International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Internet of Things Application for Green Border Surveillance, Based on Edge Detection Techniques

Astrit Hulaj[1], Rame Likaj*[2], Xhevahir Bajrami[3]

Submitted: 11/11/2022 **Revised**: 23/01/2023 **Accepted**: 13/02/2023

Abstract: In the last decade, state border security and its evaluation and improvement techniques have aroused great interest. In particular, a greater focus is on evaluating and improving green border security techniques. This field is very current and delicate, as it is about national security and border protection against attacks and threats of various kinds. Border protection does not include only physical state security, but recently border security has created a specific economic interest because of the damage it causes in many aspects. The implementation of IoT technology, namely the application of multimedia sensors for green border surveillance, is accompanied by an efficient algorithm for detecting the edges of images captured by sensors. Our approach will increase detection efficiency, improve the time required for edge detection, and reduce energy consumption and the amount of memory used by the sensors. Furthermore, a new approach algorithm is introduced to improve the existing algorithms in terms of edge detection in those areas where edge detection is difficult. The proposed algorithm's performance is experimented with using a low-cost hardware Raspberry pi 3B+. Also, the achieved results will be analyzed and compared with others existing algorithms for detecting the edges of the images.

Keywords: *Algorithm, edge detection, internet of things, green border, WSN*

1. Introduction

The IoT nowadays is a technological revolution. IoT today is evolving rapidly, and wireless IoT applications have shown an explosive growth trend [1]. Devices in an IoT network represent an interface between the physical world and the world of electronic devices. These devices are sophisticated devices [2] that are often used to detect or collect information in a particular physical environment, such as motion detection, changes in temperature, pressure, vibration, humidity, and others.

Technically, they are devices that enable the transformation of the parameters of an event from the physical environment into various signals that can be measured, interpreted, and analyzed. In other words, equipment practically measures anything of interest and provides an electrical or optical signal at the output.

Nowadays, there have many applications of IoT devices. For example, applications for heart monitoring, automobiles with built-in sensors, farm animals equipped with biochip transponders, field operation devices used by firefighters in search and rescue, and so on [3]. In other words, the IoT allows private and public-sector organizations to manage assets, optimize performance, and develop new business models [4], [5]. Today, devices that have awakened interest considerably in many applications and research are sensor devices. In particular, the focus is on multimedia sensors. The multimedia sensors are devices that provide views of their monitoring area.

Therefore, the application of these devices has aroused great interest in many research and applications. Due to the benefits that the multimedia sensor offers, we have proposed that such a device be applied for border security issues, respectively, along the green borderline. This area is very current and delicate, as it is about national security and border protection against attacks and threats of various kinds. Therefore, multimedia sensors will provide green state border surveillance based on video detection techniques. However, these video detection techniques pose some challenges, as security authorities have to deploy multimedia sensors in areas not easily accessible. On the other hand, the life span of multimedia sensors depends directly on their battery [6].

Finding suitable alternatives that will affect energy consumption saving is a significant factor. A much more important step in energy saving by sensor nodes [7] is transforming captured images by sensors in black and white images. However, transforming the image to a black-

[1]*Faculty of Computer Science and Engineering, University for Business and Technology, Prishtina, KOSOVO*
ORCID ID : 0000-0002-4059-2034
[2]*Department of Mechatronics University of Prishtina, Prishtina, KOSOVO*
ORCID ID : 0000-0003-2127-2016
[3] Department of Mechatronics *University of Prishtina, Prishtina, KOSOVO*
ORCID ID : 0000-3343-7165-777X
** Corresponding Author Email: rame.likaj@uni-pr.edu*

and-white image will result in the loss of some pixels of the object's structure inside the image. For the preservation of object structure, edge detection has a very significant role. Therefore, in this paper, we will practically test the performance of our proposed image edge detection algorithm, and the results obtained will be compared and analyzed with traditional edge detection filters.

2. Related Works

The use of new technology for improving security along the state borderline is an essential factor [8]. So, borderline security nowadays is hard to imagine without the use of modern technology. Therefore, Internet of Things technology plays a significant role in border security.

In particular, the use of multimedia sensors along the green borderline has a very significant role. However, the use of sensor technology is characterized along the green borderline by challenges of different natures [8]. As we have mentioned, among the primary challenges is the electrical power supply of multimedia sensors [8]. As is well known, the lifetime of sensor nodes is directly dependent on their battery life. So, constantly research the most suitable methods to save the sensor node's energy. Therefore, in our research, we present an efficient algorithm that enables the transformation of black-and-white images. Also, the proposed algorithm detects the edges of objects to preserve their structure. Today, we can find several types of research and algorithms that enable the detection of image edges. In the following will be presented some of the research in this field by other authors.

In [8], has been presented an algorithm that treats the energy-saving process for sensor nodes. The authors proposed that the images captured are converted by the sensor nodes to a black-and-white image. The authors have proposed a concrete method that enables the restoration of image pixels corrupted by various noises such as Salt & Pepper, Periodic Speckle, Poisson, FFT Phase, and Gaussian noises [8]. Then, to determine the shape of the objects in the black and white image, pixels are classified in general into two extreme values. These values will correspond to the minimum and maximum values of the image pixels. Thus, at the output, after clearing the image from various noises, they obtained an image of black and white with a clean structure [8]. They have achieved this without applying any filters to detect the edges of objects in the image.

In [9], the authors have developed a reliable, robust, and low-cost network to monitor various thermal anomalies in critical volcanic zones in real-time, based on the IoT. The proposed network uses the LoRa communication protocol, and continuous monitoring of temperature values at different points in the desired areas is applied. The proposed network by the authors has shown good performance in the monitoring process.

In [10], the authors have proposed two integrated algorithms to eliminate noise and detect the edges of the image. First, the proposed algorithms address the reduction of noises from the image and then address the proposed methods for detecting pixels that correspond to the information representing the edges of objects. The authors conclude that the proposed algorithms are efficient for application to the devices applied for border control. There the authors also analyze various issues related to green border security.

In [11], the authors proposed a fuzzy technique for detecting the edges of images in the field of medicine. In this technique, the authors have proposed a fuzzy technique that will be applied to adapt the change of hesitation constant for the image. They have also proposed changing the threshold level instead of using a technique with permanent rules, as applied to many other fuzzy methods and techniques. The authors conclude that their proposed technique is more efficient than other fuzzy techniques.

In [12], the authors have proposed an improved method to detect the edges of images. However, the focus of applying the proposed method by authors has been the application in detecting the edges of X-ray images. "The proposed method on applying the Gaussian filter and the statistical range is based. In this method, the authors have used the Gaussian Filter for pre-processing and image enhancement" [12]. Whereas, authors have applied the Statistical range to calculate the difference between the maximum and minimum points. During the calculation, the authors used a 3x3 matrix. The authors in their research have also presented comparisons between the proposed method and four other existing methods.

In [13], the authors have proposed an energy-efficient saving algorithm for monitoring purposes along the borderline. The proposed algorithm was designed for wireless sensor networks to be applied. They have analyzed routing process information from sensor nodes. Also, they have proposed that the sensors go into sleep mode when the sensor nodes are idle. This logic directly will affect to increase the network of sensor lifetime. The authors also proposed an efficient algorithm for routing information from one node to one sensor node. The proposed algorithm enables the sensor nodes to handle the information collected from the monitored area and send a minimum number of reports to the network. Therefore, this will affect a minimum number of alarms for the same event along the borderline that node sensors have sent to the network. Furthermore, it will affect sensor nodes not to spend energy for the same event along the borderline.

This section briefly presents some of the other authors' research that has addressed and analyzed various problems related to object edge detection within the image. However, other authors do not address in their paper the detection of image pixels in those parts where the difficulty of detection increases. In our research, we propose an algorithm that enables efficient edge detection in those parts of the image where the difficulty of pixel detection increases.

The results that we presented show that the existing algorithms fail to detect edges in those parts of the image where the difficulty of detection increases. The following are the solutions and results achieved by testing our modeled algorithm. The results obtained from the algorithm testing are comparable to the results achieved by the existing algorithms.

3. Problem Description and Solution Proposal

IoT has aroused interest, especially after increasing the network capacity provided by the latest generations of mobile technology. In addition, the installation of low-cost sensors in different equipment and machines has made tracking, surveillance, analyzing, and responding much easier and more efficient. So, IoT technology can be found today in national security, business, agriculture, manufacturing, transport, sports, and others [14].

Each of the devices connected to the Internet, in a way, passes different information on the Internet that another device can use, also connected to the Internet to perform specific tasks [15, 16]. In other words, each device that can connect to the Internet in one way or another can be considered IoT. This new technology encourages everyone to learn, apply, improve and develop it. One of the IoT devices that has aroused much interest among many researchers is sensor technology. In particular, multimedia sensors are the future technology that will provide solutions to many problems at a low cost [17]. Many states today have different problems regarding the security of their state borders. Particularly challenging for security authorities is improving the security state along the green borderline. The most significant challenge is to improve security in those border areas where the terrain is difficult to monitor with high-resolution cameras and drones.

This research proposes an alternative solution with low cost and effective surveillance of these border areas. The alternative that we proposed is the application of multimedia sensor technology. We proposed in our research the placement of multimedia sensors along the green borderline, as in Figure 1. The placement, of the node sensors along the green borderline, as in Figure 1, provides continuous and complete monitoring of that area. However, the proposed sensors are supposed to decide during areas borderline that are not easily accessible by security authorities, as well as their life depends directly on their battery. Therefore, to improve the performance of the sensors during operation, we propose an efficient algorithm.

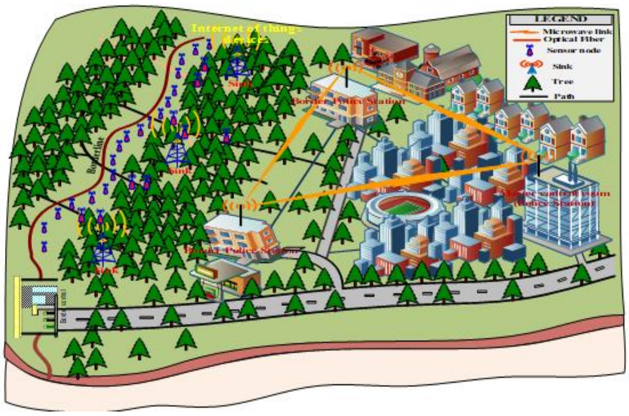

Figure 1. The architecture of placement of sensors during the green borderline [6].

The proposed algorithm enables the conversion of images captured by sensors to black-white images and improves the existing algorithms for detecting pixels corresponding to the edges of objects. Transforming images to black-white affects the reduction of processing and transmission power requirements to the sensor nodes. Reducing the requirements for processing and transmission affects energy savings. Respectively, it affects the increase of the lifetime of the sensor nodes. We use IoT technology to implement and experiment with the proposed algorithm in this context.

4. Proposed Algorithm

Nowadays can be applied many methods for detecting pixels corresponding to the edges of the image. In this research, we have proposed an efficient edge detection algorithm that we also will test in practice. Our algorithm has applied a dynamic change of the threshold and factor value. Then, the threshold value will be compared to the gradient value. The gradient value was calculated two loops by applied. The first loop is used to evaluate the image pixels. Inside the first loop is implemented a 3x3 loop as a filter. The logic applied to the proposed algorithm is presented below through pseudocode.

The alternative that we proposed is the application of multimedia sensor technology. We proposed in our research the placement of multimedia sensors along the green borderline, as in Figure 1. The placement, of the node sensors along the green borderline, as in Figure 1, provides continuous and complete monitoring of that area. However, the proposed sensors are supposed to decide during areas borderline that are not easily accessible by security authorities, as well as their life depending directly on their battery. Therefore, to improve the performance of the sensors during operation, we propose an efficient algorithm. The proposed algorithm enables the conversion of images captured by sensors to black-white images and improves the existing algorithms for detecting pixels corresponding to the edges of objects. Transforming images to black-white affects the reduction of processing and transmission power requirements to the sensor nodes. Reducing the requirements for processing and transmission affects energy savings. Respectively, it affects the increase of the lifetime of the sensor nodes. In this context, we use IoT technology to implement and experiment with the proposed algorithm.

Algorithm: Pseudocode of our modeled Algorithm.

1. The connection of the Raspberry with MATLAB;
2. Begin Main program;
3. Give value for Thresh and Factor and start step with ***k=1;***
4. ***for ii*** → ***1*** to number of frames;
5. ***If k*****<** ***ii then k*** is equal with ***ii***;
6. ***end*** first ***if;***
7. ***else***
8. ***if k*** is equal with 1 ***then k*** is equal with 100;
9. ***end*** **loops**
10. The following apply the conditions for Reading Frames and Edge Detection;
11. ***while*** → Stopframe <= No_of_frames;
12. Reading of videoobjects, included;
13. Startframe and Stopframe;
14. ***for l*** → ***1*** to number of frames;
15. The number of frames captured during registration is defined ***a(i, j);***
16. Convert captured frames to grayscale frames, ***A(i,j);***
17. Application of loop for detecting images pixels ***A(i,j);***
18. Where ***i*** take values ***i ϵ (1.....n-2)*** and ***j*** take values ***j ϵ (1....m-2);***
19. $A1(i,j) = \sum_{i=1}^{n-2}\sum_{j=1}^{m-2} A((i:i+2, j:j+2)$
20. Application 3x3 filter within loop;
21. $A2(x,y) = \sum_{x=1}^{3}\sum_{y=1}^{3} A1(x,y)$
22. Gradient magnitude calculation;
23. Application of conditions for finding edges;
24. ***if*** → gradient value > threshold value
25. ***then*** → it is the edge
26. ***else*** → it is not the edge
27. ***end if***
28. Now, the edges are found, including the Thresh and Factor value;
29. After the edges are found→ **writeVideo** (vid, detect edge);
30. ***end for***
31. Startframe increases + k;
32. Stopframe increases + k;
33. ***end for***

5. Results and Discussions

First, in this section, we have presented the results achieved by applying traditional algorithms for detecting pixels representing the edges of the image.

Second, we have presented the results achieved by our proposed algorithm for edge detection. The achieved results will be interpreted and compared depending on the algorithm applied. To experiment with existing and our algorithms' performance, we have used MATLAB 2020a and an image [18] of 153x329 pixels. The reason for choosing this image for experimentation and testing of existing algorithms and the proposed algorithm exists because of difficulties detecting edges in some specific parts within the image. The main problem exists in the detection of image edges on the part of the eagle's tail. In this part, the color of the object is very similar to the background color. Precisely, the performance measurement of the algorithms is performed based on their efficiency in detecting the pixels representing the edges of the image in this part. In the end, we present an analysis of the results achieved by the practical experimentation of the algorithms.

5.1. Results Achieved with the Application of Traditional Edge Detection Filters

To analyze the performance and behavior of the proposed algorithm, compared to existing algorithms, in the following, we have analyzed and presented the achieved results. The results achieved are shown by applying traditional edge detection algorithms in Figure 3. Also, to better measure the efficiency of the existing edge detection algorithms in detecting pixels corresponding to the edges of objects within the image, in Table 1, we have presented the number of pixels with values of 1s and 0s detected by applying these filters.

Initially, the recorded image into a grayscale image converted, and then into a black and white image. After converting the image to black and white, was used a specific filter to detect pixels corresponding to the contour of the objects. From the results presented in Figure 2, we can see that, when applied Roberts, Prewitt, and Sobel filter for detecting the edges of the objects in the image does not provide a good detection of the edges of the objects within the captured image. The inefficiencies of these filters also can be ascertained from the results presented in Table 1. By analyzing the results achieved by applying these filters, we can see that we have lost a considerable number of pixels corresponding to the edges of the figure.

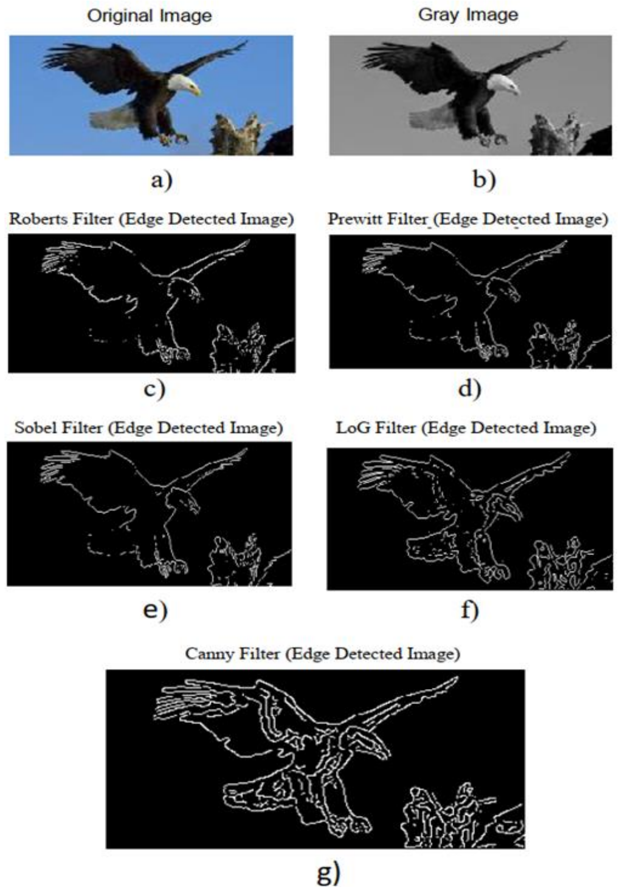

Figure 2. Results after applying a) Original image; b) Grey Image; c) Roberts filter; d) Prewitt Filter; e) Sobel Filter; f) Laplace Filter; g) Canny Filter.

Especially in areas where the difficulty of detecting pixels representing the edges of the image (in this analysis in Eagle's tail) increases. The pixels in the eagle tail area are with nuance roughly similar to the background pixel nuance. In this part, these filters have almost failed to detect edges in that area. The better results if compared to Roberts, Prewitt, and Sobel filter by applying the log filter we have achieved. However, even though we have achieved better results, we still cannot say that we have a good extraction of image features. The number of pixels 1s detected by applying the log filter is 2364, which is significantly higher than when we implemented the Roberts, Prewitt, and Sobel filter but much smaller than when we implemented the Canny filter the algorithm proposed.

Table 1. Number of pixels after applying some of the filters

Filters	Roberts	Prewitt	Sobel	LoG	Canny
Total pixels	50337	50337	50337	50337	50337
Total of pixels 0s	48576	48657	48660	47973	46884
Total pixels 1s	1761	1780	1677	2364	3453

Significantly, better results than when we implemented the LoG, Roberts, Prewitt, and Sobel filters when we implemented the Canny filter we have achieved. However, although this filter provides significantly better results than the LoG, Roberts, Prewitt, and Sobel filters, this filter has failed to extract several important image characteristics. In particular, this is more pronounced in the several difficult detection areas of the pixels, namely the pixels in the most problematic areas of the detection (in this analysis in the Eagle's tail). Analyzing the results achieved with the application of the Canny filter, we can conclude that the Canny filter fails to extract in the best possible way the details of the figure, namely the structure of the Eagle tail in this case.

Thus, with the application of the Canny filter, the best possible result is not achieved. However, it can see when are compare the results in Figure 2(g) and Table 1 with the results obtained with the proposed algorithm's implementation.

5.2. Presentation of the Results Achieved with the Application of the Proposed Algorithm

This subsection will present the results achieved by applying the proposed algorithm for image edge detection and the interpretation and comparison of the achieved results. The results achieved from this algorithm are compared and interpreted in the context of the results achieved by traditional filters. Figure 3 and Table 2 presented the results achieved by implementing the proposed algorithm. The logic used to obtain the results is the same as that used in traditional filters.

The accuracy of the proposed algorithm compared to the Canny filter in qualitative and quantitative aspects can be analyzed.

In the aspect qualitative, we can see that this algorithm enables a clear image structure with all the detected features (see Figure 3). Initially, we can notice the accuracy of the proposed algorithm during the detection of pixels in the lower left of the eagle wing. If we analyze the results presented in Figure 2(e) and Figure 3, we can see that when the Canny filter is applied, the edges detected on the left side of the Eagle are less pronounced than when the proposed algorithm is applied. Another advantage of this algorithm is the detection of pixels in the most problematic parts of the image. So, the accuracy in detecting pixels in areas where the color contrast representing objects is very similar to the background of the image captured.

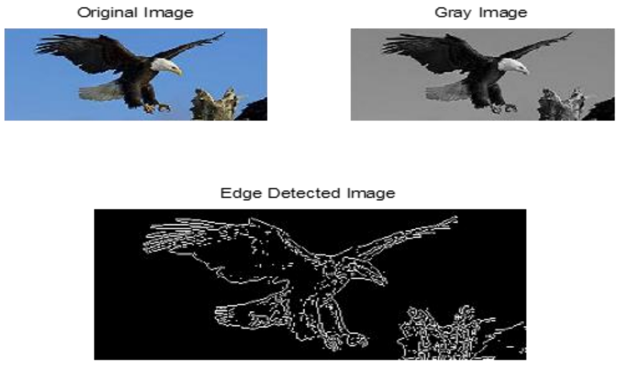

Figure 3. Results after implementation of the proposed algorithm.

From Figure 3, we can see that by implementing the proposed algorithm, the complete structure of the eagle tail is extracted. The eagle structure presented in Figure 3, cannot be achieved by implementing the Canny filter and other traditional filters, especially in the parts of the image structure where edge detection is of a high degree of difficulty.

In quantitative terms, be noticed that the proposed algorithm reaches to detect more 1s pixels compared to existing filters. The analysis of the proposed algorithm in the context of quantitative efficiency is in summary form in Table 2.

Table 2. Results After Applying the Proposed Algorithm

Proposed Algorithm	**Number of pixels**
Total pixels	50337
Total of pixels 0s	46831
Total pixels 1s	3506

Based on the results presented in Table 2, we can see that the number of pixels 1s detected by applying the proposed algorithm is 3506. This number of pixels 1s is significantly higher than when are applied the Roberts, Prewitt, Sobel, and LoG filters, but in comparison to the Canny filter, this number is only 53 pixels. Thus, based on the results presented in Figure 3 and Table 2, we can conclude that implementing the proposed algorithm can provide a good detection of the edges of the image and detection of the complete image structure captured by sensors.

5.3. Comparison of the Results of the Proposed Edge Detection Algorithm with Existing Filters

To measure the accuracy and efficiency of the proposed algorithm along the process of detecting the edges of the image captured by the sensors, in this sector, we will compare and analyze the results achieved with the application of the proposed algorithm against existing filters. In summary form, Table 3 and Table 4 presented the results achieved from the performed simulations. Based on the results presented in Table 3, the number of pixels detected and corresponding with the edges of the image captured by the sensor is significantly higher when applied the proposed algorithm compared with the Roberts, Sobel, Prewitt, and LoG filters.

A minor change is in the case of applying the canny filter. The proposed algorithm and the Canny filter are only 53 pixels. However, as we have mentioned, the accuracy and efficiency of the proposed algorithm are especially pronounced when the difficulty of detecting the edges of the image is greater. Therefore, based on the results in Table 3, we can conclude that the proposed algorithm for detecting the edges of the image improved the existing algorithms by: 1.5% compared with the Canny filter, 32.57% compared with the LoG filter, 49.77% compared with the Roberts filter, 52.08% compared with the Prewitt filter, and 52.17% compared with the Sobel filter.

Table 3. Comparison of the Results of the Proposed Algorithm with the Existing Edge Detection Filters

Comp. of results	Roberts	Sobel	Prewitt	LoG	Canny
Proposed Algorithm	3506	3506	3506	3506	3506
Existing filters	1761	1677	1680	2364	3453
Difference	1745	1829	1826	1142	53
Difference in %	49.77	52.17	52.08	32.57	1.5

We also have measured the performance of the proposed algorithm regarding image processing time. Results are presented in Table 4 about the image processing time for each existing filter and the proposed algorithm. From the results presented in Table 4, the proposed algorithm, compared to the traditional filters, improves the time required for processing and detecting the edges of the image.

Table 4. Comparison of Results Based on the Time Required to Detect Edges

Comp. of results	**Roberts**	**Sobel**	**Prewitt**	**LoG**	**Canny**
Proposed Algorithm	0.21s	0.21s	0.21s	0.21s	0.21s
Existing filters	0.28s	0.26s	0.22s	0.30s	0.26s

5.4. Practical Implementation and Experimentation of the Proposed Algorithm

In this sector, we will practically implement and experiment with the accuracy and efficiency of the proposed algorithm. We experimented with the algorithm: Raspberry pi 3B +, Web-Cam: Sony IMX219 Color CMOS with an 8-megapixel sensor. The configured system for algorithm experimentation is shown in Figure 4.

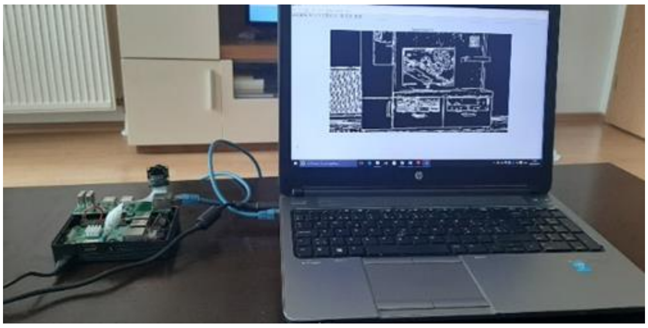

Figure 4. Implementation of the system for practical testing of the proposed algorithm.

After system configuration, the system is connected to MATLAB 2021a software. When the connection to the MATLAB program is completed, we have executed the written code. Algorithm performance experimentation is performed in a closed environment. The experiment is performed with different objects. In this case, recorded a video with a length of 15 seconds. However, due to the impossibility of presenting the video in this paper, we have analyzed the last frame (image) in this video. This image is used to experiment with the performance of each algorithm. The results obtained from the practical experiment for each algorithm are shown in Figure 5. From the results in Figure 5, we can see that the existing filters fail to detect the edge of the TV at the bottom left. Some of the traditional filters fail to detection the pixels of the image in many other parts as well. Slightly better results are obtained by applying the Canny filter. Nevertheless, even the Canny filter fails to detect the edges when the detection difficulty increases (the bottom edge on the left side of the TV).

Exactly the accuracy and efficiency of the proposed algorithm are highlighted compared to traditional filters in the ability of this algorithm to detect pixels in this part of the image. Moreover, as can be seen from the results presented in Figure 5(g), this algorithm reaches to detection pixels of the image even in those cases when the difficulty of detecting them is more problematic (in this case, including the bottom edge on the left side of the TV). Therefore, based on the results obtained from the performed experiments, we can conclude that our algorithm effectively detects pixels in those parts of the image where traditional filters fail to detect them.

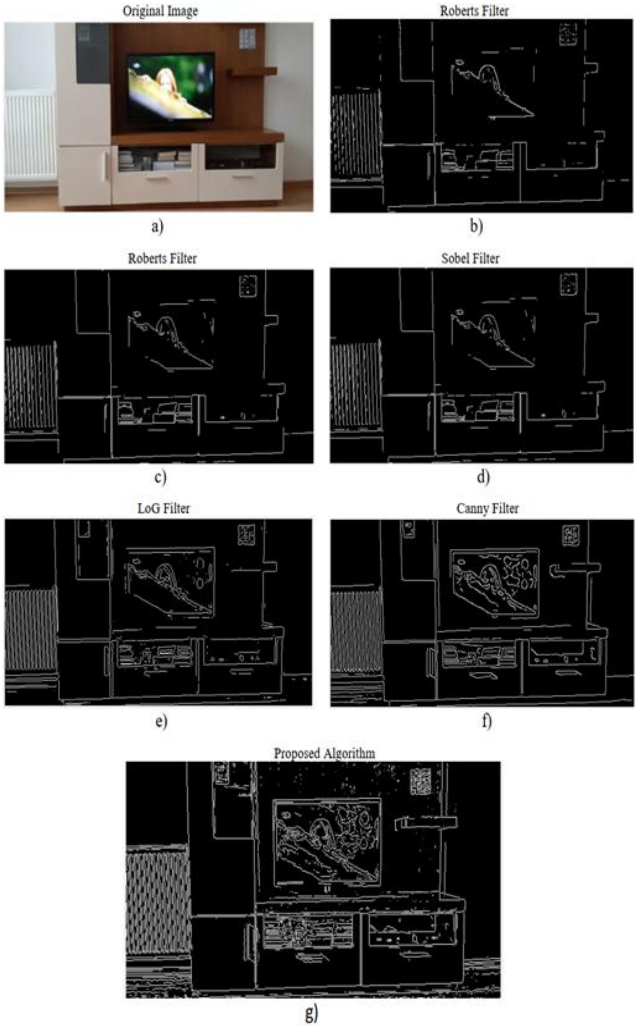

Figure 5. Results achieved from the practical implementation of the proposed algorithm: a) Original image; b) Roberts filter; c) Prewitt Filter; d) Sobel Filter; e) Laplace Filter; f) Canny Filter; g) proposed algorithm.

6. Conclusion

This paper presents our efforts to construct an algorithm that improves existing algorithms in the edge detection of the object in the image. This algorithm improves algorithms from two points of view: the point of view of the precision of edge detection and the point of view of time efficiency required for image edge detection. Also, to experiment with algorithm efficiency in real-time, the IoT technology we have applied, as a technology of the time. From the practical experiment, we proved that the algorithm efficiency is better than the existing filters. Moreover, our algorithm was more efficient, especially in detecting pixels corresponding to the edges of objects in those areas where detection difficulty was harder. The results presented in this work can have great significance for security authorities and national security in general. Therefore, we can conclude that this algorithm is accurate and convenient to implement in security systems and beyond.

Acknowledgments

This research is supported by the University for Prishtina and Technology and the Ministry of Education, Science, Technology, and Innovation.

Author contributions

Astrit Hulaj: Conceptualization, Methodology, Software, Field study **Rame Likaj:** Data curation, Writing-Original draft preparation, Software, Validation., Field study **Xhevahir Bajrami:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

[1] A. Hulaj, E. Bytyci, and V. Kadriu. "An Efficient Tasks Scheduling Algorithm for Drone Operations in the Indoor Environment," International Journal of Online and Biomedical Engineering (iJOE), vol. no. 11, pp. 42–57, 2022. https://doi.org/10.3991/ijoe.v18i11.29977

[2] O. Vermesan, M. EisenHauer, M. Serrano, P. Guillemin, H. Sundmaeker, Z. E. Tragos, and C. E. Darmois, "The next generation internet of things–hyperconnectivity and embedded intelligence at the edge," *Next Generation Internet of Things. Distributed Intelligence at the Edge and Human Machine-to-Machine Cooperation*, pp. 19-102, 2018.

[3] R. Desai, A. Gandhi, S. Agrawal, P. Kathiria, and P. Oza, "Iot-based home automation with smart fan and ac using nodemcu," *In Proceedings of ICRIC 2019*, pp. 197-207, 2020, Springer. https://doi.org/10.1007/978-3-030-29407-6_16

[4] O. Vermesan, and P. Friess, "Internet of things applications-from research and innovation to market deployment," vol. 29, 2022.

[5] M. El-Hajj, M. Chamoun, A. Fadlallah, and A. Serhrouchni, "Analysis of authentication techniques in Internet of Things (IoT)," *In 2017 1st Cyber Security in Networking Conference (CSNet)*, pp. 1-3, 2017. IEEE. https://doi.org/10.1109/CSNET.2017.8242006

[6] A. Hulaj, A. Shehu, and X. Bajrami, "Application of Wireless Multimedia Sensor Networks For Green Borderline Surveillance," *Annals of DAAAM & Proceedings*, 27, 2016. https://doi.org/10.2507/27th.daaam.proceedings.122

[7] Novian Anggis Suwastika, Yovan Julio Adam, Rizka Reza Pahlevi and Maslin Masrom, "Math Balance Aids based on Internet of Things for Arithmetic Operational Learning" International Journal of Advanced Computer Science and Applications (IJACSA), vol 13, no. 8, 2022. http://dx.doi.org/10.14569/IJACSA.2022.0130826

[8] A. Hulaj, and A. Shehu, "An Efficient Algorithm to Energy Savings for Application to the Wireless Multimedia Sensor Networks," *In International Conference on Emerging Internetworking, Data & Web Technologies*, pp. 349-358, 2018. Springer, Cham. https://doi.org/10.1007/978-3-319-75928-9_31

[9] S. Awadallah, D. Moure,and P. Torres-González, "An internet of things (IoT) application on volcano monitoring. Sensors," vol.19, no. 21, pp. 4651, 2019. https://doi.org/10.3390/s19214651

[10] A. Hulaj, A. Shehu, and X. Bajrami, "The application of a new algorithm for noise removal and edges detection in captured image by WMSN," *TRANSACTIONS on SIGNAL PROCESSING*, pp. 2224-3488, 2016.

[11] M. A. Alawad, A. D. F. Rahman, O. O. Khalifa, and A. N. Malek, "Fuzzy logic based edge detection method for image processing," *International Journal of Electrical and Computer Engineering*, vol. 8, no. 3, pp. 1863, 2018. https://doi.org/10.11591/ijece.v8i3.pp1863-1869

[12] K. A. Bharodiya, and M. A.Gonsai, "An improved edge detection algorithm for X-Ray images based on the statistical range," *Heliyon*, vol. 5, no. 10, pp. 02743, 2019. https://doi.org/10.1016/j.heliyon.2019.e02743

[13] A. Razaque, and M. K. Elleithy, "Energy-efficient boarder node medium access control protocol for wireless sensor networks," *Sensors*, vol. 14, no. 3, pp. 5074-5117, 2014. https://doi.org/10.3390/s140305074

[14] I. Lee, and K. Lee, "The Internet of Things (IoT): Applications, investments, and challenges for enterprises," *Business horizons*, vol. 58, no. 4, pp. 431-440, 2015. https://doi.org/10.1016/j.bushor.2015.03.008

[15] F. Oquendo, "Formally describing self-organizing architectures for systems-of-systems on the internet-of-things," *In European Conference on Software Architecture*, pp. 20-36, 2018. Springer, Cham. https://doi.org/10.1007/978-3-030-00761-4_2

[16] V. Vujović, and M. Maksimović, "Raspberry Pi as a Wireless Sensor node: Performances and constraints," *In 2014 37th international convention on information and communication technology, electronics and microelectronics (MIPRO)*, pp. 1013-1018, 214, IEEE. https://doi.org/10.1109/MIPRO.2014.6859717