

INFORMATION TECHNOLOGY FOR DETECTING FOREST FIRE CONTOURS USING OPTICAL SATELLITE DATA

Abstract. The number of forest fires has increased significantly over the past ten years. It indicates that forest area estimates fires are a very urgent task today. The use of satellite-based data simplifies the process of assessing forest fires. The aim is to develop an information technology for automated forest fire contours detection on digital optical satellite datas in conditions of non-stationarity and uncertainty based on convolutional neural networks. The most popular tools for forest fire analysis are considered. This work proposed using hotspots to identify all fire and smoke pixels for automated forest fire contour detection. It made it possible to obtain contour polygons of the corresponding areas with various attributes: position, size, etc. The results are tested on Sentinel 2 satellite images of the Bvila region. The proposed method has an overall accuracy of 94.3% for the selection of forest fires.

Keywords: mapping forest fire, hotspots, Sentinel-2 satellite imagery, burned polygons

Statement of the problem. Forests are regularly affected by fires over a large area, measured in millions of hectares [1]. This problem has been relevant for more than ten years due to the extreme summer in Europe. The classic approach to solving the task of determining burnt areas and the degree of burning is based mainly on the analysis of field materials surveyed. Besides using such methods to associate with financial and labor costs, their regular use throughout the country is hardly economically justified and practically feasible. In recent years, satellite images are increasingly used. It makes it possible to significantly increase the completeness of detection and the accuracy of determining the area of drying planted areas, monitors the extent of the global deforestation of the planet [2], as well as more effectively organize a ground assessment of the quantitative characteristics of their condition. However, the detection and analysis of forest fires obtained using the special thermal sensors without using automation tools is an expensive and difficult process. For this reason, work is currently underway around the world to create automated systems for detecting and evaluating forest fires. At the same time, the main direction in the creation of such systems is the development of methods for the auto-

mated processing of satellite data. Since the use of the latter greatly simplifies the process of assessing burnt areas and in some cases (swamps, protected areas) exceeds the accuracy of the assessment on the ground.

Therefore, the relevance in research is due to the need for a prompt and economically feasible assessment of the consequences of forest fires.

Analysis of recent research and publications. An analysis of the literature data [3-5] allows us to draw the following conclusions: existing approaches are diverse based on simplified calculations and include a limited number of factors, most natural ones; forest fire monitoring from space is carried out in practice, as a rule, without atmospheric correction of satellite data; there are isolated examples [6] of procedures for an approximate consideration of optical-geometric conditions of observations in algorithms for satellite monitoring of forest fires. However, they do not investigate the influence of this factor on the effectiveness of early detection of fires from space. And given the variety of factors that affect the possibility of a forest fire, it dictates the need to use an integrated approach to include both natural and anthropogenic factors.

Using hyper-accurate neural networks for fire detection can provide better accuracy than conventional methods, as CNN automatically learns a set of visual features based on the training data [6]. The characteristics of CNNs provide certain advantages in visual processing, especially for multidimensional input vector images that can be directly injected into the model, thus avoiding the complexities of data recovery in feature extraction. Therefore, the currently existing models for predicting development dynamics using neural network technologies eliminate some of the shortcomings inherent in traditional models.

The purpose of the study is to develop information technology for detecting forest fire contours on digital optical satellite images in conditions of non-stationarity and uncertainty based on convolutional neural networks.

Statement of the main research material. The proposed information technology is described in detail. It consists of downloading input optical satellite images of any size, including data from the IR channel. Preprocessing of input data is provided, such as interference filtering, radiometric, and geometric data correction with spectral correction. The next step is CNN training of optical satellite data and classification for the three classes: fire, smoke, and background [7], and detection of hot-spot fire polygons. To identify hotspots proposes to combine them into one object and draw a contour of the territory on which it operated. It will allow not only to estimate the area of the fire but also to carry out its joint analysis with various maps,

determining, for example, the territory of which region the fire was active, what types of vegetation it passed through, etc. The construction of the general contour of the firebases on new observational data (hotspots) for the fire area becomes available and added to the previously formed fire polygon. The workflow detection of the hotspot fire polygons is shown in fig.1. At the same time, using various cartographic information, an annotation of individual hot spot polygons formed on their basis in a particular observation session. Also, practice is to obtain a polygon of the current fire by comparing data obtained at different times. Thus, at the end of the fire, we have its final contour (final polygon) with various attributes: in which region it operated, what area it passed (including covered and not covered with forest), the total local of forest types traversed by fire, the type of territory, on which a fire broke out, etc. In a specialized database was stored this information for further analysis.

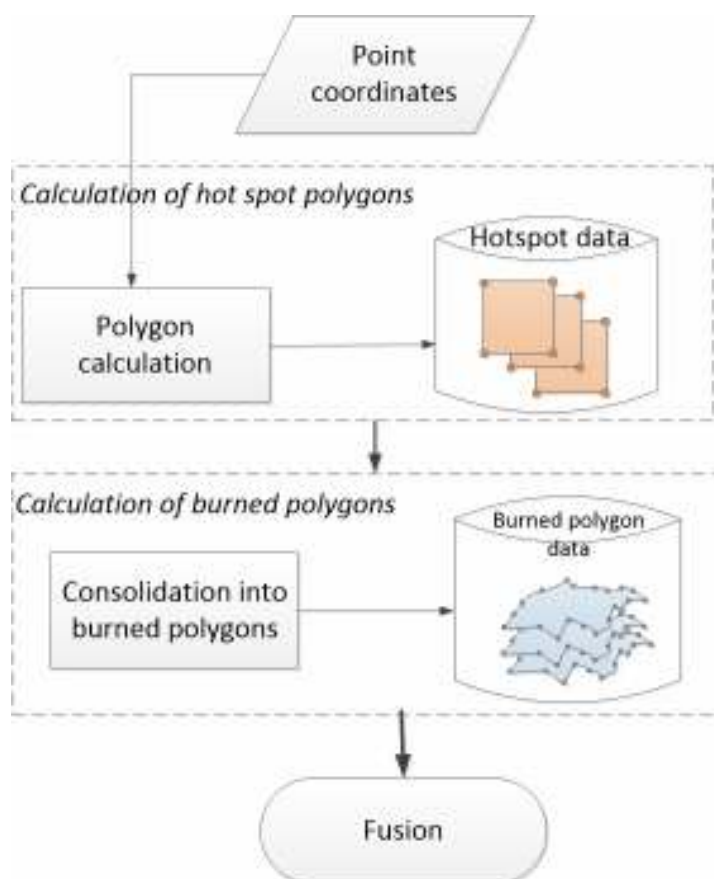


Figure 1 - Flowchart of the hotspot fire polygons methodology

The formation of polygons of fire sites uses results by the criterion of radiation temperature of active fires based on thermal sensors of the satellite with a spatial resolution of 1 km. These polygons may also include territories unaffected by the fire. This kind of error reaches its maximum values at the boundaries of the fire and

decreases as it approaches its center. The model formula (1) applies to reduce this kind of error [8]:

$$S_a = \begin{cases} \left(1 - \frac{k \cdot \Delta \cdot (1 - \delta)}{\sqrt{S_f}}\right) \cdot S_f \forall S_f > (k \cdot \Delta)^2, \\ \delta \cdot S_f \forall S_f \leq (4\Delta)^2 \end{cases} \quad (1)$$

where S_f is fire area in km²; S_a is adjusted fire area in km²; δ is pixel size in km; Δ is correction coefficient.

The proposed information technology was implemented using the Programming Tool Python. The client part consists of an interface (figure 2) for easy interaction with the system (navigation of interface, visual design of program screen forms), program code for loading algorithms, and a module responsible for sending data and receiving a response. Our work used the PyQt6 library for the implementation technology. The functionality of this library fully satisfied all the requirements for the visual design of the client side.

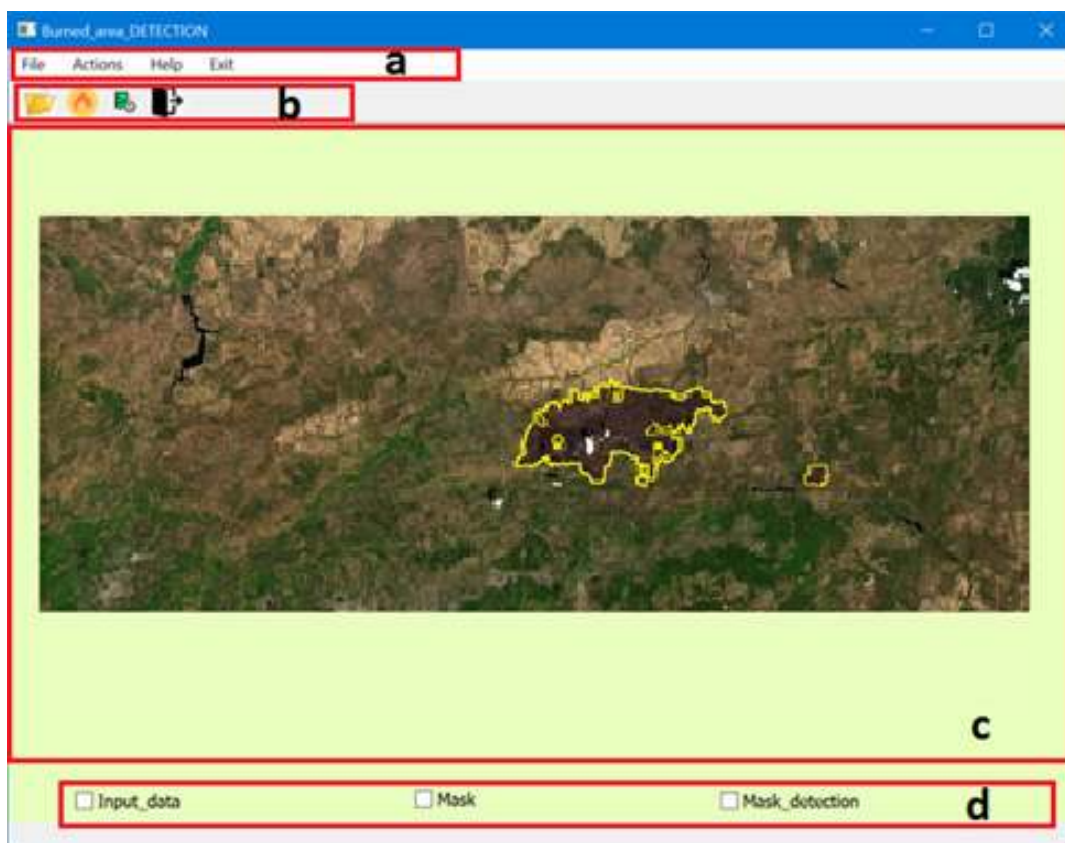


Figure 2 - User friendly Graphical Interface for fire detection:

- a) Menu bar; b) Tool bar; c) Display selected images view;
- d) Display control training related step's view

The algorithm for sending an image and getting a verdict and providing the results to the user was implemented using two helper functions (fig.3). The first function takes as input the path to the directory and reads all satellite imagery files (.tiff resolution) or image files (.jpeg) from it. The PyQt6 library used the `getExistingDirectory()` function of the `QFileDialog` class for the earlier step. This function allows selecting a directory in the opened explorer and returns the absolute path to the chosen directory.

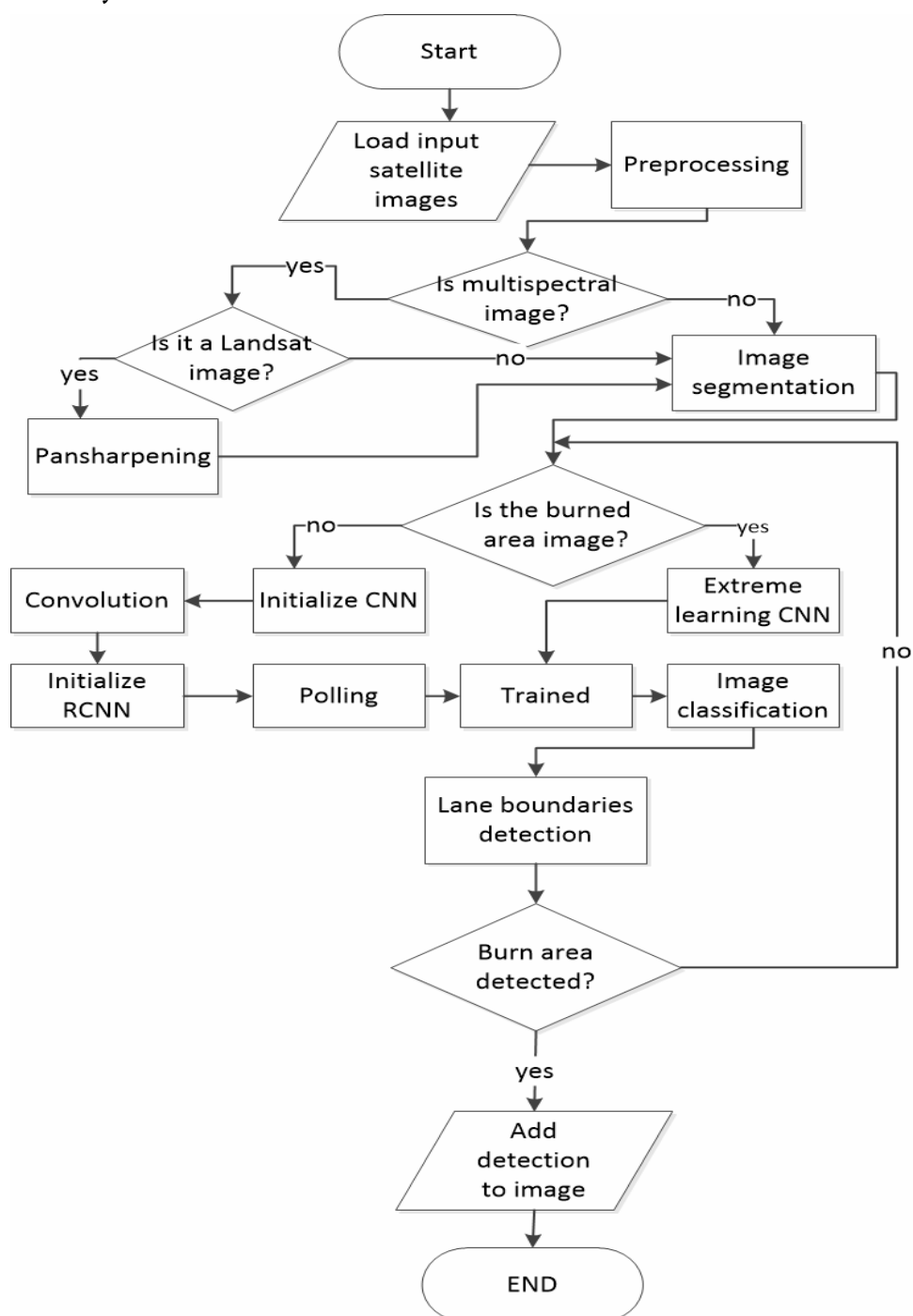


Figure 3 - Flowchart of the program realization

Next, using the Operation System library, we get the full names of all files stored in the selected folder and check their extensions. If the file extension matches the requirement (.tiff, .jpg), then this file is read using the `imread()` function of the OpenCV library. In this step, the algorithm checks the input data from which satellite they were received. If data from a Landsat satellite (which contains multispectral and panchromatic images (bands)), then it performs pansharpening to increase the resolution of the multispectral image to panchromatic. Band fusion results in a high-resolution color image. The following function is responsible for the serial transmission of images read from the user-selected directory for further analysis using a neural network. A friendly Graphical Interface provides the program results for the user. Used the library of the `post()` procedure for sending a request. Further, the main program window allowed them to view the contours of burnt areas (violations of the forest cover) for the user. The OpenCV library used the `imshow()` function to display images.

Figure 4 presents an activity diagram based on functional and non-functional requirements. This diagram shows the process of the user interacting with the system to identify wildfire detections.

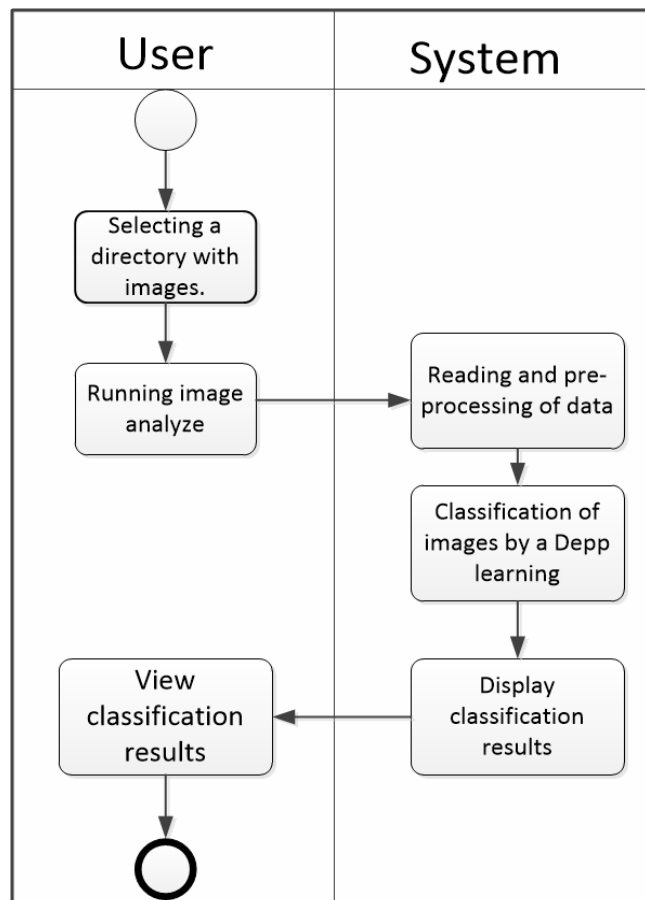


Figure 4 - Activity diagram

Experiment. Experiments were carried out on one small test area. It is the Avila region in Spain (Fig.5a). A fire was identified in 2021 from Sentinel-2 satellite imagery taken between July and the end of September. Therefore, in the work, the first stage of the proposed technology is the radiometric and geometric correction of data, as shown in Fig. 5b. Examples of CNN fire detection and construction of its polygon are shown in Fig. 5c. The overall accuracy for the Avila region from Table 1 corresponds to the high classification accuracy of the proposed method. The confusion matrix [9] is one of the most widely used methods for assessing the quality of a classification used in machine learning and image analysis, also known as the fit matrix. This method makes it easy to evaluate how effectively the system separates two classes: burnt area and not burnt area. Table 2 shows the confusion matrix results.

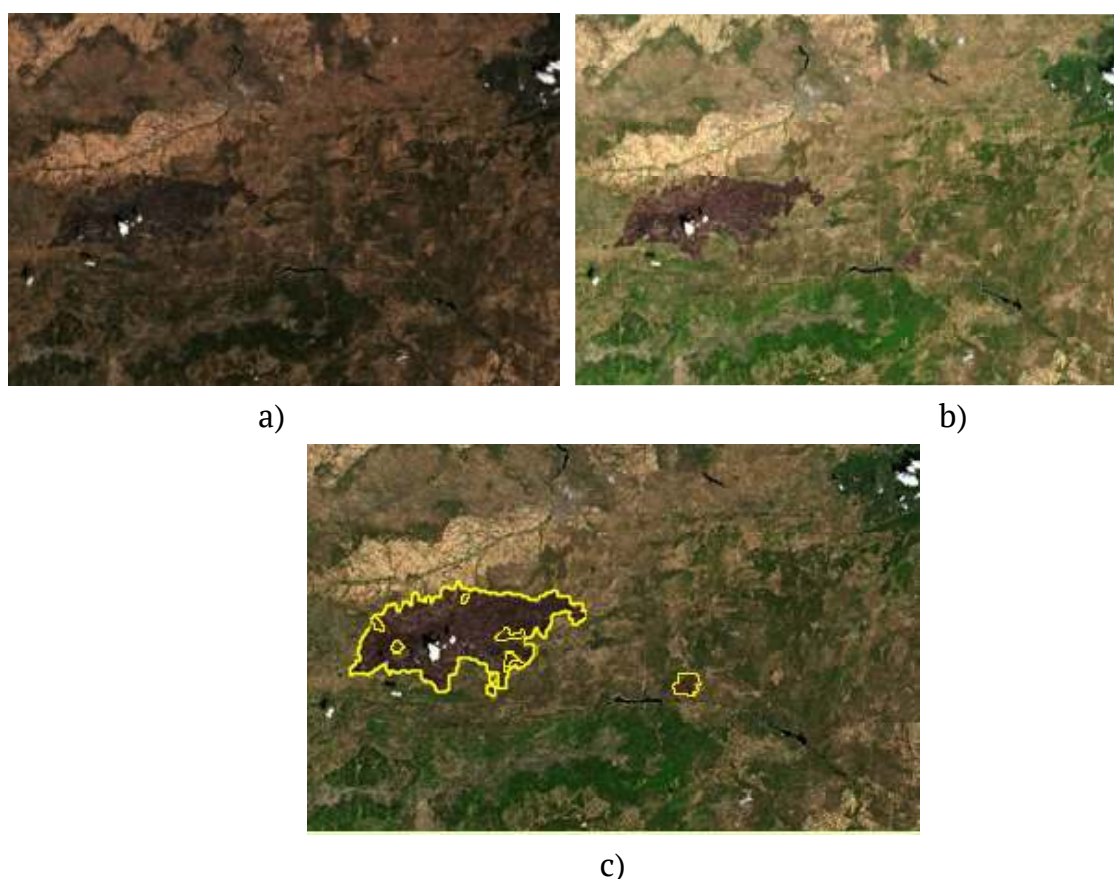


Figure 5 - Satellite image from Avila:

- a) after fire synthesized according to the scheme Band4-Band3-Band2;
- b) after data processing;
- c) result of the forest fire contour detection

Table 1

Accuracy assessment of the spectral indicators and the proposed technology

Territories	Overall accuracy, %		
	dNBR index	BAIS2 index	Proposed technology
Avila region	87.4	90.2	94.3

Table 2

Confusion matrix

Territories	Expert review, %		Overall accuracy	Proposed Technology (automated), %		Overall accuracy
	Was fire	Wasn't fire		Was fire	Wasn't fire	
Burnt area of Avila region	50,8	22,4	9,4	63,7	1,6	7,4
Not burnt area of Avila region	49,2	77,6	90,6	36,3	98,4	92,6

Conclusions. This paper presented an information technology for automated forest fire contours detection in conditions of non-stationarity and uncertainty based on convolutional neural networks. The functionality of the technology allows solving the tasks, starting from the moment of receiving the input data and ending with the export of a hot-spot fire polygonal file describing the area that has undergone a burnout. The data from the Sentinel-2A and Sentinel-2B satellites are characterized by the best ratio of spatial, spectral, and temporal indicators among publicly available satellite remote sensing data. The results were tested on optical Sentinel 2 satellite images for Avila regions and the proposed method shows an overall accuracy of 94.3%.

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***Інформаційна технологія визначення контурів лісових пожеж
за даними оптичної супутникової зйомки***

Кількість лісових пожеж протягом останніх десяти років істотно збільшилась. Це вказує на те, що оцінка площі та розташування територій, пройдених лісовими пожежами, є дуже актуальною задачею сьогодення. Використання даних супутникової зйомки значно спрощує процес оцінки лісових пожеж. Мета досліджень полягає в розробці інформаційної технології автоматизованого визначення контурів лісових пожеж на цифрових оптичних супутникових знімках в умовах нестационарності та невизначеності на основі згорткових нейронних мереж. Для визначення контурів лісових пожеж запропоновано використати точки теплових аномалій для ідентифікації пікселів

вогню та диму. Це дозволило отримати полігони відповідних областей з різними атрибутами: положенням, розміром, тощо. Результати протестовані на супутникових оптичних знімках Sentinel 2 регіону Авіла. Запропонований метод має загальну точність виділення лісових пожеж 94,3%.

Ключові слова: лісова пожежа, теплова аномалія, супутникові знімки Sentinel-2, полігон, згарище.

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