DEEP LEARNING APPROACH APPLIED TO DRONE IMAGERY FOR REAL ESTATE TAX ASSESSMENT: CASE OF THE TAX ON UNBUILT LAND KENITRA-MOROCCO

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ABSTRACT:

According to the Court of Audit, urban taxation is the main source of revenue for local authorities in almost all regions of the world. In Morocco, in particular, the tax on unbuilt urban land accounts for 35% of the revenue from taxes managed directly by the municipality. The property tax assessment system currently adopted is not regularly updated and is not properly monitored. These difficulties do not allow for a significant expansion of the land base. The current efforts aim at accelerating the census of the urban heritage using innovative and automated approaches which are intended to lead to the next generation of urban information services and the development of smart cities. In this context we propose a methodology that consists of acquisition of high-resolution UAV images. Then the training of a deep learning algorithm of semantic segmentation of the images in order to extract the characteristics defining the unbuilt land. U-Net, the deep architecture of the convolutional neural network that we have parameterized in order to adapt it to the nature of the phenomenon treated and the volume of data we have as well as the performance of the machine, offers a segmentation accuracy that reaches 98.4%.
Deep learning algorithms are seen as more promising for overcoming the difficulties of extracting semantic features from complex scenes and large differences in the appearance of unbuilt urban land. The results of prediction will be used for defining urban areas where updates are made from the perspective of tracking urban taxes.

1. INTRODUCTION

the Royal Will endorses the New Development Model as a priority of the nation, of which the tax system is the launching pad. This tax system must fulfil a requirement of coherence, visibility, equity, efficiency and assistance to the increase of the activity and the production of national added value. A tax system that would fully perform its role of solidarity, reduction of inequalities and contribution to social cohesion (CESE, 2019).

In the meantime, Morocco has adopted the dynamics of advanced regionalisation, which organises the country into regions, provinces and municipalities. These give each level of local government powers and prerogatives, including those relating to economic and social development, which could not be envisaged without including the fiscal dimension. In this context, local taxation takes on its full importance.

It is therefore essential to ensure its effectiveness through a new reform that aims to:

- Modernise and intensify the census operations by mobilising new information and communication technologies that allow the implementation of an information system dedicated to the management.
- Complete the targeted tax arsenal by a fairer and more equitable taxation of the patrimony. In this context, the taxation of non-productive assets (ex. Unbuilt land) would be particularly targeted.
- Build a new tax system that is strongly interlinked with other public policies to foster innovation and upward mobility in the value chain, and to ensure social inclusion and visibility.
- Establish a census of all the land affected by any urban expansion in order to facilitate the identification phase and to constitute the databases necessary for the assessment and control operations.

In order to approach this subject, it is essential to highlight the following crucial elements (CESE, 2019):

- According to statistics established by the Court of Accounts in 2015, Urban taxation is the main source of revenue for local governments in practically all regions of the world. In Morocco, taxes on land and property account for almost 80% of total revenue. These include the tax on unbuilt urban land, which accounts for 35% of the revenue from taxes managed directly by the municipalities.
- The property tax assessment system currently adopted is not regularly updated and is not properly monitored with regards to removing or adding a new real estate unit, so that the revenue remains unknown at its potential. As a result of these complications, the authority has experienced delays and a shortage of collected revenues.
- The difficulties related to the periodic census of assets do not allow for a significant expansion of the land basis. These difficulties have an impact on the low yield of property taxes. In fact, the census procedure is rarely implemented because of its complexity and the number of resources it requires. It is often inefficient, even ineffective, and marred by numerous malfunctions.

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- The management of local taxes by the municipalities suffers from the lack of genuine computerised solutions to assist with tax work and from the precariousness that profoundly affects the implementation of the tax process depending on the taxes and charges paid, particularly the tax on unbuilt land (TNB).

To overcome the limitations of the property tax assessment system and to fill the need for accurate, meaningful and efficient information, we will use drone photogrammetry coupled with artificial intelligence:

- It is an automated approach to detect unbuilt land, which would replace physical inspections and significantly reduce hand reporting and improve work efficiency.
- It is a solution to the two major challenges faced by tax assessors: - Obtaining physical access to the property to carry out a proper assessment; - Having enough assessors in the field to cover all properties on the tax records.
- It a visualisation of the unbuilt land information on a GIS application in an interactive mode that provides reliable geospatial and semantic information (position, area and consistency).
- It as an essential observation tool that aims at leading to the next generation of urban information services and smart city development. The potential use of this solution would be highly advantageous in urban planning and development by providing an appropriate decision possibility for the daily urban planning.

2. LITTERATURE REVIEU

Many initiatives have been taken to reform the tax system. They aim at modernizing and intensifying the census operations, mobilizing new information and communication technologies. They promote innovation and the increase in the value chain. Here are some experiences that seek to overcome the limitations of the property tax assessment system and fulfill the need for accurate, meaningful and efficient information.

2.1 Case 1: Use of the drone in the evaluation of real estate

A study conducted by Tahar and Radzali aims to highlight the potential of drone photogrammetry in the tax evaluation of properties. It consists of the production of orthophotos on which the actual geometry of each two-storey house will be identified on the basis of the roof separating them. This method is based on the determination of the area of the roof between the two floors that may present an extension of the house (Tahar & Radzali, 2018).
On the produced orthophotograph, each two-story house with a terrace is digitised: terrace boundary, real dimensions and extension area. The house area is calculated by its geometry dimensions. By applying the tax base, the standard rate is calculated from the real dimensions of the house. To calculate the new tax rate, the roof area, calculated from the differences between the extent dimension and the real dimension, was used to calculate the additional rate.
The result of the study is presented as a property information map of two-story houses in Section 8, Shah Alam, which features the classification of the property floors as well as the extension, labeled according to the color:

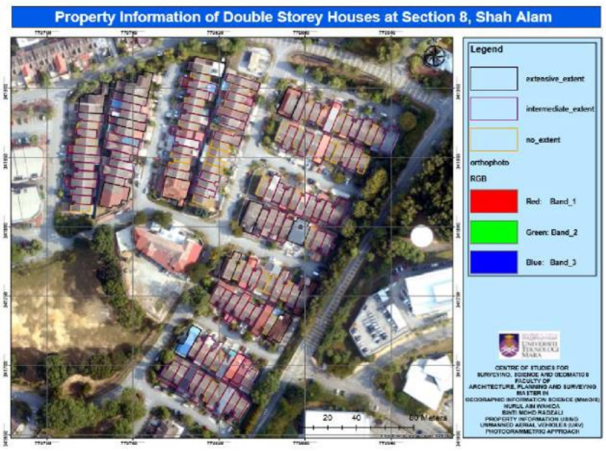

Figure 1. Map of two-storey houses in Section 8 of Shah Alam, Selangor (Tahar & Radzali, 2018).

2.2 Case 2: The use of satellite imagery in the creation of tax maps and local revenue collection

In this study, Wild, Ali and Deininger illustrate how high-resolution satellite imagery can be used to assess the completeness of pre-existing tax maps by estimating built-up areas on the basis of building heights and footprints. Combined with sales price information from the land register, targeted surveys and routine statistical data, this method makes it possible to use mass valuation procedures to generate tax maps. This study highlights the reliability of the proposed method and its potential significant impact on revenue (Wild, Ali, & Deininger, 2018).
To generate built-up area information, Pleiades Tri-Stereo images with 0.5m spatial resolution are used over a 340 km² study area that covers the central business district (CBD8) and the majority of the city of Kigali.
After filtering the trees using the vegetation index (NDVI), building heights can be retrieved for each of the 0.5 m/pixels of the image being the difference between the digital surface model and the digital terrain model generated from the image.

Figure 2. Estimated building heights, Kigali center (Wild, Ali, & Deininger, 2018).

2.3 Conclusion

The purpose of these studies is to evaluate the potential of photogrammetry and remote sensing in the fiscal assessment of property. They provide an overview of the experiences of

different countries around the world in solving the problem of periodically updating land information through access to property while using more efficient and less expensive techniques. This is a revolution in the tax census.
However, these techniques still require a great amount of human intervention for the processing of the data and therefore consume a lot of time and energy.

3. EXPIREMENTS WITH RESEARCH PROCEDURE

After presenting the state of the art on the use of drone and satellite imagery in taxation, this section is dedicated to present the proposed methodology as well as analysing and comparing the obtained results.

The methodology we propose consists of a number of sequential processes of acquisition and generation of high resolution ortho-rectified images that will form our database. Then to the development and training of a deep learning algorithm for semantic segmentation of the images in order to extract the features defining the undeveloped land. The results provided will be validated by approved plans and physical inspections.

3.1 Materials

In order to implement the proposed methodology, we have used the following elements:

- Drone type Phantom 4 to carry out the mission of aerial photogrammetry,
- Pix4D to generate the Orthomosaic,
- Global Mapper to cut the Orthomosaic into tiles.
- Apeer to create masks
- Image J to normalize theses masks
- Google Colaboratory as a development environment for the model using python language, especially the Tensorflow, Keras and OpenCV libraries,
- Qgis for the spatial analysis of the results.

3.2 Dataset

We planned an aerial photograp by drone that cover the subdivision El-Hadada in the city of Kenitra with an area of 15ha. Taking into account the field conditions on the day of the

mission we have chosen as a parameterization, a height of 120m and a lateral coverage of 50% and a longitudinal coverage of 50%.

Figure 3. Planning of the aerial shooting.

The images produced are processed in the Pix4D Mapper software to ortho-rectify the images. We then obtain the Orthomosaic. However, we need a considerable number of images, to do this, we proceed to the cutting of the orthomosaic in elementary orthoimages of the same size while preserving the geospatial information.
To complete the database, we must create for each elementary orthoimage, a corresponding binary mask that highlights the non-built land contained in the image. This is a manual extraction of the unbuilt land by filled polygons that follow the boundaries of these lands with the rest of the details. Then, we adjust the contrast at the level of these masks so that the radiometric values are between 0 and 1. This is the normalization of the data.

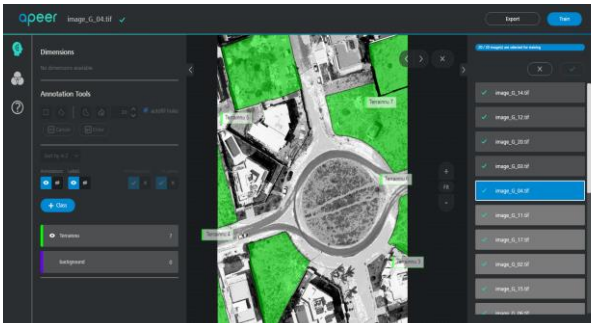

Figure 4. Example of an image annotation on APEER.

Finally, we have structured our data in 3 folders: 75% of the database is dedicated to training, 20% to validation and 5% to testing.

3.3 Deep Learning model

3.3.1 Database preparation

Once our database is ready, we proceed to develop the deep learning model behind the automation process.

In the first place, we ensured that the image-mask pairs do not present any failure that can alter the results of the model, we then we set a script to visualise each image together with its mask.

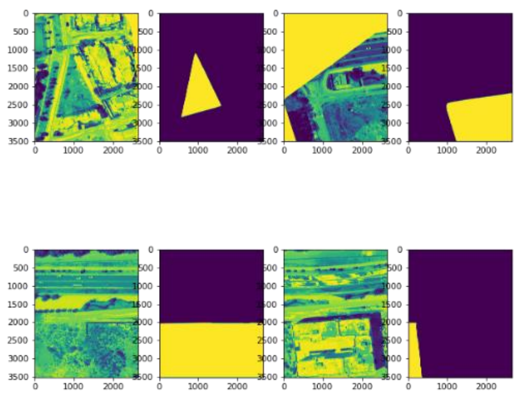

Figure 5. Samples training pairs (Image & mask).

Taking into account the limited amount of data we have and in order to enhance the learning of the model, we decided, in the second place, to increase the amount of training data (images and masks) by applying a set of transformation. This involves producing several sophisticated copies of a single image using operations such as rotations, cropping, flipping, scaling, translations, shearing …

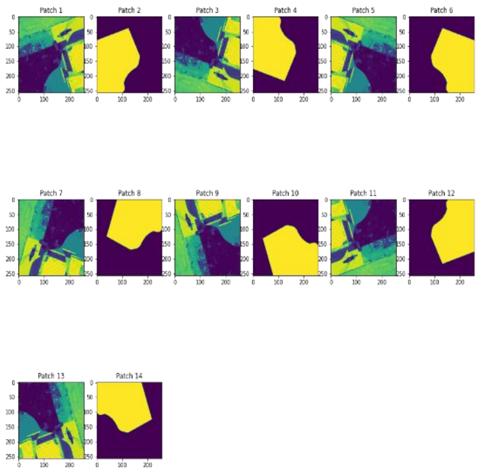

Figure 6. Samples of data augmentation applied to a drive torque.

To overcome the data multisourcing concern and the variation in data acquisition methods, we consider it wise to normalize the images. It consists of a scale change of the data according to the original range, so that all values are between 0 and 1.
Now we dispose of an augmented and normalized data base ready to feed the chosen model.

3.3.2 U-Net Model: training and adjustment

The chosen model is none other than the convolutional neural network, one of the famous architectures for Deep Learning that learns directly from the data, thus avoiding manual feature extraction.
Specifically, we have used the well-known U-Net deep architecture, applied to frequent quantification problems, such as pixel detection and geometry measurements for building extraction from satellite images (Xu, et al., 2018).
Our choice is motivated by several reasons. First, the U-Net architecture offers a very high performance on segmentation applications and especially on very diverse images. Second, it has as a revolutionary feature which is the connection skips, which provides the necessary details to reconstruct precise segmentation boundaries by adding fine details (Ronneberger, Fischer, & Brox, 2015). Finally, it allows to combine contextual information with spatial information.

The U-Net architecture is based on an encoder-decoder mechanism which, instead of using pooling indices, transfers and sets the feature maps from the encoder to the decoder. In other words, it completes a usual contractual network through successive layers, where the pooling operations are replaced by oversampling operators. Theses layers thus increase the resolution of the output. Moreover, a successive convolutional layer can then learn to assemble an accurate output based on this information.
The expansion path is approximately symmetrical to the contraction part, and results in a U-shaped architecture, given the large number of feature channels in the oversampling part, which allows the network to propagate contextual information to higher resolution layers.

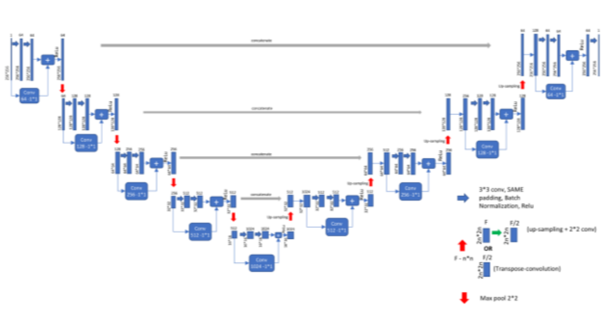

Figure 7. U-Net standard architecture.

In the perception of adjusting the chosen architecture to the treated problematic, we have brought numerous modifications to the original architecture.
These modifications concern the hyper parameters of the U-Net model:

- The number of initialisation kernels: Weight initialization is used to define the initial values of neural network model parameters before training the model on a data set. It is a starting point in the space of possible weight values from which to begin the optimization process.
- Learning rate: the step in the gradient descent algorithm. When this rate is too low, the model takes a long time to converge. On the other hand, if it is too high, the model diverges, and the loss can fluctuate indefinitely. To ensure optimal learning, an initial learning rate is first defined, then the rate is updated by scaling it periodically with a decay factor.
- Batch size: the amount of data used in a single iteration of an epoch during the training of the model. Then, the size of the batch to be used is fixed according to the available computing power.
- Number of epochs: The number of times all the training data goes through the model, defined in order to obtain the optimal weights at the end of the training process.
- Loss function: During training, the weights are continuously updated after each iteration, and become more suitable to the data by comparing the predicted outputs to the actual outputs, this difference (error) is practically calculated by the loss function.
- The optimization function: This is a mathematical equation that determines the output of a neural network. The function is attached to each neuron in the network, and determines whether it should be activated or not, depending on whether the input to each neuron is relevant to the model prediction.

The learning of the model is essentially done by successive iterations while trying to minimize the global error of a model measured by its loss function. This type of problem refers to all optimization techniques. Basically, the optimization of the algorithm involves modifying the hyper-parameters of the model, i.e. the features of the neural network such as the weights and the learning rate in order to minimize the errors, and just like the loss functions, they vary in performance depending on the model, the data and the type of problem we face.

3.3.3 Results and discussion

The modifications we made to the original architecture are summarized in the following table:

Input size	Test1	Test2	Test3	Test	Test5	Test6	Test7
Initial filters	256 * 256						
Learning rate	4						16
Batch size	0.01		1			1	
Number of epochs	8	4					
Loss function	600	400			100	300	
Optimization function	Binary crossentropy		Focal loss	Binary crossentropy			
Input size	Adam		Delta		Gradient Descent Optimi	Delta	

Table 1. Summary of adjustment tests.

In accordance with the table above, we present the training results for each model tested: we randomly chose an image among the 10 images reserved for the test, in order to illustrate the level of segmentation reached for each model tested by comparing it to the real image and the manually segmented mask.

Figure 8. manually segmented image and mask for test.

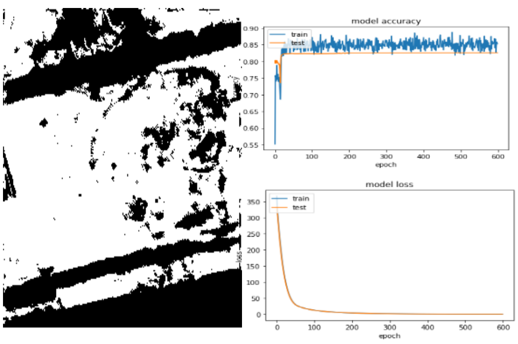

Figure 9. Test 1 predictions: segmented image, model accuracy, model loss

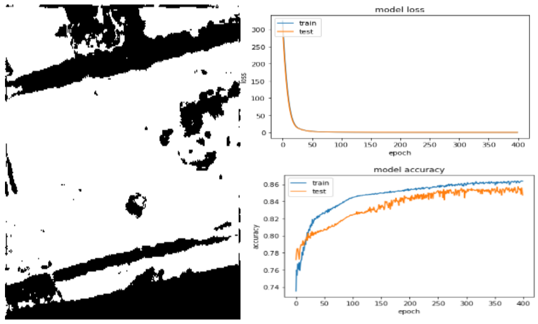

Figure 10. Test 2 predictions: segmented image, model accuracy, model loss

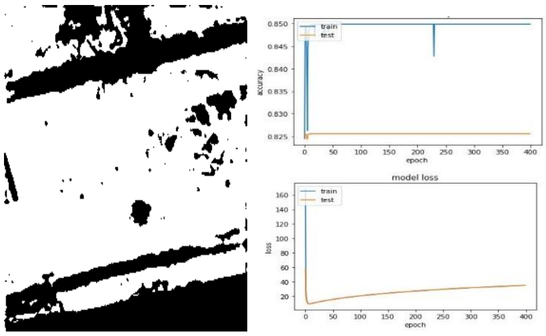

Figure 11. Test 3 predictions: segmented image, model accuracy, model loss

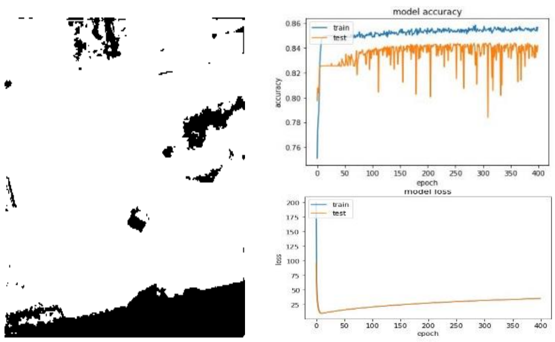

Figure 12. Test 4 predictions: segmented image, model accuracy, model loss

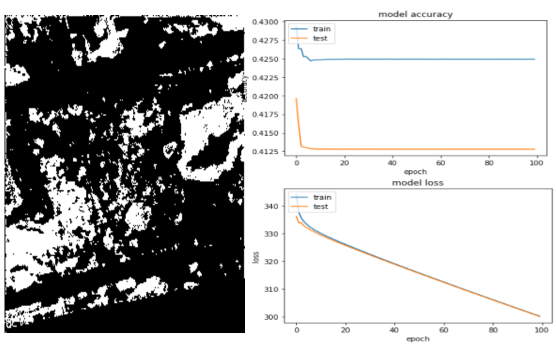

Figure 13. Test 5 predictions: segmented image, model accuracy, model loss

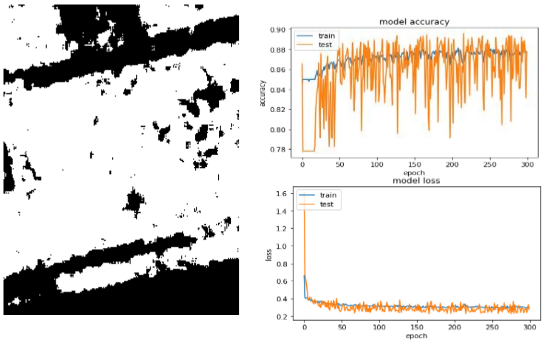

Figure 14. Test 6 predictions: segmented image, model accuracy, model loss.

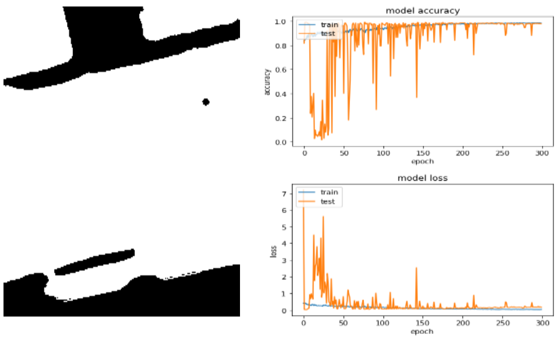

Figure 15. Test 7 predictions: segmented image, model accuracy, model loss

We rejected tests where:

- The validation accuracy curve stalls at a value x, while the training accuracy curve continues to evolve. In other words, even if the model is fit to the training data, it fails to achieve good predictions on the validation data. This is due to the complexity or the insufficiency of the training data.
- The accuracy curve or the loss curve takes a uniform or linear evolution, this is a behavior not compatible with the evolutionary nature of the learning process.

We have also taken into account the global accuracy of the model to be maximized in order to obtain the optimized model for this theme.

The adopted architecture is based on layers, 16 filters for initiation and a growth factor of 2. We have also integrated a drop rate of 0.5 as a value to prevent overfitting. The number of trainable parameters in this chosen model is 7.865.475. (Appendix 1)

3.3.4 Spatial analysis

To take advantage of the potential of automated extraction of unbuilt land, we propose a tax-oriented GIS application.
It is a spatial analysis at the interface of the qgis environment which consists in overlaying the results of predictions:

- firstly, to the urban planning documents in order to include the urbanistic dispositions such as the non-edificated zones, the wooded zones, the parks etc.
- Secondly, to a property map, defining the land and his owner in order to assign to each land its consistency and its content, in other words, its area and whether it is built or not. For this purpose, we used the statistical zonal plug in on Qgis which allows to calculate several pixel values of a raster layer (in this case, it is the results of the segmentation) with the help of a polygonal vector layer (it is the property map).

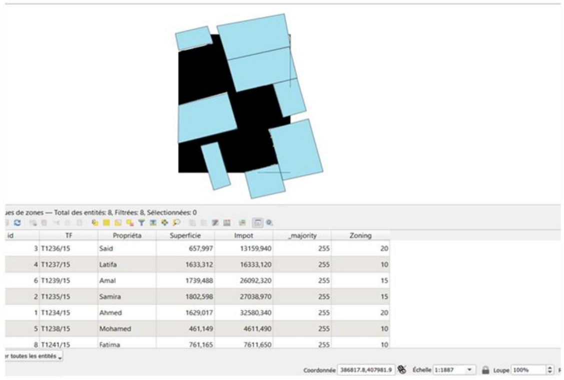

Figure 16. Result of the tax-oriented GIS application.

4. CONCLUSION

The U-Net architecture that we experimented during this project provided significant results for the segmentation of unbuilt land from drone orthoimages. The adopted model reached a global prediction accuracy of 98.4% thanks to the adjustment of hyper-parameters according to the nature of the problem considered, the available data and the performance of the platform dedicated to learning. Certainly, the exploitation of a larger database and a cloud platform allows to boost the prediction performance, at this level the model is largely sufficient to identify the undeveloped land and reach the expected target in terms of performance, reliability and speed. The results of the prediction were used to feed the pre-existing parcel status by defining whether the parcel is built-up or not.

The methodology explored allowed us:

- first, the creation of a Moroccan urban database from drone images.
- second, the development of a deep learning solution for the semantic segmentation of undeveloped land.
- thirdly, the guarantee of a very interesting segmentation quality that reaches 98% in an extremely reduced time while reducing human intervention.
- lastly, the alignment with the strategic orientations of the country that aims at promoting the new technology in favor of an exclusive fiscal system for a smart and resilient city.

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