 2007)	HMT (Benali et al., 2014)	HMT (Chandana et al., 2015)	TH (Benblidia et al., 2006)	TH (Benali et al., 2014)	(Hao et al., 2015)	(Qian et al.,, 2016)	(Dikmen and Halici., 2014)	(Benali et al., 2017)	RGB-SPLIT
71.50	74.33	81.22	89.00	86.56	92.79	85.00	79.15	84.46187	89.18883678

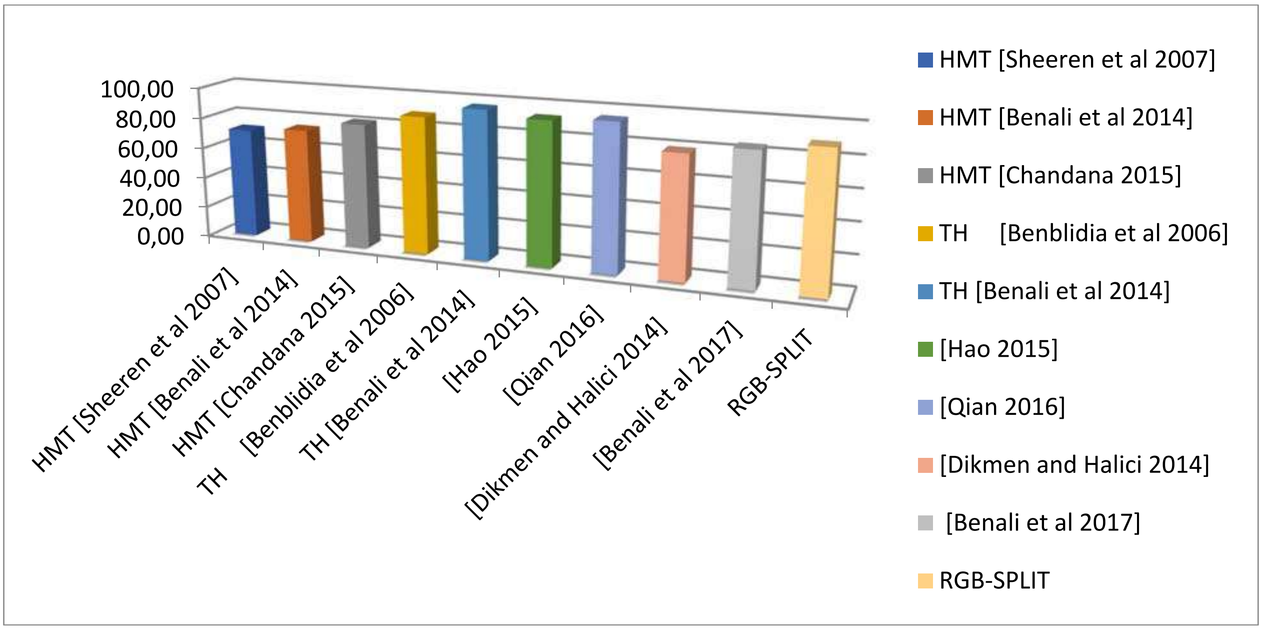

Fig. 10. Qualitative evaluation with: Recall

From (Table 4) we can confidently affirm the effectiveness of our approach, which has provided us with superior precision compared to other methods.

The two methods from (Table 5) that show a higher recall are the method of Hao et al. (2015) and our proposed method, which further demonstrates the effectiveness of our contribution.

VI. Conclusion

In this paper we have adopted a different approach which consists in separating the spectral components of an image then applying the hybridation method proposed in our previous paper (Benali et al., 2017) that we already developed to improve the efficiency of buildings detection.

The separation of the three spectral components allowed us clearly distinguishing the intensity variations of the pixels for each of the three components, which allowed us clearly delimiting the contours of the structures to be detected and to preserve the different shapes.

Our approach allowed reducing the deformations caused by the morphology operators, and the rejection rate.

The detection accuracy is well over 90%, which is very promising to our field which is the built-up areas extraction.

As perspectives, we can apply our method to other types of image to take advantage of it, such as medical or other images.

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РАЗРАБОТКА НОВОГО RGB-СПЛИТ МЕТОДА ДЛЯ УЛУЧШЕНИЯ ВЫДЕЛЕНИЯ ЗДАНИЙ НА СПУТНИКОВЫХ СНИМКАХ

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Резюме. Обработка изображений необходима в различных научных приложениях и областях исследований, особенно в спутниковой съемке. В области дистанционного зондирования, которая является сферой наших интересов, несколько исследователей разработали очень полезные методы классификации и сегментации. Однако их применение ограничено сложностью и разнообразием спутниковых изображений.

В этой статье мы предлагаем оригинальный метод обнаружения зданий на RGB спутниковых снимках. Идея заключается в раздельной обработке трех матриц RGB для точного определения изменений интенсивности пикселей, что обеспечивает лучшее обнаружение контуров зданий. Наш метод в основном основан на применении операторов математической морфологии. Метод представляет собой гибридизацию двух методов, основанных на математической морфологии, а именно: преобразования Hit or Miss и Top Hat. Преобразование Hit or Miss обнаруживает все здания благодаря своей надежной точности в обнаружении сегментов, после применения этого метода мы применяем Top Hat для уточнения результата сегментации и, наконец, четко обнаруживаем все здания на спутниковом изображении.

Мы применили наш метод на нескольких изображениях из многих наборов данных, в основном на изображениях Ikonos и Sentinel-2. Результаты применения нашего метода дали отличные результаты: точность превысила 95 %, отзывы – 89 %. В качестве перспективы, чтобы воспользоваться преимуществами метода, мы можем применить его к медицинским или другим типам изображений.

Ключевые слова: *обработка изображений, математическая морфология, RGB-изображение, классификация*

PEYK ƏKSLƏRİNDƏ BİNALARIN AYRILMASI KEYFİYYƏTİNİN YÜKSƏLDİLMƏSİ ÜÇÜN YENİ RGB-SPLİT METODUNUN İŞLƏNİLMƏSİ

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Xülasə. Təsvirlərin işlənilməsi müxtəlif elmi tədqiqatlarda, xüsusən peyk əkslərində istifadəsi mütləqdir. Bizim maraq sferamızda olan distansiyon zondlama sahəsində bir sıra tədqiqatçılar olduqca faydalı təsnifatlar və seqmentasiya metodları işləmişlər. Lakin onların tətbiqi peyk əkslərinin müxtəlifliyi və mürəkkəbliyi ilə məhdudlaşmışdır.

Bu məqalədə RGB peyk əkslərində (şəkillərində) binaların aşkar edilməsinin orijinal metodunu təklif edirik. İdeyanın məğzi piksellərin dəyişmə intensivliyinin dəqiq təyini üçün üç RGB matrislərinin ayrıca işlənilməsindən ibarətdir ki, bu binaların konturlarının daha yaxşı aşkar edimənsini təmin edir. Bizim metod riyazi morfologiya operatorlarının tətbiqinə əsaslanır. Metod riyazi morfologiyaya əsaslanan, daha doğrusu Hit or Miss və Top Hat operatorlarının dəyişilməsi – 2 metodun hibridləşməsindən ibarətdir. Hit or Miss çevrilməsi seqmentlərin aşkar edilməsində öz etibarlı dəqiqliyinə görə bütün binaları fiksasiya edir, bundan sonra seqmentasiya nəticələrinin dəqiqləşdirilməsi üçün Top Hat metodundan istifadə edilmişdir və nəhayət peyk əkslərində bütün binaları aydın aşkar edirik.

Bizim metod çoxlu çeşidli məlumatlar içərisində, əsasən, Ikonos və Sentinel-2 təsvirlərində tətbiq etdilmişdir. Metodumuzun tətbiqi qiymətləri 95% - dən, daha doğrusu 89% - dən çox dəqiqliklə əla nəticələr verdi. Perspektivdə bu metod tibbi və digər problemlərin həlli üçün istifadə oluna bilər.

Açar sözlər: *təsvirlərin işlənilməsi, riyazi morfologiya, RGB-təsvir, təsnifat*