МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА АВІАЦІЙНИХ КОМП'ЮТЕРНО-ІНТЕГРОВАНИХ КОМПЛЕКСІВ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
В.М. Синєглазов
"21" 11 2020 р.

ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ "МАГІСТР"

Тема: Система візуального розпізнавання об'єктів

Виконавець: **Гайда М.В.**

Керівник: **к.т.н., доцент, Василенко М.П.**

Консультант з екологічної безпеки: **к.т.н., доцент Явнюк А.А.**

Консультант з охорони праці: **старший викладач Козлітін О.О.**

Нормоконтролер: **к.т.н., професор Філяшкін М.**

Київ 2022

EDUCATION AND SCIENCE MINISTRY OF UKRAINE
NATIONAL AVIATION UNIVERSITY
DEPARTMENT OF AVIATION COMPUTER INTEGRATED COMPLEXES

ADMIT TO DEFENSE
Head of department
Viktor M. Sineglazov
"21" 11 2022

MASTER'S THESIS
(EXPLANATORY NOTE)

GRADUATE OF EDUCATION AND QUALIFICATION LEVEL
"MASTER"

THEME: Visual Object Recognition System

Executor: Haida M.V.

Supervisor: Ph.D., Associate Professor Vasylenko M.P.

Advisor on environmental protection: Ph.D., Associate Professor Iavniuk A.A.

Advisor on labor protection: Senior Lecturer Kozlitin O.O.

Norms inspector: Ph.D., Professor Filyashkin M.K.

Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій
Кафедра авіаційних комп'ютерно - інтегрованих комплексів

Освітній ступінь: магістр

Спеціальність 151 "Автоматизація та комп'ютерно-інтегровані технології"

Освітньо-професійна програма "Комп'ютерно-інтегровані технологічні процеси і виробництва"

ЗАТВЕРДЖУЮ

Завідувач кафедри

Синєглазов В.М.

"21" 11 2022 р.

ЗАВДАННЯ
на виконання дипломної роботи студента

Гайди Максима Володимировича

1. Тема роботи: «Система візуального розпізнавання об'єктів».
2. Термін виконання роботи: з 19.09.2022р. до 15.11.2022р.
3. Вихідні дані до проекту (роботи): метод виділення контуру цілі на відео, метод розпізнавання символів, метод визначення координат цілі, алгоритм програми, середовище Matlab.
4. Зміст пояснювальної записки (перелік питань, що підлягають розробці): 1. Актуальність системи візуального розпізнавання об'єктів; 2. Аналіз існуючих підходів для виявлення об'єктів; 3. Теоретичні основи системи відеоспостереження контуру цілі; 4. Вирішення задачі виявлення номерної таблички розробленою програмою та експерименти.
5. Перелік обов'язкового графічного матеріалу: 1. Структурна схема експериментальної установки; 2. Блок-схема алгоритму роботи програми; 3. Графічне зображення знайдених характерних точок; 4. Графічне зображення відфільтрованих характерних точок; 5. Папка із зображеннями шаблонів цифр та літер; 6. Початкове зображення із виділеною рамкою та символами.

6. Календарний план-графік

№ п/п	Завдання	Термін виконання	Відмітка про виконання
1	Отримання завдання	22.08.2022-23.08.2022	виконано
2	Формування мети та основних завдань дослідження	23.08.2022-27.08.2022	виконано
3	Аналіз існуючих методів	27.08.2022-10.09.2022	виконано
4	Теоретичний розгляд рішення задачі	10.09.2022-17.09.2022	виконано
5	Розробка структури системи відеоспостереження за контуром цілі	17.09.2022-01.10.2022	виконано
6	Розробка програмного та апаратного забезпечення системи відеоспостереження за контуром цілі	01.10.2022-16.10.2022	виконано
7	Проведення експериментів та налаштування системи	16.10.2022-21.10.2022	виконано
8	Оформлення пояснювальної записки	21.10.2022-04.11.2022	виконано
9	Підготовка презентації та роздаткового матеріалу	04.11.2022-15.11.2022	виконано

7. Консультанти зі спеціальних розділів

Розділ	Консультант (посада, П. І. Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Старший викладач, Козлітін О.О,		
Охорона навколишнього середовища	к.б.н., доцент, Явнюк А.А.		

8. Дата видачі завдання 22.08.2022

Керівник: ____________________ Василенко М.П.
(підпис)

Завдання прийняв до виконання: ____________________ Гайда М.В.
(підпис)

NATIONAL AVIATION UNIVERSITY

Faculty of aeronavigation, electronics and telecommunications

Department of Aviation Computer Integrated Complexes

Educational level: master

Specialty 151 " Automation and computer-integrated technologies"

Educational and professional program "Computer-integrated technological processes and production"

APPROVED BY

Head of department

Victor M. Sineglazov

"21" 11 2022

Graduate Student's Diploma Thesis Assignment

Haida Maksym Volodymyrovych

1. The thesis title: «Visual Object Recognition System».

2.**The thesis to be completed between:** from 19.09.2022 to 15.11.2022.

3. **Output data for the thesis:** the method of selecting the target contour on the video, the method of character recognition, the method of determining the coordinates of the target, algorithm of the program, the Matlab environment.

4. **The content of the explanatory note (the list of problems to be considered):** 1. The relevance of video surveillance system of target contour 2. Analysis of existing approaches of objects detection; 3. Theoretical basis of the video surveillance system of target contour; 4. Solution of number plate detection problem by the developed program and experiments.

5. List of compulsory graphic material: 1. Block diagram of the experimental setup; 2. Block diagram of the algorithm of the program; 3. Graphic representation of the found characteristic points; 4. Graphic representation of filtered characteristic points; 5. Folder with images of number and letter templates; 6. Initial image with a selected frame and symbols.

6. Planned schedule:

№	Task	Execution term	Execution mark
1	Task receiving	22.08.2022-23.08.2022	done
2	Purpose formation and describing the main research tasks	23.08.2022-27.08.2022	done
3	Analysis of existing methods	27.08.2022-10.09.2022	done
4	Analysis of existing systems	10.09.2022-17.09.2022	done
5	Theoretical consideration of the problem solution	17.09.2022-01.10.2022	done
6	Development of software and hardware for video surveillance system of target contour	01.10.2022-16.10.2022	done
7	Experiments execution and system configuration	16.10.2022-21.10.2022	done
8	Making an explanatory note	21.10.2022-04.11.2022	done
9	Preparation of presentation and handouts	04.11.2022-15.11.2022	done

7. Special chapters' advisors

Chapter	Advisor (position, name)	Date, signature	
		Assignment issue date	Assignment accepted
Labor protection	Senior lecturer, Kozlitin O. O.	[signature]	[signature]
Environmental protection	Ph.D, Associate Professor, Iavniuk V.F.	[signature]	[signature]

8. Date of task receiving: 22.08.2022

Diploma thesis supervisor: ____________________ Mykola P. Vasylenko
(signature)

Issued task accepted: ____________________ Maksym V. Haida
(signature)

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «Система візуального розпізнавання об’єктів»:   с.,   рис.,   табл., 20 літературних джерел.

Об’єкт дослідження: процес візуального розпізнавання об’єкта.

Мета роботи: вдосконалення методів візуального розпізнавання об’єкта та розробка нової системи, що здатна з порівняно невеликими обчислювальними затратами здійснювати виявлення контуру визначеного об’єкта.

Для досягнення цієї мети необхідно розв’язати наступні завдання:

- проаналізувати існуючі методи виявлення контуру об’єкта;
- проаналізувати існуючі апаратні засоби, придатні для реалізації розглянутих методів;
- на основі проведеного аналізу здійснити вибір методу який би дозволив відеоспостереження за контуром цілі з мінімальними обчислювальними та фінансовими затратами;
- розробити програмне та апаратне забезпечення реалізації обраного методу;
- провести експериментальне дослідження роботи розробленої системи.

Предмет дослідження: розробка методу візуального розпізнавання об’єктів на основі кадрів відеопотоку.

Методи дослідження: теорія обробки зображення, теорія розпізнавання зображень, теорія машинного зору.

ВІДЕСПОСТЕРЕЖЕННЯ; ОБРОБКА ЗОБРАЖЕННЯ; ВИДІЛЕННЯ КОНТУРУ; РОЗПІЗНАВАННЯ ЗОБРАЖЕННЯ; ХАРАКТЕРНІ ТОЧКИ.

ABSTRACT

Explanatory note to the thesis " Visual Object Recognition System ": p., figures, tables, 20 literary resources.

The object of research: the process of visual object recognition.

The purpose of the work: improvement of visual object recognition methods and development of a new system capable of detecting the contour of a specified object with relatively low computational costs.

To achieve this purpose, it must be solved the following tasks:

- to analyze the existing methods of detecting the contour of the object;
- to analyze the existing hardware suitable for the implementation of the considered methods;
- on the basis of the analysis to choose a method that would allow video surveillance of the target contour with minimal computational and financial costs;
- to develop software and hardware for the implementation of the selected method;
- to conduct an experimental study of the developed system.

Subject of research: development of a method of visual object recognition based on video stream frames.

Methods of research: theory of image processing, image recognition theory, machine vision theory.

SURVEILLANCE; IMAGE PROCESSING; CONTOUR DETECTION; IMAGE RECOGNITION; CHARACTERISTIC POINTS.

CONTENT

GLOSSARY

AVSS – Automated video surveillance system

CV – Computer Vision

LTI – Linear Time Invariant

FIR – Finite impulse response

MSE – Mean square error

PSNR – Peak signal to noise ratio

CP – Characteristic points

FAST – Features from accelerated segment test

CSS – Curvature scale space

CNN – Convolutional Neural Networks

GPU – Graphics processing unit

CPU – Central processing unit

RAM – Random access memory

SSD – Sum of squared differences

CCORR – Cross-correlation

PC – Personal computer

INTRODUCTION

There is a significant need for establishing visual object recognition systems at a time when robberies, thefts, and other crimes are occurring increasingly frequently. These systems have already acquired popularity and are present in all supermarkets and controlled structures.

However, since video quality and optical sensor quality in general continue to improve year over year, it is no longer sufficient to merely capture the video stream on a storage medium. To make the most of the storage memory and ensure that the system operates automatically without the operator's input, the video must be pre-processed.

The solution to the issues mentioned above is the intelligent video monitoring system of the license plate contour proposed in this study.

A system that automatically locates the coordinates of the license plate, highlights it, and recognizes the characters on it was developed using a combination of techniques for object detection in the image such as template matching, contour detection, and feature detection. This system has good accuracy and speed, can be installed statically or be mobile, and does not require expensive equipment or computing resources to function.

Additionally, during the course of the work, it is possible to learn about the importance of solving such a challenge, currently used algorithms for work realization, theoretical information, and experimental system work results.

CHAPTER 1. THE RELEVANCE OF VISUAL OBJECT RECOGNITION SYSTEM

1.1. Video surveillance system's description

Digital technologies are now widely used in a variety of human endeavors due to the capability of video processing tools' quick development and their comparably low cost. In particular, computerized video surveillance systems have expanded in offices, supermarkets, airports, and banks to monitor people flow and look for potential suspects. Additionally, video cameras have been actively installed and used recently at bus stops, parks, squares, schools, and other nearby locations. In forensics, systems for access control and security systems, such technologies are increasingly used [1].

The number of cameras in automated video surveillance systems (AVSS) is always increasing, which results in increased resource usage. The fact that these systems require a lot of operators to maintain them, however, is a serious constraint. As a result, intelligent AVSS were adopted. Such systems, however, decrease AVSS efficiency and demand substantial processing resources [2].

One of the key elements and holding a significant position in the entire framework of integrated security systems for buildings and people are video surveillance systems. Video surveillance systems are the best way to stop, spot, and warn against crime, violence, terrorist attacks, and security breaches in a world where these problems are on the rise [1].

Video surveillance systems are being incorporated into more and more facets of modern life. The breadth of their use is one possibility for categorizing such systems:

- video monitoring of highways and streets assessing the speed of vehicles, identifying crossing the center line, driving through a red light, and other traffic law offenses [1];

- public and business security: keeping an eye on public spaces to spot and stop crime. Individual buildings such as schools, banks, supermarkets, theaters, department shops, parking lots, and stadiums as well as complete transportation networks such as airports, trains, subways, seaports, etc. are included in this.

- environmental study and monitoring, including the research of pollution and forest fires, animal habitats and migration, highlands, plant diseases, and the preservation of historical and archaeological sites and cultural assets;

- military sphere: guarding national borders, tracking refugee movements, keeping an eye on people, maintaining the security of military installations, providing aid and managing during hostilities, etc.;

- quality assurance: keeping an eye on production facilities, automated procedures, and defects that may have crept into their infrastructure;

- smart houses and personal security: monitoring of patients', children's, and animals' health as well as intrusion and theft prevention;

- video manage and analyze: identification of patterns and irregularities in the movement of vehicles, pedestrians, athletes, sports markers, traffic in malls and amusement parks, etc.

1.2. Services provided by computer vision

Analyzing images and videos is a focus of the artificial intelligence discipline known as computer vision (CV). It consists of a collection of methods that enable the computer to "see" and gather data from what it observes [3].

A photo or video camera, along with specialized software for object identification and classification, build up the systems. They have the ability to decipher faces, emotions, and visuals (images, photographs, videos, and barcodes).

A computer can be taught to "see" through the application of machine learning methods. It is possible to find traits and feature combinations for the further identification of related items thanks to the large amount of data that has been gathered.

Typically tasks involving computer vision boil down to analyzing an image or video stream (which is actually a series of alternate images), on which it is first essential to choose a fragment holding the relevant data. For recognition, a rectangular zone is typically employed, which either restricts the original fragment or just chooses the pixels that correspond to it [4].

1.2.1. Identification

To categorize the entire image is the identification task. In order to achieve this, important regions of the image are selected, and classification is then carried out on them, for instance using convolutional neural networks or decision trees.

1.2.2. Recognition of objects

Ability to choose a specific group of objects from the image is required. The method is unable to categorize arbitrary objects in the image until the general case of the problem is resolved. Nevertheless, it can accurately recognize a collection of items that have already been learnt.

1.2.3. Segmentation of images

Similar to target detection, the task requires choosing the pixels that make up the object rather than surrounding the objects that are discovered with frames. In various fields, including manufacturing to identify assembly-related flaws in parts, primary image processing in the medical field, and creating terrain maps from satellite pictures, segmentation is used. The U-Net model, which consists of numerous layers of a convolutional network that vary in size and are U-shaped in the stack, as indicated by the name, is one of the common segmentation techniques.

1.2.4. Estimating the pose

Segmentation continues in some ways with the difficulty of estimating an object's position. It entails choosing a certain frame of the object—say, the skeleton in the case of people—and figuring out where this frame should be placed within the image. The direction of movement can be predicted using this skeleton in the future, for instance. A Single-person pose estimate and Multi-person pose estimation are differentiated based on the quantity of items taken into account. The second instance is different in that it additionally needs to account for the possibility of object overlap. To complete this challenge, the backdrop is first removed, keeping only the images of the objects themselves. Next, using convolutional neural networks, joints are found in each of the objects, and the joints are then connected.

1.2.5. Recognition of text

One of computer vision's primary functions. The written text is first detected using detection techniques, and then it is immediately recognized, for instance using segmentation methods. However, due to interference in the latter scenario that prevents you from detecting specific letters, the tasks of recognizing text written on a sheet of paper and text written elsewhere on an image (referred to as "in the wild"), such as a text on a road sign, a car number, etc., are very different. Learning to guess a letter from the other letters in a word, for instance, can be useful in this situation.

Fig.1.1. An illustration of a real-world text recognition challenge - Identifying door numbers

1.2.6. Generating objects

Considering a known collection of items, the aim is to discover how to make identical objects that do not coincide with any of the test objects. Create cartoon-style animated figures, for instance, with just a few of them being drawn by hand. These designs include variational autoencoders, which learn from the probability densities of the initial data in order to produce an item that is similar to the original but not exactly the same, and generative adversarial networks, which are networks divided into two and one of which attempts to build an object while the other seeks to reject it.

Fig. 1.2. An illustration of the GAN algorithm being used to create images

1.2.7. Analyzing video

All the duties that were previously outlined apply to videos because they are a collection of identically sized photos that are typically recorded at various times. Other challenges include situation awareness, which involves being able to locate each object in a movie, and motion prediction, which involves forecasting an object's position in the following frames from a collection of frames. and status on each video frame.

1.3. Recognizing the target contour's importance

A video surveillance system, which is used to gather, display, and visually analyze video data, is generally defined as an information system composed of video cameras, a complex of display and storage of multimedia data. Both real-time and recorded footage from other storage can be used for video surveillance [1].

The intelligent video surveillance system, on the other hand, is a system with a real-time operating system of its own that offers great dependability and utilizes system resources as effectively as possible. Has long-term stability and enables achieving the fastest possible speed as well as the quickest possible response to events.

The contour of the image provides the most useful information when identifying things. A section of an object called an object contour is one that largely depends on the texture and color of the image and carries a significant amount of data about the object's overall shape.

The contour can be applied to examine the object's shape. For the setup of automatic or automated systems, knowledge about the object's shape is frequently sufficient. Additionally, switching to object detection based on their contours allows for a significant order-of-magnitude reduction in the amount of data processed. The contours are also invariant to brightness modifications.

The identification and characterization of the contour is a crucial step in image analysis since it contains the fundamental details about an object's shape.

1.4. Problem solving need

There is a huge need to create systems with algorithms for tracking the contour of the target in today's world where video surveillance systems are established at practically all regulated accesses to private areas (for example, parking lots, territories of government agencies, etc.). This entails keeping track of and identifying the license plate of a vehicle that enters or exits a zone under control, recording the time of entry and exit, the vehicle's coordinates, and identifying and recording the symbols on the license plate.

The deployment of the neural network deep learning technique is the first solution that occurs to you while fixing this issue. But it takes hours to train a neural network to recognize an object since it needs a lot of photos out of a training sample (thousands of examples). The method of its calculation on the video adapter processor, which already places limitations on the application of hardware, is the approach's greatest drawback. The foregoing information indicates that such a system will be similarly costly.

A second method of resolving the issue is using automatic number plate recognition systems. They operate quickly and don't need a lot of computational power. The license plate must be the largest rectangle in the screen and the car must fill the full frame for this type of system to function effectively. These algorithms are extremely sensitive to shifts in the subject's location and other disturbances in the image, and recognition turns unreliable if the backdrop scenes of the frame take up more than 20% of the entire frame.

These days, proprietary, pricey, and with limited availability of code are intelligent video surveillance systems with the capability to track the object. The pricing of the system demonstrated in this work is solely based on the cost of the camera and controller and contains an open source software.

Therefore, it is necessary to develop a quick, low-cost, and simple-to-install system for monitoring the shape of the license plate and identifying license plates. What is going to be discussed in this paper.

CHAPTER 2. EXISTING OBJECT DETECTION METHODS ANALYSIS

The issue of recognizing the contour of the object can be solved using a wide range of established techniques. Some are based on the identification and placement of objects moving in the livestream, while others identify the object by its attributes and membership in a specific class. The known techniques for finding things in video and photos will be gradually described in the following chapters.

2.1. Object detection in images using correlation

The purpose of detection is to determine whether objects (brightness regions) with specific characteristics are present in the image and, if so, to establish their coordinates on the current frame [5].

The fundamental idea behind object recognition in images is to contrast the brightness function of the image with a predetermined "standard" – a portion of the brightness field that contains the desired object. The standard fragment is moved successively around the visual field during the detection process, and at each place its resemblance to the actual function of brightness on the segment is assessed. Noise and distortions, as well as the fact that there is typically incomplete knowledge of the shape and structure of the item, prevent total concurrence of the standard and the image from occurring, on average (you must employ a standard that only broadly characterizes the item).

The function of the standard object's brightness, stated on a specific area D in the standard's own coordinate system, will be denoted by the symbols $t(k,l)$, $(k,l) \in D$. (is typically thought of as a D-shaped rectangle with the origin in the middle.). The brightness function of the observed image should be represented by the samples $x(m,n)$. At the position (m, n), the difference between the standard and the image is calculated using the most typical quadratic measurement:

$$\varepsilon^2(m,n) = \sum_{(k,l)\in D} [x(m+k,n+l) - t(k,l)]^2 \qquad (2.1)$$

It is believed that the image segment and the standard are similar at that particular point *(m, n)*, if:

$$\varepsilon^2(m,n) < L_\varepsilon \qquad (2.2)$$

Where L_ε- a certain threshold depending on the level of the noise.

A schematic representation of the concept of comparison with a standard is shown in Fig.2.1..

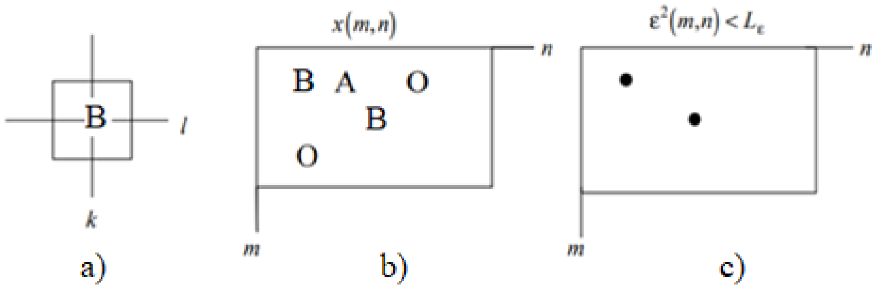


Fig.2.1. An example of how to compare something to a standard: a) a comparison standard; b) investigated area; c) coincidences with the standard

In reality, it is more common for related, but more easily calculated numbers to be used instead of the measure (2.1). Convert the quadratic measure of difference equation as follows:

$$\varepsilon^2(m,n) = \sum_{(k,l)\in D} x^2(m+k,n+l) - 2\sum_{(k,l)\in D} x(m+k,n+l)t(k,l) + \sum_{(k,l)\in D} t^2(k,l) \quad (2.3)$$

The first expression in this context describes the picture energy inside "window" D. According to *(m, n)*, this energy typically fluctuates very slowly and hardly ever describes the thing being sought for. The third term describes the standard's energy and is independent of *(m, n)*. Only the second component, which defines the cross-correlation of the signal and the standard, is crucial for detection up to a constant factor [5]:

$$B(m,n) = \sum_{(k,l)\in D} x(m+k,n+l)t(k,l) \qquad (2.4)$$

The cross-correlation (2.4) is high when the reference and picture line up, ensuring that the quadratic measure is minimal (2.1). Cross-correlation as a sole indicator of similarity, however, typically yields subpar detection accuracy. This is because if the brightness of the image near the point with coordinates *(m, n)* is high, cross-correlation may grow even if the picture does not meet the standard. The normalized cross-correlation can be used to get around this problem:

$$R(m,n) = \frac{\sum_{(k,l)\in D} x(m+k,n+l)t(k,l)}{\sqrt{\left[\sum_{(k,l)\in D} x^2(m+k,n+l)\right]\left[\sum_{(k,l)\in D} t^2(k,l)\right]}} \qquad (2.5)$$

If the standard and image coincide up to a fixed non-negative factor, the value *R(m, n)* is equivalent to the maximum value (one). If *R(m, n)>LR'*, where *LR'* is the measure threshold, the object at the place *(m, n)* is deemed detected in this scenario (2.5).

If we first successfully complete adaptive element-by-element image analysis with a "window" D to balance the energy (variance) of the image

$\sum_{(k,l)\in D} x^2(m+k, n+l)$ all over the field, we can simplify the form of function (2.5). This is done by first choosing the energy of the standard equal to one, or by making sure $\sum_{(k,l)\in D} t^2(k,l) = 1$. It furthermore eliminates the impact of image variance variations. Using *x'(m,n)* to denote the normalized picture, we may return to the linear cross-correlation measure:

$$B'(m,n) = R'(m,n) = \sum_{(k,l)\in D} x'(m+k, n+l)t(k,l) \qquad (2.6)$$

It is clear that the two-dimensional signal, a normalized picture with the coordinates *x'(m, n)*, passes through a two-dimensional LTI system with an impulse response of *h(k,l)= t(-k,-l)* to create the normalized cross-correlation function (2.6):

$$B'(m,n) = x'(m,n) ** h(k,l) = x'(m,n) ** t(-k,-l) \qquad (2.7)$$

As a result, we get at the correlation detection algorithm's general design, which is depicted in Fig. 2. In this case, the last stage results in a binary image with ones where object recognition points should be:

$$g(m,n)=\begin{cases}0, B'(m,n)\le L'_R,\\ 1, B'(m,n)>L'_R.\end{cases}$$

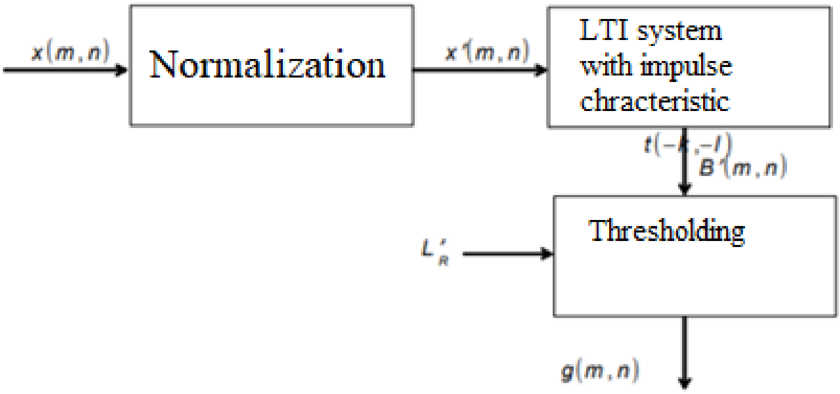


Fig. 2.2. The correlation detection method's flowchart

A spectral processing (fast convolution) or window (direct convolution) can be used to implement the LTI system, which in this instance is known as the correlator.

The considered correlation detection method is relatively simple, but it is characterized by rather high probability of errors (false detection or missing objects), which is explained by ignoring the properties of noise when synthesizing the image processing algorithm.

2.2. The process of identifying an object in a picture by its contour

The contour of the image provides the most useful information when identifying things. An outline of an object is a portion of the object that primarily focuses on the object's shape and bears minimal resemblance to the image's texture and color.

Along the contour, it is possible to determine the object's shape. For the setup of automatic or automated technologies, knowledge about the object's shape is frequently enough. Additionally, switching to object identification by their contours enables for a several-orders-of-magnitude reduction in the amount of information processed, and the contours are invariant to brightness alterations.

Each pixel uniquely identifies the background or the image after digitalization. Different kinds of criteria are used to determine if a pixel is part of the picture's background or contour.

A secondary image with the same size as the source is created as a result of the contour selection. The pixels in this image are initially completely black, but as the contours of the pixels that match to the object's border points are chosen and painted white, the black points turn into white.

The difference in intensity is represented by the contour in the color image. The contours connected to sharp shifts in hue and brightness in zones of constant intensity are not included in this definition, though.

The process of creating a discrete signal that specifies the borders of a digital frame is known as contour representation (encoding).

Algorithms for contour representation must meet certain criteria:

1. lowering the amount of storage memory required;

2. minimizing the complexity and duration of further operations;

3. getting information about the object's informative features.

According to studies, biological mechanisms of vision primarily distinguish objects by their outlines rather than their brightness. Due to the video capture equipment's limits and distortion, the differences will not be apparent in practice. Often, rather than analyzing the brightness values itself, it is easier to trace the brightness variations along the boundaries as increases in the first brightness derivatives.

The number of incorrect contours and the quantity and size of contour breaks are balanced out while solving the issue of contour identification. It is well recognized that minor gaps have a significantly smaller impact on the outcome of follow-up procedures. Compared to fake contours, which are simple to misinterpret, they are simpler to get rid of [1].

The noise resistance of the contour selection method determines the correlation between the quantity of erroneous contours and the quantity and size of gaps. Internal features and contour features (boundary points) are present in any region D of the complex variable. The first among them has the characteristic that parts of their environment and themselves are wholly within region D. While contour points are not internal, there are internal area D features and external (background) elements in every tiny neighborhood of such points. A line that passes through the entire center of Region D can connect any two of its points, which is known as the connectedness attribute of Region D.

When all of the inside points of area D make up the straight lines segment linking any two of a contour line G's points, the line is referred to as convex. In the event that such a segment contains external (background) points, the contour segment will be concave. (Fig. 2.3.).

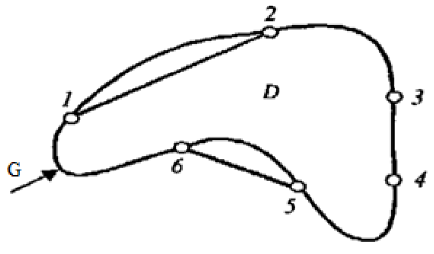


Fig. 2.3. The G contour in pieces: 1, 2 - convex; 3, 4 - indefinite; 5, 6 - concave

A binary encoded image's internal pixel ω(m1,m2) has the attribute of four connectedness, which means that adjacent elements on the top, bottom, left, and right directly belong ω (m1,m2).

It is important to encode the contour, or establish a specific number in accordance with each contour component, in order to analyze it analytically. The contour code is the set of these numbers in order. On the grid pattern, there are eight possible standard positions.

Let's look at different methods for contour encoding.:

1. Coding using the length of the current elementary vector, the rotational axis in which the next elementary vector is moved, and the angle connecting nearby elementary vectors.

2. The three-dimensional binary coding of the current elementary vector (numbers from 0 to 7). Widely used in image processing, this algorithm was presented by Freeman.

3. The origin of the elementary vector paired with the two projections of the present elementary vector form a two-dimensional code for the elementary vector.

4. The contour is represented in polygons by using linear segments to approximate it (Fig. 2.4).

The purpose of coding is to resolve the coordinates of these segments' ends. Thanks to the conciseness of the descriptions that may be provided, this approach has gained popularity. As a result, there is a segmentation issue that is comparable to the signal sampling issue. Real-world instances typically include the loss of information on the geometry of the objects..

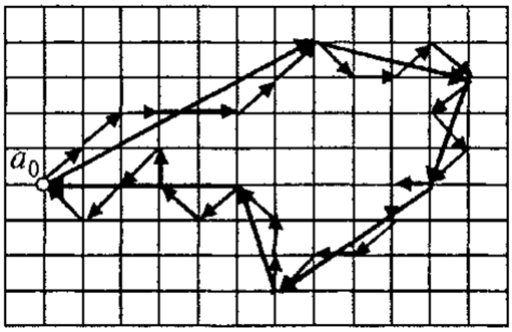


Fig. 2.4. Using linear segments to approximate a contour, a polygonal approximation of that contour is created

5. Polar code description of a contour line. The pole is chosen as the starting point of the standard (point P) standard (own) coordinate system, or the referencing frame related to this picture, in the image *ω(m1,m2)*. All of the image's border points are attached to the point P at their centers. The outcome is a set of radius

vectors β (n) that specifically describe the image's contour(Fig. 2.5). The image's center of mass is frequently in line with the center.

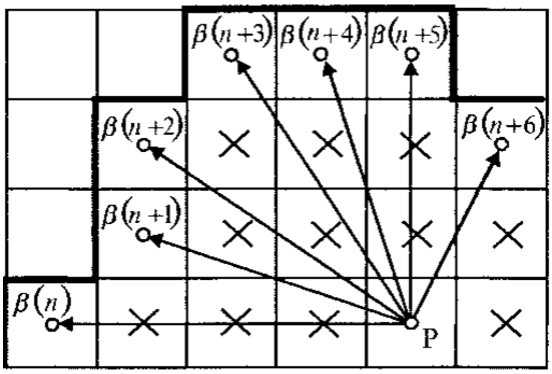


Fig. 2.5. An illustration of how to describe a section of contour in polar coordinates

The two main categories of contour selection techniques are extreme and differential correlation. The contour is chosen by a threshold component in differential approaches, the intensity disparities are enhanced by numerical differentiation, and then the binary image is sent to secondary processing with the goal of thinning to the one pixel contour. The techniques are effective and simple to use, but their noise immunity is poor. The location of the brightness difference serves as the primary criterion for evaluating the contours' noise immunity.

On the other hand, selecting edges or choosing the section of a point that creates an object are the two methods used to define and characterize a contour.

The literature provides and describes a huge variety of algorithms for choosing contours and borders. The Roberts', Kirsch, Robinson, Sobel, Previtt, operator, Canny algorithm, and LoG algorithm are the most often used approaches. These methods emphasize the distinct brightness contrasts that characterize object outlines.

2.2.1. Roberts' operator approach

One of the first contour selection methods that computes the sum of the squares of the differences between diagonally adjacent pixels is the Roberts operator. A two-core image convolution will be used in this:

$$\begin{bmatrix} +1 & 0 \\ 0 & -1 \end{bmatrix} and \begin{bmatrix} 0 & +1 \\ -1 & 0 \end{bmatrix} \quad (2.8)$$

Although Roberts' operator is still employed for calculating speed, its high noise sensitivity makes it less efficient than alternatives. It makes the lines thinner than other methods of contouring, which is almost equivalent to calculating the final differences along the X and Y coordinates. It is sometimes called the "Roberts filter".

2.2.2. Laplace operator approach

In image analysis, the discrete Laplace operator is frequently employed to draw attention to contours. The discrete Laplacian is determined as the total of the "neighbors" differences of the center pixel and is defined as the sum of the second derivatives. A discrete Laplacian may be expressed as a convolution with the following core for a one-dimensional input:

$$D_x^2 = [1 \ -2 \quad 1] \quad (2.9)$$

A two-dimensional input, meanwhile:

$$D_x^2 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} or \ D_x^2 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & -8 & 1 \\ 1 & 1 & 0 \end{bmatrix} \quad (2.10)$$

2.2.3. Prewitt operator approach

The Prewitt operator is a technique for choosing outlines in image analysis that determines the local orientation of the contour in each pixel by computing the greatest deviation on a collection of convolution cores. Dr. Judith Prewitt developed it to recognize the contours of medical photographs.

In order to determine the estimated values of the derivatives, horizontally and vertically, the operator convolves the original picture using two 3 × 3 cores :

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} \; and \; G_x = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & +1 & +1 \end{bmatrix} \tag{2.11}$$

2.2.4. Sobel operator approach

The estimated value of the picture gradient is determined by the discrete differential operator known as the Sobel operator. It is frequently employed in contour algos in the field of image processing. The brightness gradient vector at such a position or its norm, determined by formulas, is the outcome of applying the Sobel operation to each point in the picture:

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * A \; and \; G_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * A \tag{2.12}$$

where A is the source picture.

2.2.5. Canny operator approach

Canny investigated the mathematical issue of generating a filter using the best selection, localization, and minimization criteria. He demonstrated that the required filter may be well approximated by the first Gaussian derivative and is the product of four exponents. Canny developed the "Non-Maximum" idea, which designates the contour pixels as those in which the local gradient maximum in the gradient vector's direction is attained. Canny's contour detector remains one of the greatest detectors, despite the fact that his work was done during the early stages of computer vision.

A collection of incoherent regions is the outcome of the algorithms presented. Additional calculation is needed to produce a connected contour, such as processing by morphology to produce the linked object edge, also known as the object's contour..

2.2.6. Comparative evaluation of the contour selection techniques presented

It is done to compare the contour selection methods that have been discussed. The measurement of picture quality is frequently utilized in comparison analysis. Numerous metrics that demonstrate how closely the final image resembles the source image define this estimate. The mean square error (MSE) and peak signal to noise ratio (PSNR) are the most well-known measurements.

A measure of how much a random variable's values vary from its mathematical expectation is the mean square error (MSE):

$$MSE = \frac{\sum_{i=1,j=1}^{m,n}\left(x_{i,j} - y_{i,j}\right)^2}{mn} \quad (2.13)$$

where *MSE* – mean square error; $x_{i,j}$ – sample component; $y_{i,j}$ – sample’s arithmetic mean; *n*, *m* - size of the sample.

The ratio of the largest potential signal value to the noise power that alters the input value is known as the peak signal to noise ratio (PSNR). The mean square error is the simplest method for calculating this ratio:

$$PSNR = 10log_{10}\left(\frac{MAX_I^2}{MSE}\right) \tag{2.14}$$

where MAX_I - the highest value of the image's pixel intensity; *MSE* - the mean square error.

The image is regarded to be crisper and more accurate the higher the peak signal-to-noise ratio value. The picture from the ORL database was used to assess the effectiveness of the resulting image with the chosen contours by the given procedures and to compare them. This photo will be regarded as the original because it is flawless in our scenario.

Speed, which is expressed in seconds, is another crucial sign of how well contour selection procedures are working. Results are shown in Table 2.1.

Table 2.1. Performance speed comparisons of existing contour selection techniques

Method for contour selection	*Performance pace, sec*
Roberts	*0,60*
Laplace	*0,86*
Prewitt	*0,63*
Sobel	*0,76*
Canny	*2,45*

The Canny approach, which is the slowest of the methods under consideration, yields the best results in standard deviation and peak signal-to-noise ratio, as can be seen from the findings.

Thereby, it is demonstrated that the contour contains the fundamental data about the object, making its collection and description a crucial task of image processing. It is also demonstrated that contours are invariant to intensity transformations and that the transition to object recognition by its contours allows for a reduction in the amount of processed data.

Additionally, a comparison of contour selection techniques was carried out. The Canny approach has the slowest contour selection speed, but it produces the best outcomes when measured by standard deviation and peak signal to noise, according to standard deviation, analysis of speed and signal to noise peak ratio.

2.3. The technique of identifying an object in a photo using its characteristic features

2.3.1. General details regarding the technique

The positions of maximum, minimum, inflection, and highest curvature are known as characteristic points (CP), which are picture points with comparatively high informativeness. Salient, keypoints, representative, feature points, characteristic points, and inflection points are further names for CP.

CP can be found, for instance, at segment ends, polygon vertices, inflection points, spline inflection points, and elliptical semi-axes' end points.

The following prerequisites for CP were found by Haralick and Shapir in 1992:

- distinctness - CP should be distinct from its neighbors and stand out visibly in the background;

- invariance - Affine transformations should not affect the detection of CP;

- stability - errors and noise should not affect the CP detection;

- uniqueness - to distinguish between repeating pieces better, CP has to have global uniqueness in addition to local variances;

- interpretability - it is important to define CPs so that they may be utilized to examine matches and find interpreted data from a picture.

According to Tuytelaars and Mikolajczyk, CPs need to possess the following qualities:

- repeatability - even if the view point and illumination have changed, CP is still in the same location inside the scene or picture object.;

- distinctiveness / informativeness - it should be possible to distribute and compare special points in a CP environment if there are significant variances from other points in the area;

- locality - To lessen the possibility of responsiveness to geometric and photometric errors between two photographs obtained at various points of view, CP should cover a tiny portion of the image;

- quantity - In order to identify even little things, there should be a sufficient amount of detected CP. The best number of CP, however, varies depending on the topic matter. The number of identified CP should ideally be adaptively decided using a straightforward and understandable criterion.

- location density - To guarantee that the image is shown in a concise manner, CP must display the image's informativeness.;

- accuracy - Both in the original picture and in images captured at a different scale, any detected CP must be localized precisely;

- efficiency - in time-critical situations, the CP detection time in the picture should be acceptable..

These characteristics generally overlap with the preceding ones, although they are interpreted in different ways.

The primary benefit of employing CP for image feature extraction is the speed and relative ease of detection..

"Keypoint detection" refers to a set of techniques for locating key points, while "Keypoint matching" refers to methods for comparing and discovering pictures using key points.. Implementing the key point detection technique to the pattern and the image, then matching the pattern's and the image's key points, is how you find a pattern in an image [6].

Typically, "key points" are determined automatically by identifying pixels whose surrounds have particular characteristics. There have been created several criteria and ways for locating them. Each one of these algorithms use heuristics to identify certain distinguishing aspects of the picture, often corners or abrupt color changes.

A detector and a descriptor are used to identify exceptional points in the procedure..

An approach for removing particular spots from a picture is called a detector. The detector assures that the same solitary points will always be found regardless of how a picture is transformed.

Descriptor: a special point's identifier that sets it apart from the other special points in the setDescriptors, on the other hand, need to guarantee that identifying a connection between single points is invariant with regard to image alterations.

A effective detector will operate rapidly and not be affected by picture alterations (important detection spots shouldn't stop or move when the image changes).

2.3.2. Corner detectors features

Facets often establish the boundary between multiple objects and/or sections of the same item, while corners are unique points generated from two or more facets. The primary characteristic of these points is that they may be distinguished because two dominating directions predominate in the region surrounding the corner of the picture gradient [7].

The function of the picture intensity *I(x,y)* has a vector value called a gradient that depicts the direction of the sharpest rise. Due to the discrete nature of the picture, the gradient vector is calculated using partial derivatives along the x and y axes by varying the brightness of adjacent image points. In general, the approaches are susceptible to noise since the majority of them take into account angularity dependent on the derivative of second order.

Different sorts of corners exist depending on the quantity of crossing facets: Y- (or T-), L-, and X-connected corners (some additionally differentiate angles that are linked by arrows.). Each of the following corner kinds has a varied response from various corner detectors.

Fig. 2.6. Different types of corners

Three sorts of methods can be used to detect unique points:

1. Using the image's pixel intensities as a basis: the characteristic points are computed directly from the image's pixel intensities.
2. Using the contours of a picture, you can either build a polygonal approximation of the contours and find the intersections or extract the contours and seek for the areas with the greatest curvature. These techniques are sensitive to neighborhood crossings because where three or more edges converge, extraction is frequently inaccurate.

3. Model-Based: Models are used as parameters, and they are adjusted to template pictures with subpixel accuracy. Depending on the templates being used, they only have a limited use with particular feature point types (such L-connected corners, for example).

The most widely utilized techniques based on picture intensity are actually employed in reality.

I'll then briefly go through the advantages and disadvantages of simple corner detectors. The usefulness of each detector in various scenarios will then be discussed in a comparison table of detectors.

2.3.3. General overview of the Moravec corner detector

The simplest detector now in use is the Moravec. The brightness of a square window W (often 3x3, 5x5, 7x7 pixels) in relation to the object of interest is examined when the window W is moved by one pixel in eight directions (vertical, horizontal, and diagonal).

Anisotropy in eight window displacement patterns is a feature of the Moravec detector. The primary drawbacks of the proposed detector are its lack of rotation transformation invariance and its propensity to discover mistakes when there are several diagonal edges.

2.3.4. General overview of the Harris corner detector

Anisotropy in all ways, or taking into account the image's brightness derivatives to examine brightness variations in many directions, was added by Harris and Stephens to the Moravec detector. Derivatives are introduced by them in certain essential directions.

The Harris detector is partly invariant to affine intensity variations and rotational invariant. The detector's dependency on the picture size and susceptibility to noise are some of the drawbacks (using a multi-scale Harris detector, this drawback is removed).

2.3.5. General overview of Shi-Tomasi corner detector

The Harris detector and the Shi-Tomasi corner detector (Shi-Tomasi or Kanade-Tomasi, 1993) are similar in many ways, but the computation of the response measure varies. The method computes the value directly because it anticipates that the search for corners would be more reliable. To examine the Lucas and Kanade's optical flow, the researchers utilized the same solution.

2.3.6. General overview of Förstner corner detector

The first approach that employs the same level of angularity as the Harris detector was introduced by Förstner and Gülch in 1987. They applied a more sophisticated computational approach. The principal components, in contrast to the Harris detector, are determined directly. The following is a definition of the Förstner angle response function:

$$R = \lambda_1 \lambda_2 / (\lambda_1 + \lambda_2) = \frac{detM}{trM} \tag{2.15}$$

Additionally, the degree of the angle's roundness is taken into account for the definition's accuracy and is equal to:

$$1 - \left(\frac{\lambda_1 - \lambda_2}{\lambda_1 + \lambda_2}\right)^2 = \frac{4detM}{(trM)^2} \tag{2.16}$$

In practice, the Förstner detector is frequently employed to enhance the possibilities of the Harris detector by locating circular keypoints in addition to angles. The algorithm furthermore has the highest localization characteristic..

2.3.7. General overview of SUSAN corner detector

By dividing circular regions into areas with comparable (orange) and distinct (blue) characteristics, corners are established (Fig. 2.7). The angles are situated where the relative area of comparable areas (comparable USAN) achieves a local minimum under a predetermined threshold.

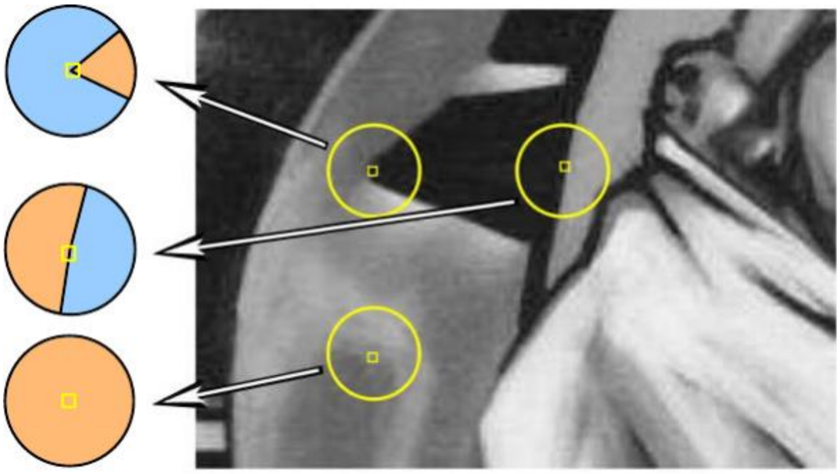


Fig. 2.7. SUSAN detection algorithm visualisation

Although the method performs well at all angles, it is not immune to image blur.

2.3.8. General overview of Trajkovic corner detector

Imagine c is the pixel to be analyzed and P be the point on the circle S_N at the center at point N so that the detector can check the area around a pixel by looking at nearby pixels. A point P' has a diameter that is opposite to P.

The Trajkovic4 technique has a lower frequency than the Harris detector, but its localisation is superior in cases when different types of angles are present and similar to finding of L-connected corners.

The notion that this 4-adjacent operator responds incorrectly to diagonal edges and is susceptible to noise are further drawbacks. As a result, the Trajkovic8 method is implemented with eight connections. In terms of how it determines angularity, Trajkovic8 is different from Trajkovic4. Trajkovic8 still detects erroneous corners on a few of the object's diagonal edges (it struggles with synthetic pictures).

2.3.9. General overview of FAST corner detector

FAST is an alternative equivalent to Harris' approach. FAST is significantly quicker than the described procedure, as the name would imply. This method looks for spots around the edges and objects' corners, or in locations where there is a contrast difference. These locations can be found: in order to determine if there is a continuous segment of pixels with length t that are K units darker (or lighter) than the prospective pixel, FAST creates a circle of radius R around it. The pixel is deemed to be a "key point" if criterion is satisfied [6].

The method's primary drawback is that several solitary points might be detected in close proximity to one another; the algorithm's effectiveness depends on how images are processed and how evenly the pixels are distributed. But compared to other products, it operates quickly enough.

2.3.10. General overview of CSS corner detector

A curvature scale space (CSS) approach to identify angles on planar curves was introduced by Rattarangsi and Chin in 1992. At different scales, CSS may be used to extract invariant geometric properties from flat curves.

The algorithm locates keypoints on the same picture at various scales. Though computationally challenging, it finds erroneous corners in circular regions.

The following drawbacks of this technique include the utilization of pictures at various scales for localization and the determination of the amount of corners using an image at a single scale. As a consequence, the system finds incorrect corners when σ is small and skips angles when σ is big.

2.3.11. A comparison of corner detectors

Table 2.2. Angle detectors' comparison (where 1 - Very poor, 2 - bad, 3 - acceptable, 4 - good, 5 - extremely good)

Operator (method)	*Precision of detection*	*Localisation*	*Frequency*	*Noise tolerance*	*Speed*
Moravec	*3*	*4*	*3*	*3*	*4*
Förstner	*4*	*4*	*3 for scaling, 5 for affine transformations*	*4*	*2*
FAST	*4*	*4*	*5*	*4*	*5*
Harris	*4*	*4 for L-connected angles, 2 for other types*	*If anisotropic gradient is calculated, 5 for affine transformations, and 3 for scaling*	*3*	*2*
SUSAN	*4*	*1 for blurred photos, 4+ in all other cases*	*2 for affine transformations and 4 for scaling*	*5*	*4*
CSS	*4*	*4*	*5*	*4*	*Varies heavily on the contour detector*
Trajkovic & Hedley	*2*	*4*	*3 (not rotationally invariant)*	*2*	*5*

Because of its simplicity, method for locating CPs, and most significantly, speed, it was chosen to adopt the FAST corner detector in algorithm after examining the alternatives.

2.4. Deep learning neural networks and machine learning for object recognition

Different methods can be applied to recognize objects. Deep learning and machine learning techniques have recently gained popularity as methods for solving object recognition issues. These methods can identify things in photos, but they act differently [8].

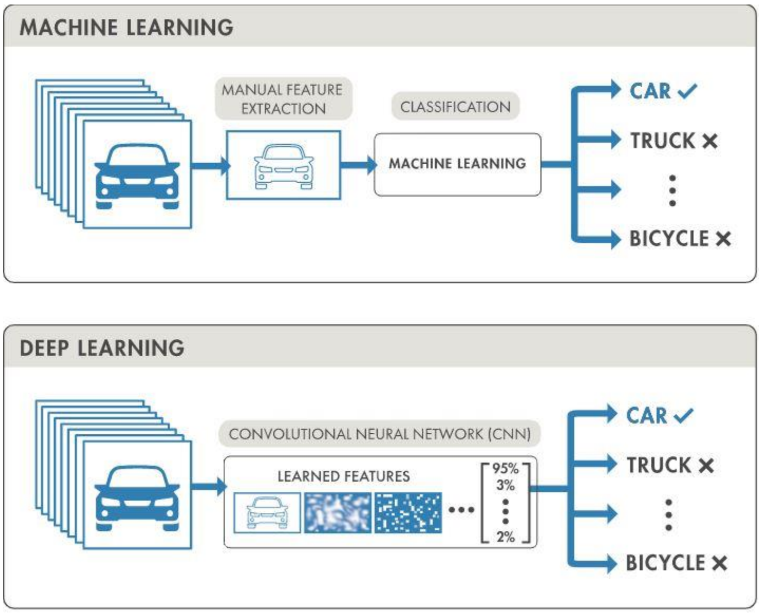


Fig. 2.8. Object recognition using machine learning and deep learning comparison

2.4.1. General explanation of deep learning for object recognition

The use of deep learning algorithms to recognize objects has grown in popularity. Convolutional Neural Networks (or CNNs), a type of deep learning model, are employed to automatically learn the innate characteristics of an item in order to recognize it. By examining hundreds of photographs and researching the traits that set cats and dogs apart, CNN, for instance, may learn to differentiate between cats and dogs..

Deep learning has two methods for recognizing objects:

- Scratch Model training. A very big labeled dataset must be gathered in order to train a deep network from scratch, and a network architecture that learns properties and constructs models must be created. Although this method involves a large amount of training data as well as the setup of CNN's levels and weights, the results can be spectacular.

- The majority of deep learning applications employ a transfer learning technique, which entails fine-tuning of pre-trained models. Firstly, fresh data including newly undiscovered classes is added into an established network, such as AlexNet or GoogleNet. Considering that the model has previously been trained using dozens or millions of photos, this technique requires less time and can produce results more quickly..

Deep learning provides excellent accuracy but needs a large amount of information to produce reliable predictions.

2.4.2. General information on object recognition with machine learning

For object recognition, machine learning methods are also common and provide alternative methods to deep learning. Typical examples of machine learning methods include:

- use an SVM machine learning model to extract HOG characteristics;

- models using a bag of terms that have features like SURF and MSER;

- various things, including as faces and the upper body, may be recognized using the Viola-Jones method..

The conventional machine learning technique requires you to start with a collection of photos (or videos) and choose the relevant attribute in each one in order to recognize things. The method of feature extraction for instance, can extract edge or angle characteristics that are useful for classifying user input. In order to assess and categorize new objects, these characteristics are included to a machine learning model that divides these traits into several groups. To build an accurate object identification model, a number of machine learning methods and feature extraction approaches can be combined.

When you use machine learning to recognize objects, you have the freedom to select the ideal set of characteristics and training classifiers. This can produce precise findings with little data.

2.4.3. Comparison between deep learning vs machine learning for object identification

Depending on the job at hand, the optimum method for object recognition must be chosen. For most situations, machine learning may be a useful technique, especially if you are aware of the picture properties that are most useful for identifying different object classes.

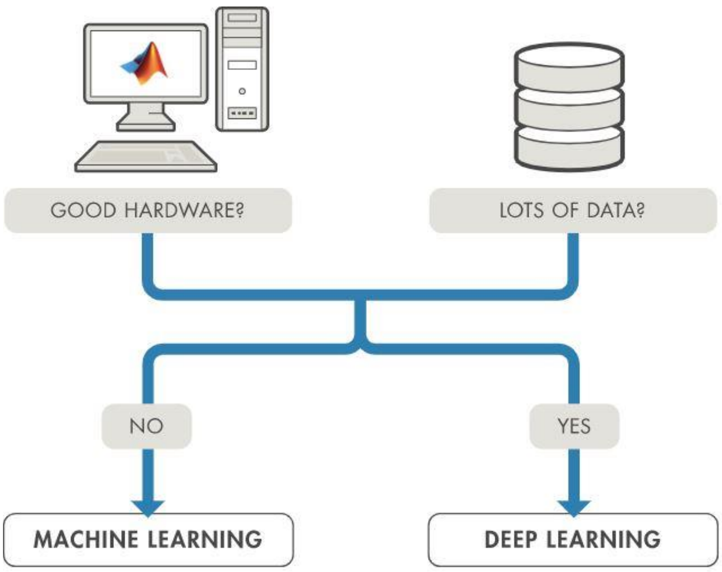


Fig. 2.9. A comparison between deep learning vs machine learning with key considerations

When deciding between machine learning and deep learning, it's important to have a strong GPU and lots of training data. A machine learning strategy may be the best option if none of these questions can be answered positively. Large datasets of pictures are often preferable for deep learning approaches, and the GPU speeds up model training.

CAPTER 3. THEORETICAL BASIS OF THE VISUAL OBJECT RECOGNITION SYSTEM

The program's target of observation was decided to be an automobile. The headlights, windshield, rearview mirrors, wheels, and registration plate are common elements on all automobiles. Nevertheless, practically all of these qualities vary in size, form, and even position for each of the present automobiles, with a big number of models.

Only neural networks could complete the task of object identification while taking into consideration all the features mentioned above. But, they need a lot of computational power and thousands, if not hundreds of thousands, of photos from the training sample to do this. So it was decided to create a custom program to recognize the automobile in the video feed by its registration number. The choice of the registration plate as the monitoring object was made since it is the component that has consistent dimensions, is found on all automobiles, and is the most effective tracking object.

3.1. Using a Gaussian filter to blur

Blurring is a crucial component of several image correcting methods designed to get rid of particular flaws (dust, flaws in the scan, and excessive detail, etc). Noise reduction, or the challenge of recovering the original image with random noise introduced to its pixels, is one of its potential uses [9].

A general-purpose image blur filter called Gaussian blur calculates the transform that is put to each pixel in a photo using a normal distribution (Gaussian distribution). As noise in the picture varies separately for each pixel, and if the mathematical expectation of the noise value equals 0, the noise of adjacent pixels will balance one another out. The average noise strength will decrease with increasing filtering window size, but considerable blurring of key visual features will also happen.

The formula for the Gaussian distribution function in N - dimensional space is:

$$G(r) = \frac{1}{(2\pi\sigma^2)^{\frac{N}{2}}} e^{-\frac{r^2}{2\sigma^2}} \quad (3.1)$$

A key downside of employing a rectangular filter to reduce noise is that pixels "r" pixels away from the treated pixel have the same impact on the outcome as pixels closer to it.

So, if the impact of pixels on one another diminishes with distance, more effective noise reduction may be achieved (a two-dimensiontional special case):

$$G(u.v) = \frac{1}{2\pi\sigma^2} e^{-\frac{u^2+v^2}{2\sigma^2}} \quad (3.2)$$

where *r* - blur radius, *r2* = *u2* + *v2*, *y* - Gaussian distribution's standard deviation.

This formula specifies a surface in two dimensions that resembles concentric circles and has a Gaussian distribution from the center. A convolution matrix is built from pixels at which distribution is nonzero and then used to the original picture. Each pixel's value is converted into a neighborhood weighted average. According to their proximity, nearby pixels receive less weights than the initial pixel value, which has the largest Gaussian value. According to theory, the distribution at every place in the picture will be nonzero, necessitating the determination of weighting factors for every individual pixel. But in reality, since they are tiny enough, pixels farther away than three are not taken into consideration when calculating the discrete approximation of the Gaussian function. In order to provide adequate precision in the Gaussian distribution approximation, it is required for the software filtering the picture to compute the matrix.

Convolution by function is utilized to implement this filter:

$$I'(i,j) = \sum_{I=-n}^{n} \sum_{k=-m}^{m} I(i-l)(j-k) * \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-d^2}{2\sigma^2}} \quad (3.3)$$

y – is the blur degree parameter. Function with *y* = *5* is shown on the graph.

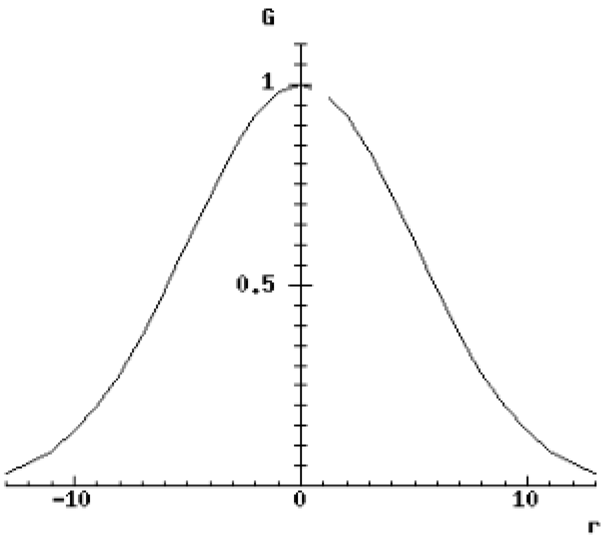


Fig. 3.1. Gaussian function visualization

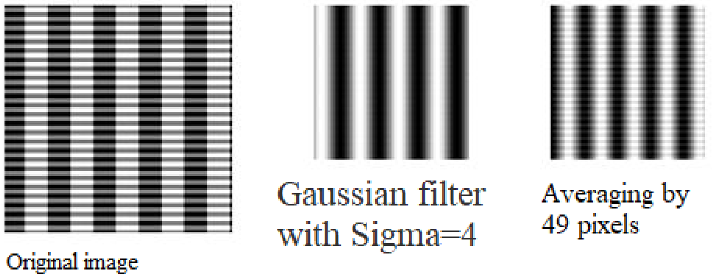


Fig. 3.2. A constant function's and the Gaussian function's convolutional results (averaging).

Since it blurs small features less and effectively reduces noise, the Gaussian filter is particularly suited for situations when a noisy image has a lot of details.

3.2. Description of the FAST feature points recognition algorithm

One of the earliest heuristic approaches for locating exceptional points, FAST was initially suggested in 2005 in the work and quickly popularized due to its high computing efficiency [10]. This approach takes into account the intensity of pixels in a circle with a point C as its center and a radius of three to determine whether to treat a specific point C as exceptional or not:

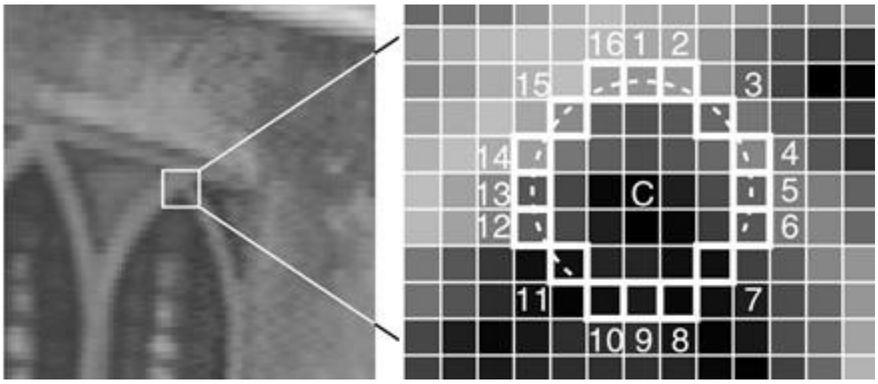


Fig. 3.3. FAST detector's consideration of pixels

For each of the three potential results, we compare the brightness of the circle's pixels to the center C brightness (lighter, darker it seems):

$$\begin{gathered} I_p > I_C + t \\ I_p < I_C + t \\ I_C - t < I_C < I_C + t \end{gathered} \tag{3.4}$$

Here, I represents the pixel brightness, while t represents a specified brightness threshold.

If there are n = 12 pixels on the circle that are brighter or darker than the center, or if there are 12 pixels that fall within either category, a point is designated as exceptional.

Practice has revealed that, on average, nine points have to be checked in order to reach a judgment. The authors suggested accelerating the procedure by merely checking the first four pixels, which are numbered 1, 5, 9, and 13. A full 16-point check is conducted if there are 3 pixels that are brighter or darker among them; otherwise, the point is instantly labeled as "not special." This drastically cuts down on operational time; typically, only around 4 points of the circle need to be questioned in order to reach a conclusion.

FAST-12 was the initial version of the method. The tree-based FAST-9 and FAST-12 algorithms are adaptations of the original method.

Original technique had a number of drawbacks, such as the possibility of numerous exceptional spots being located in a given neighborhood and the dependence of the algorithm's effectiveness on the pixel distribution and processing order.

The FAST method is improved by Reid Porter, Edward Rosten and Tom Drummond (2008) because they apply machine learning to recognize keypoints.

This algorithm was given the name FAST-ER (ER - Enhanced Repeatability). The method is stable to the repeatability property, which states that feature points associated with the same objects may be seen on the same scene when viewed from various perspectives.

Unlike FAST, this technique use a circle that is larger than one pixel (48 pixels). Decision trees are used by the authors to categorize keypoints (if a candidate is a characteristic point) using the ID3 method. To provide the most computationally effective detector, the ID3 technique improves the sequence in which pixels are processed.

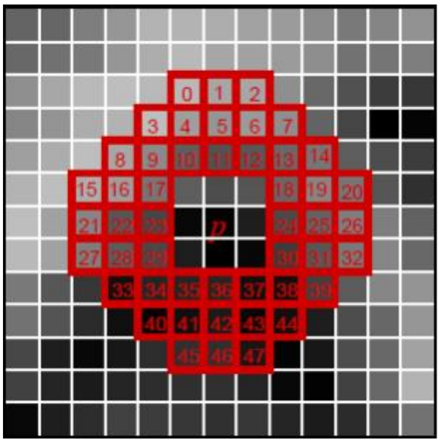


Fig. 3.4. Considered by the FAST-ER detector pixels

The cost function for the decision tree is determined as follows:

$$cost = (k_R + R^{-2})(k_N + N^{-2})(k_S + S^{-2}) \quad (3.5)$$

Where R - repeatability measure; N - detected feature points number; S - nodes amount in the decision tree.

FAST-ER is superior than FAST but executes more slowly. The FAST-ER detector, according to the authors, is the most efficient considering repeatability.

The FAST method was selected for usage after tests on photos showed that it completely satisfies the program's requirements.

3.3. Selection of contours by the Prewitt operator description

All currently used techniques are founded on discontinuity, one of the brightness signal's fundamental characteristics. Processing a picture with a sliding mask, also known as a filter, pattern, window, or kernel, which is a form of square matrix matching to a designated set of pixels in the original image, is the most popular method for locating gaps. Coefficients are the common name for matrix elements. Filtering, often known as spatial filtering, is the process of employing a similar matrix in any local changes. [11].

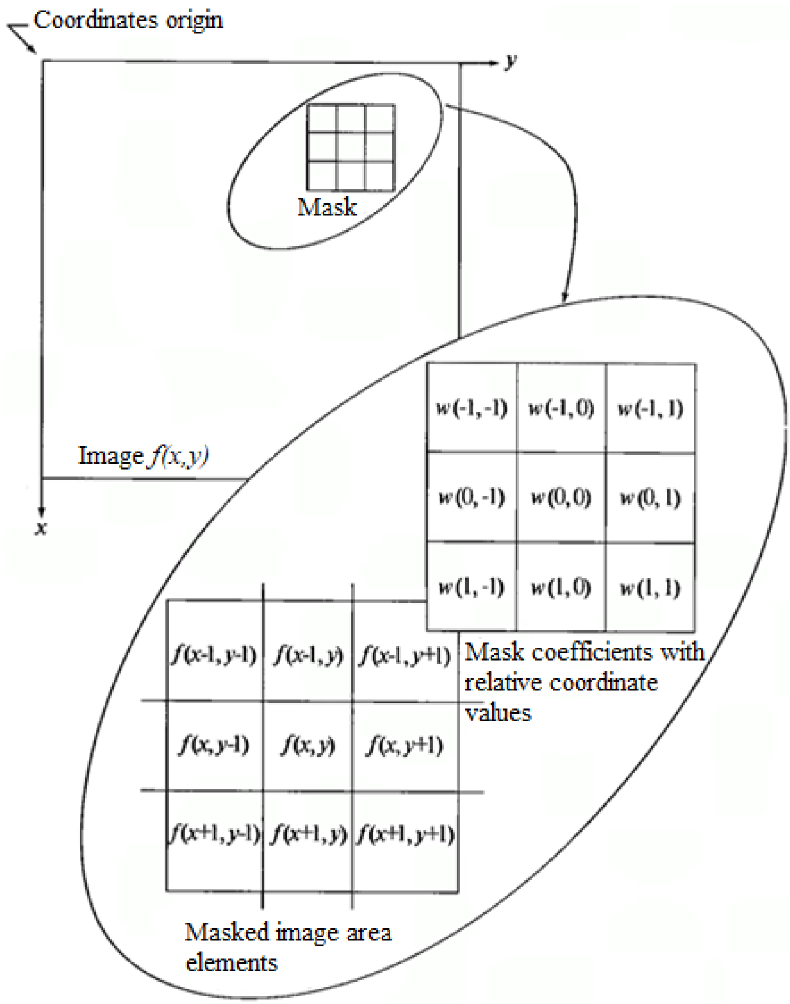


Fig. 3.5. Method for spatial filtering

A preset set of connections are used to compute the filter response at every point (x, y) in the process, which is based on simply shifting the filter mask across the picture. When using linear spatial filtering, the reaction is determined by adding the filter coefficients and the corresponding pixel values inside the filter mask's covered region. The outcome (response) R of linear filtering just at position (x, y) of the picture will be for the 3x3 element mask illustrated in Figure 3.5:

$$R = w(-1,-1)f(x-1,y-1) + w(-1,0)f(x-1,y) + \cdots$$
$$+w(0,0)f(x,y) + \cdots + w(1,0)f(x+1,y) + w(1,1)f(x+1,y+1) \qquad (3.6)$$

This, as you've seen, is the total of the pixel values right beneath the mask multiplied by the mask coefficients. Keep in mind that the mask is positioned at the point *(x, y)* since the coefficient *w (0,0)* is located at the value of *f(x, y)*.

When identifying variations in brightness, discrete analogs of the first and second order derivatives are utilized. We will only discuss one-dimensional derivatives for the sake of presenting simplicity.

The difference in values of adjacent components is what is referred to as the the one-dimensional function’s first derivative *f(x)*:

$$\frac{\partial f}{\partial x} = f(x+1) - f(x) \tag{3.7}$$

In this situation, we utilized a partial derivative expression to maintain the same notation while dealing with partial derivatives through two spatial axes for two variables, f(x, y). The consideration's core is unaffected by the employment of a partial derivative.

The second derivative, in a similar manner, is described as the difference between the first derivative's neighboring values:

$$\frac{\partial^2 f}{\partial^2 x} = f(x+1) + f(x-1) - 2f(x) \tag{3.8}$$

A number of a two-dimensional gradient discrete approximations are used to calculate the first derivative of a digital picture. The gradient of the picture *f(x, y)* at the position *(x, y)* is, by definition, the vector:

$$\nabla f = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \qquad (3.9)$$

The gradient vector's direction matches the direction of the function's *f* highest rate of variation at the point *(x, y)*, as is well known.

The modulus of such a vector, indicated by ∇f, plays a significant role in the identification of contours and equals to

$$\nabla f = |\nabla f| = \sqrt{G_x^2 + G_y^2} \qquad (3.10)$$

This number is equal to the greatest rate of change for the function *f* at the coordinates *(x, y)*, with the largest rate of change occurring in the vector ∇f direction. The gradient is another name for the value of ∇f.

Another crucial property is the gradient vector's direction. The angle between the ∇f vector's direction at the location *(x,y)* and the x-axis is denoted by the symbol *α(x,y)*. According to mathematical analysis,

$$\alpha(x, y) = arctg\left(\frac{Gy}{Gx}\right) \qquad (3.11)$$

It is simple to determine from here the contour's direction at point (x, y), which is parallel to the gradient vector's direction at this location. Additionally, by figuring out the values of the partial derivatives $\partial f/\partial x$ and $\partial f/\partial y$ for each point, you can figure out the gradient of the image.

Let the brightness values around some picture element be represented by the 3x3 region depicted in the figure below (see Fig. 3.6).

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

Fig. 3.6 3x3 neighborhood in the picture

The following formulas define how the Prewitt operator will employ such a mask:

$$G_x = (z_7 + z_8 + z_9) - (z_1 + z_2 + z_3) \quad (3.12)$$

and

$$G_y = (z_3 + z_6 + z_9) - (z_1 + z_4 + z_7) \quad (3.13)$$

The approximated value of the derivative along the x-axis in these calculations is the difference of the sums along the top and bottom rows of a 3x3 neighborhood, and the derivative along the y-axis is the difference between the sums along the first and final columns of this neighborhood. The Prewitt operator, which is utilized to execute these calculations, is represented by the masks in Fig. 3.7.

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	0	1

Fig. 3.7 Masks for Prewitt operator

3.4. Binarization of images using the Otsu technique

The main effect of image binarization is that the most important and brightest pixels for any further processing get as bright as possible, turning into white points (the maximum intensity or brightness color), while all other points that are assumed background are minimally bright, so, they are transformed into black points (absolute color absence, minimum intensity or brightness). As a result, the entire binarization process is simplified to the standard pixel-by-pixel conversion of each image point to either white or black, relying on a certain brightness characteristic, that is, on a specific minimum allowable brightness value, over which the pixel turns white. The first step in implementing picture binarization is to find this characteristic, which will be referred to as the binarization threshold [12].

There are currently a wide range of binarization models and techniques, from straightforward manual ones (the threshold is initialized individually and depends on the image itself) to sophisticated adaptive and multi-methods (such as multilayer binarization), but the Otsu method will be highlighted here as an intriguing and successful one.

Otsu's approach divides picture pixels into two classes—"useful" and "background," thanks to a straightforward statistical analysis of the picture that, while classifying pixels, ensures that the variation within one class is as low as possible.

The variance inside a class, which is the sum of the weights of the variances among two classes, is what Otsu's technique searches for as a threshold [13]:

$$\sigma_\omega^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) \quad (3.14)$$

where the weights ω_i — are two classes probabilities of two classes with threshold t separation, μ_i — their classes' diversity.

Otsu demonstrated that increasing variation between classes is comparable to increasing variance within a class:

$$\sigma_b^2(t) = \sigma^2 - \sigma_\omega^2(t) = \omega_1(t)\omega_2(t)[\mu_1(t) - \mu_2(t)]^2 \qquad (3.15)$$

which is a mathematical expression that can be updated repeatedly and is stated in terms of probability ω_i and arithmetic mean μ_i. This concept produced a successful algorithm:

Presented with a single-colored picture $G(i,j), i = \overline{1, Height}, j = \overline{1, Width}$, counter for repetitions k=0.

1. Determine the histogram $p(l)$ for the image and for every intensity level of the picture G the frequency $N(l)$.
2. Establish the starting values for $\omega_1(0)$, $\omega_2(0)$ и $\mu_1(0)$, $\mu_2(0)$.
3. For every value $t = \overline{1, max(G)}$ - semitones - the histogram's horizontal axis:
   1. Updating ω_1, ω_2 and μ_1, μ_2
   2. Calculate $\sigma_b^2(t) = \omega_1(t)\omega_2(t)[\mu_1(t) - \mu_2(t)]^2$
   3. If $\sigma_b^2(t)$ is larger than the current one, then take note σ_b^2 and the threshold *t* value.
4. The required threshold matches the highest $\sigma_b^2(t)$

$$N_T = \sum_{i=0}^{\max(G)} p(i),$$

$$\omega_1(t) = \frac{\sum_{i=0}^{t-1} p(i)}{N_T} = \sum_{i=0}^{t-1} N(i), \quad \omega_2(t) = 1 - \omega_1(t),$$

$$\mu_T = \frac{\sum_{i=0}^{\max(G)} i * p(i)}{N_T} = \sum_{i=0}^{\max(G)} i * N(i),$$

$$\mu_1(t) = \frac{\sum_{i=0}^{t-1} i * p(i)}{N_T * \omega_1(t)} = \frac{\sum_{i=0}^{t-1} i * N(i)}{\omega_1(t)}, \ \mu_2(t) = \frac{\mu_T - \ \mu_1(t) * \omega_1(t)}{\omega_2(t)}.$$

Fig. 3.8. Otsu threshold binarization of the original picture

3.5. Description of the template matching approach

The template matching approach, which compares the input picture with the template, was used to identify whether characters are present on the number plate [6].

An image's "similarity" is determined using a certain measure. In other words, the picture is "superimposed" with the pattern, and the difference between the two is taken into account. The location of the target object will be shown by the position of the template where this disparity will be minimized.

You can choose from a variety of metrics, such as cross-correlation (CCORR) or the sum of squared differences (SSD). Let's say that f and g are a photo and a template, respectively, with sizes of (k, l) and (m, n) and (color channels omitted); I j are the place on the image to which the template was "connected.

$$SSD_{i.j} = \sum_{a=0..m,b=0..n} \left(f_{i+a,j+b} - g_{a.b}\right)^2 \quad (3.16)$$

$$CCORR_{i.j} = \sum_{a=0..m,b=0..n} \left(f_{i+a,j+b} - g_{a.b}\right)^2 \quad (3.17)$$

Let's attempt to use the square difference to discover a kitty on the image.

Fig. 3.9. Example of tamplate image

Fig. 3.10. Photo from the website PETA Caring for [6]

The values of the measure measuring how closely a location in an image resembles the template are shown on Fig. 3.11 (SSD values for different i, j). The change is more noticeable in the dark area. This indicates the location that most closely follows the template; in Fig. 3.12, this location is circled.

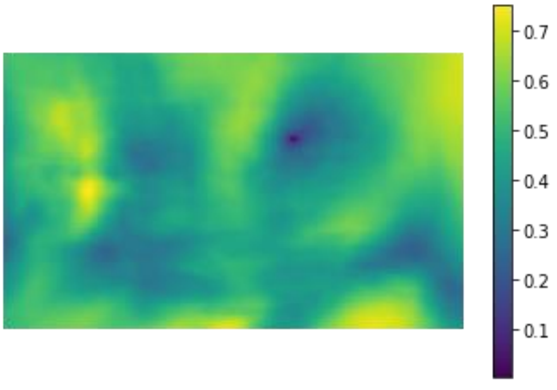


Fig. 3.11. SSD values for various I and j

Fig. 3.12. Matching area highlighted

Convolution of two pictures is what cross-correlation is in reality. Using the Fast Fourier Transform, convolutions may be applied fast. The convolution theory stated that following the Fourier transform, the convolution becomes a straightforward element-wise multiplication:

$$CCORR_{i.j} = f * g = IFFT\big(FFT(f * g)\big) = IFFT\big(FFT(f) \cdot FFT(g)\big) \quad (3.18)$$

Where the convolution operator * is used. The cross-correlation may be readily determined in this manner. When implemented this way, the overall complexity is O(klmn), as opposed to O(klmn) when implemented straight. Convolution may also be used to implement the squared difference since, once the brackets are expanded, it becomes the difference between the cross-correlation and the square sum of the photo pixel values:

$$SSD_{i.j} = \sum_{a=0..m,b=0..n} \left(f_{i+a,j+b} - g_{a.b}\right)^2 = \quad (3.19)$$

$$\sum_{a=0..m,b=0..n} f_{i+a,j+b}^2 - 2f_{i+a,j+b}g_{a.b} + g_{a,b}^2$$

$$= \sum_{a=0..m,b=0..n} f_{i+a,j+b}^2 + g_{a,b}^2 - 2CCOR_{i.j}$$

The method might not be effective when resizing. This is because the function counts on the item being shrunk by the same amount horizontally and vertically. But that may not be the case. The distortion brought on with the log-to-polar conversion causes the search to become unstable when the size is adjusted too much.

CHAPTER 4. NUMBER PLATE RECOGNITION PROBLEM SOLUTION AND EXPERIMENTAL RESULTS

4.1. Overview of the test experimental installation

In order to make the detection of number plate contour possible such experimental installation is introduced:

1) WEB-camera "**WebCam PRO**".
2) Raspberry Pi 4 Model B with installed Matlab2020.
3) Developed program for computing the algorithm.

To obtain photos, images and videos, was used the optical sensor of the **WebCam PRO webcamera** with a fixed focus distance, 90 degs view and 1280x1024 pixel resolution.

Microcomputer Raspberry Pi 4 Model B 4GB RAM was used as a computer. Its characteristics are described in Table 4.1.

Table 4.1. Raspberry Pi 4 characteristics.

Microcomputer name	*Raspberry Pi 4 Model B 4GB RAM*
CPU	*Broadcom BCM2711*
Core number	*4 cores Cortex-A72 (ARMv8)*
Number of logical processors	*4*
RAM	*4 Gb*
Power supply	*USB Type-C (5V, min 3A).*

Fig. 4.1. Used webcam and microcomputer

The Matlab2020 programming environment and its libraries, including Image Acquisition Toolbox, Image Processing Toolbox, Computer Vision Toolbox, and Support Package for USB Webcams, were loaded on the PC to be used in the creation of the software. The easiest way to do the task is using this program, which makes it possible to easily deal with image and video processing with.

A brief block schematic of the experimental setup is displayed below.

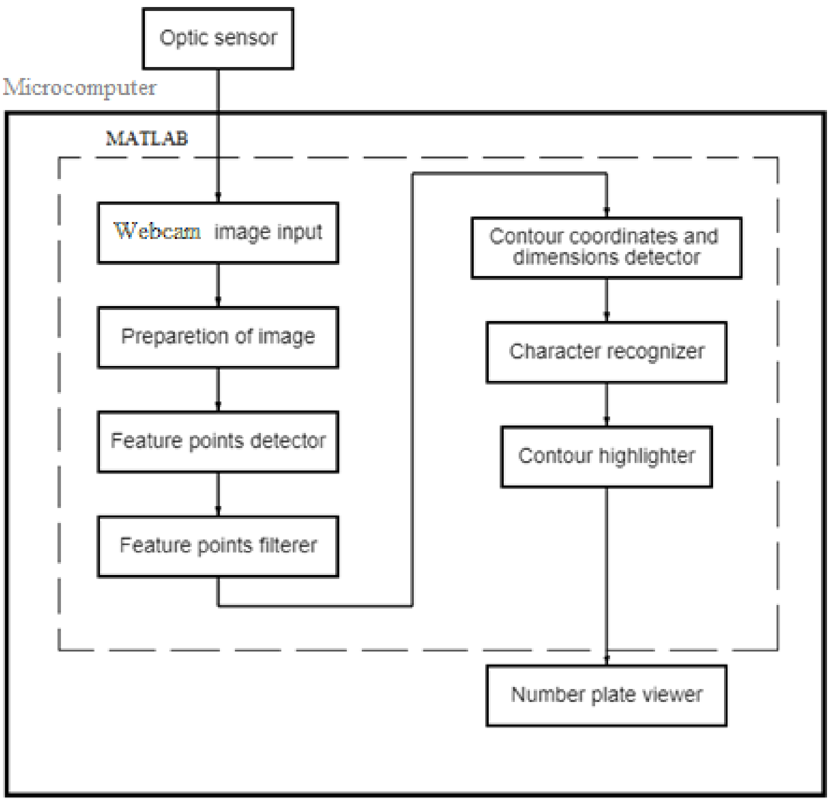


Fig. 4.2. Diagram of the experimental setup in blocks

4.2. An explanation of the program's algorithm

A working algorithm:

1. Recording the input frame to a computer;
2. Photo preparation for processing:

   a. Using the MATLAB programming environment to upload an image;

   b. Create a grayscale version of the image.;

   c. Cropping extra pixels from a picture;

   d. Gauss filter used to blur the pixels in an image;
3. Identifying every characteristic feature in the picture;
4. The characteristic features are filtered;
5. Determining the license plate's size and coordinates;
6. Recognition of symbols found on the license plate;
7. Determining the plate's shape from the input image and printing the recognized characters.

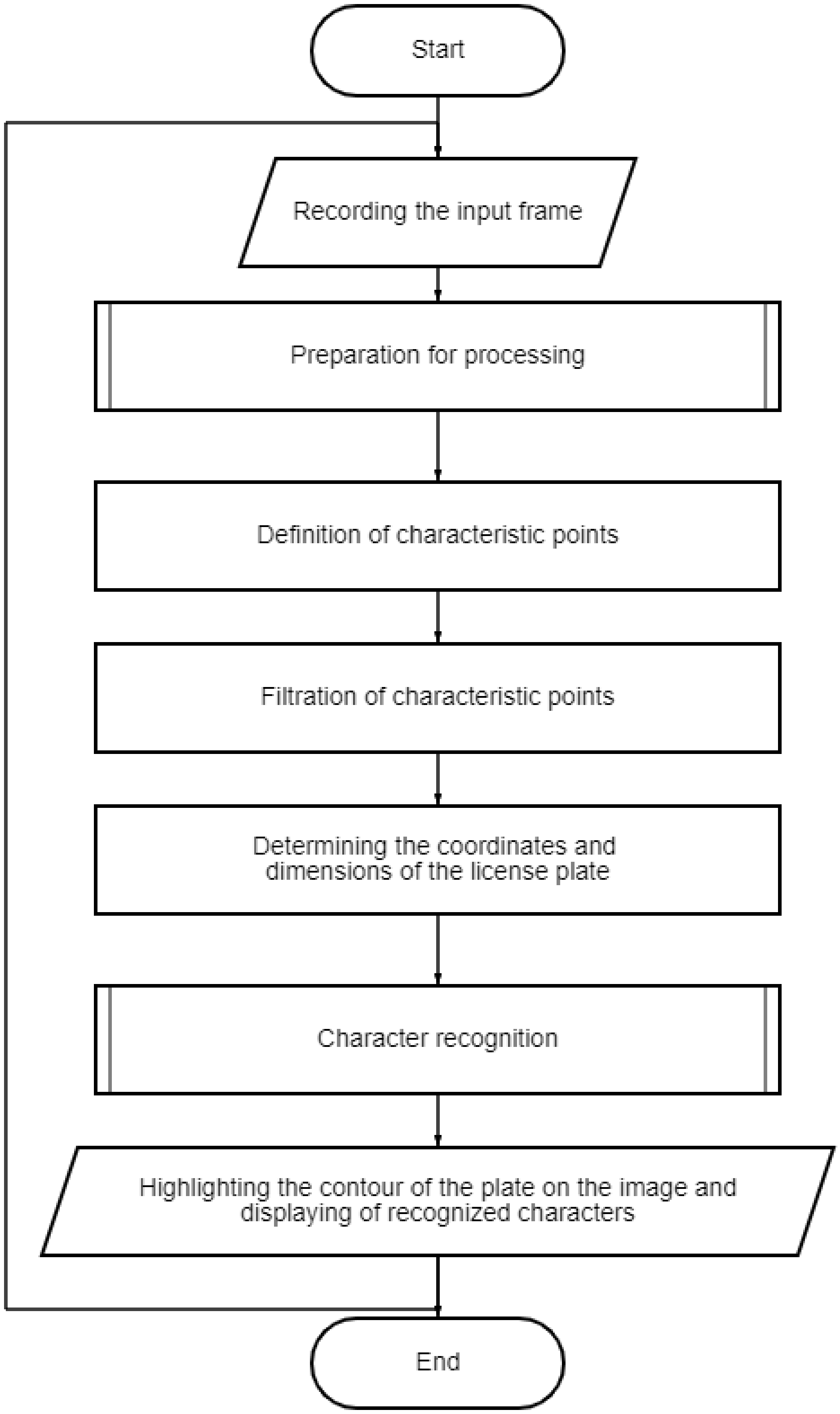


Fig. 4.3. Block diagram showing the program's algorithm work

4.2.1. Getting ready the picture data for processing

Images from the sensing device are acquired in Rgb color model with a resolution of 1280 960 dots, but they also contain a lot of noise and extraneous data. It is necessary to prepare the data stored in the photo in advance so that it may be processed and subjected to various mathematical processes. Subsections after that will explain this.

a. Uploading a picture on the Matlab software environment

Importing the image from the disk into the Matlab2020 development platform, which includes the necessary built-in capabilities and tools, is the initial step in image processing.

Using the imread function, the picture is imported and then saved to a variable as a three-dimensional data array. This data array shows the value of each pixel on the three channels (red, green, and blue), which combine to determine the color of the pixel (Fig. 4.4).

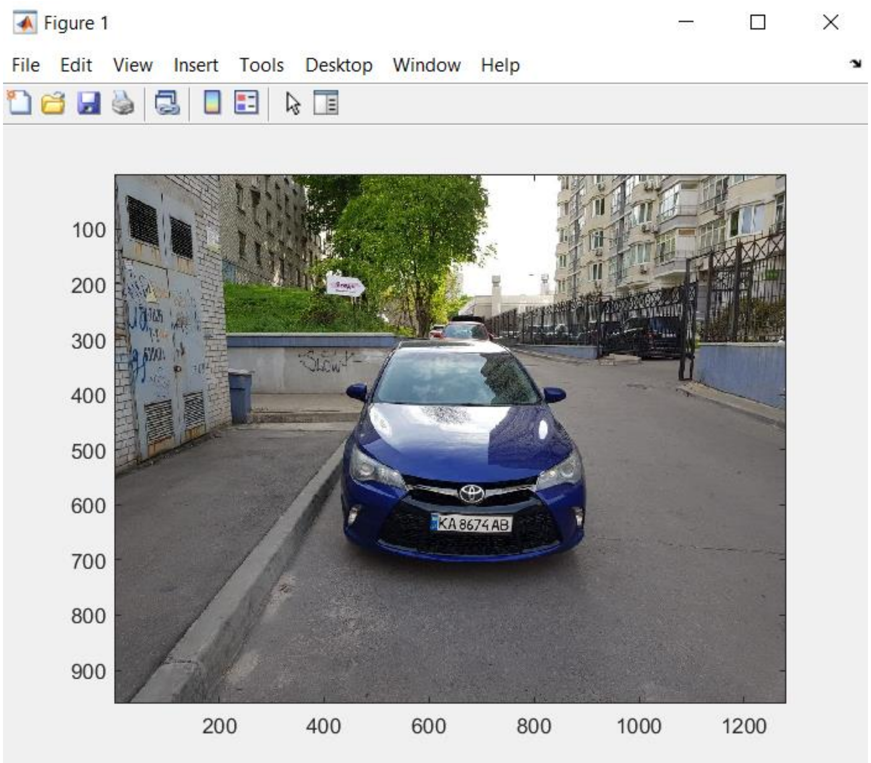


Fig. 4.4. An illustration of a downloaded "raw" photo

Now, computations may be made in the program code thanks to these arrays.

b. Convert the picture to grayscale

The *uint8* data type, a 1 byte-sized integer with a range of 0 to 255, will be used for further computations.

Pixel values for the R, G, and B channels range from 0 to 255. Those three channels should be merged into one grascaled since the value of their aggregate may be more than 255. This issue is resolved using the function *rgb2gray ()*.

The rgb2gray function weights the R, G, and B elements to generate a grayscale value from an RGB value.:

$$I_{gray} = 0.2989 * R + 0.587 * G + 0.114 * B \quad (4.1)$$

A grayscale picture (Fig. 4.5), which was captured as a one-dimensional grid of dots, was obtained as the output..

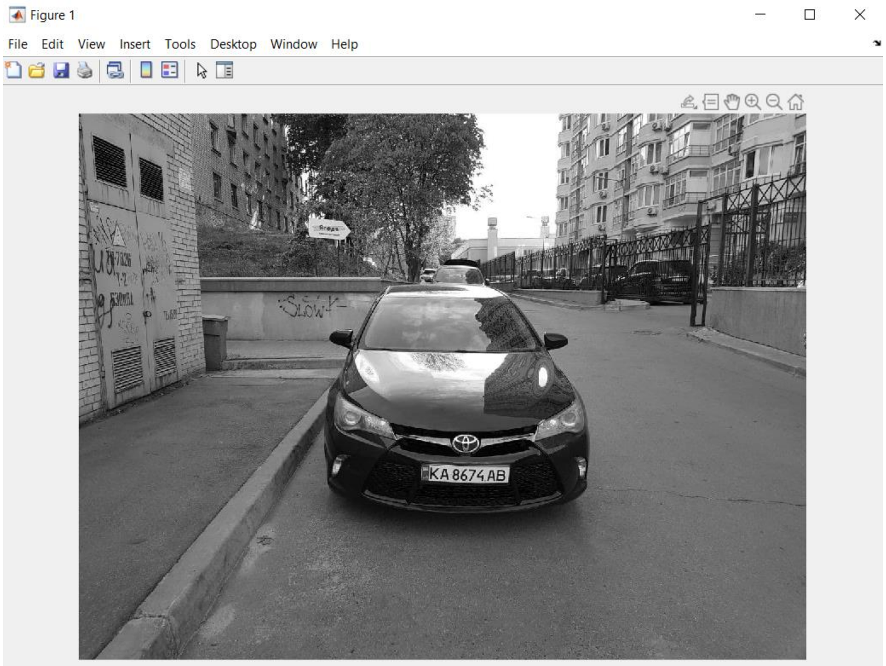


Fig. 4.5. Image conversion to grayscale

c. Cropping extra picture pixels

The image above demonstrates that in addition to the car itself, the optical sensor also captured a number of other items. This will make it more difficult to identify characteristic features in the ongoing activity. The picture should be cropped at its boundaries to a specific number of pixels with the function imcrop in order to limit the quantity of extraneous information (Fig. 4.6.).

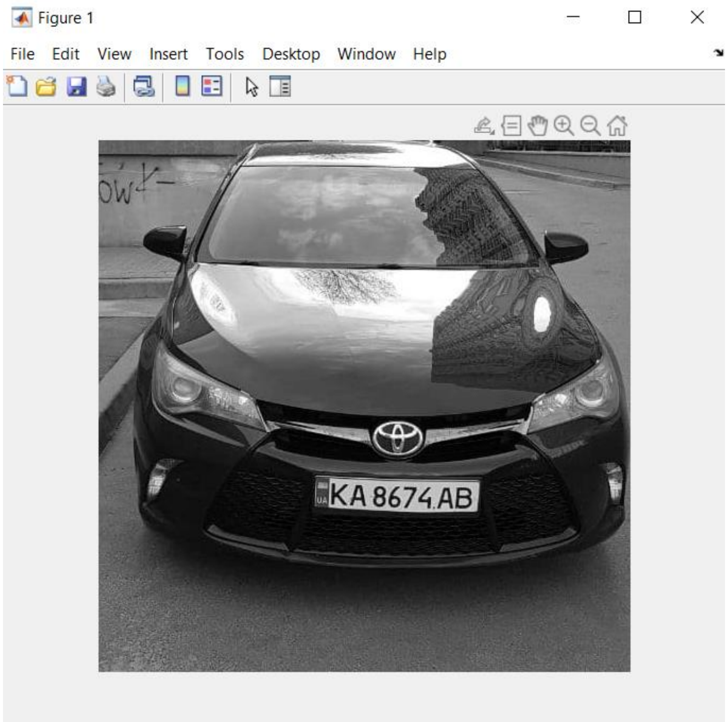


Fig. 4.6. Cropped photo

The amount of pixels and extraneous data in the image were reduced after cropping, which sped up the program's operation.

d. Gauss filter used to blur the pixels in an image

Once the grayscale picture has been trimmed, 2-D Gaussian filtering must be used to remove any extraneous noise [14].

The sliding window's pixels that are nearer the examined pixel need to have more of an impact on the filtering outcome than the extreme ones. Consequently, a bell-shaped Gaussian function may be used to define the coefficients of the mask weights. A two-dimensional Gaussian filter is utilized to filter pictures:

$$G_{\sigma} = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} * \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{y^2}{2\sigma^2}} \quad (4.2)$$

The blurriness of the image increases with increasing parameter σ size. The usual filter radius equals $r = 3\sigma$. Here, the mask size $2r+1 \times 2r+1$ and the matrix size $6\sigma+1 \times 6\sigma+1$. The Gaussian function's values will be insignificant outside of this area. The *imgaussfilt ()* function in MATLAB may be used to apply a Gaussian filter to an image, as seen in Fig. 4.7.

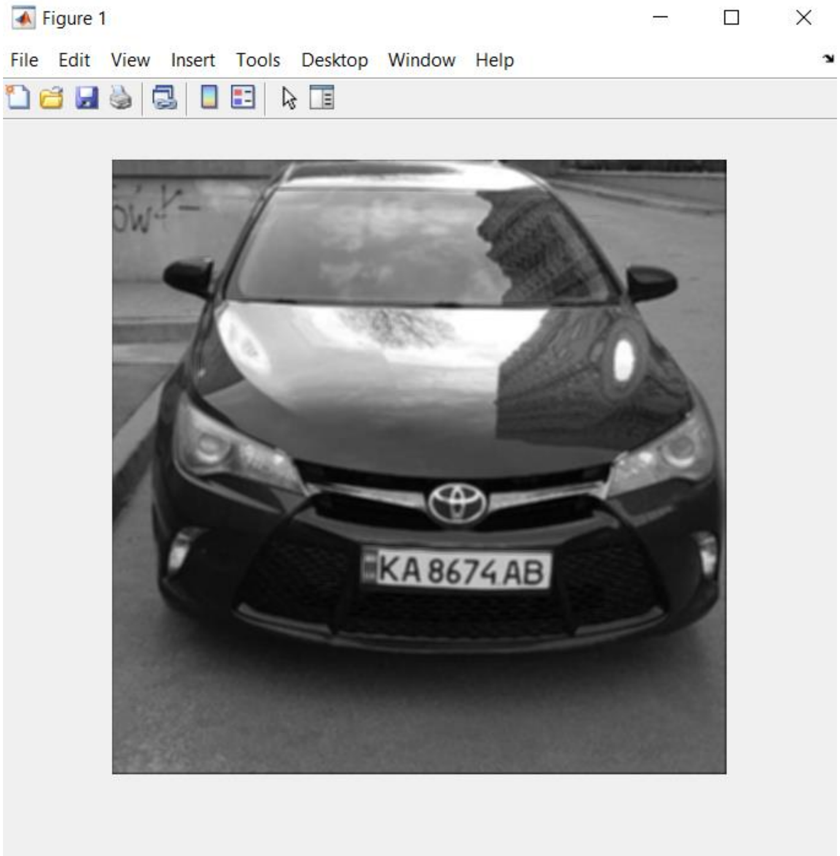


Fig. 4.7. Gaussian filtering's output

4.2.2. Recognition of all feature points in the picture

The program's job is to keep track of the target's shape. In this scenario, an automobile serves as the tracking object, and the numberplate is one of the most frequent and recognizable features seen on every standard car. Its exact location will therefore be detected.

Finding all the unique features in the image is necessary before processing them in order to determine where the license plate is located.

The neighborhood of a point in the picture known as a feature point *m* may be differentiated from the region *o(m)* of any other image point known as a keypoint *o(n)* in a different neighborhood of the keypoint $o_2(m)$. A detector and a descriptor are used to identify keypoints in a process.

A detector is a tool for removing particular spots from images. The detector guarantees that the same feature points will always be found regardless of how an image is transformed. The most well-known feature point detectors are the Harris corner detector, SIFT, and FAST.

The FAST detector is optimal at identifying the distinctive spots, according to the research methodology. As its name implies, this algorithm operates more quickly than its rivals while still achieving its intended goal. This method seeks out spots around an object's edges and corners, or locations where contrast decreases (Fig. 4.9.).

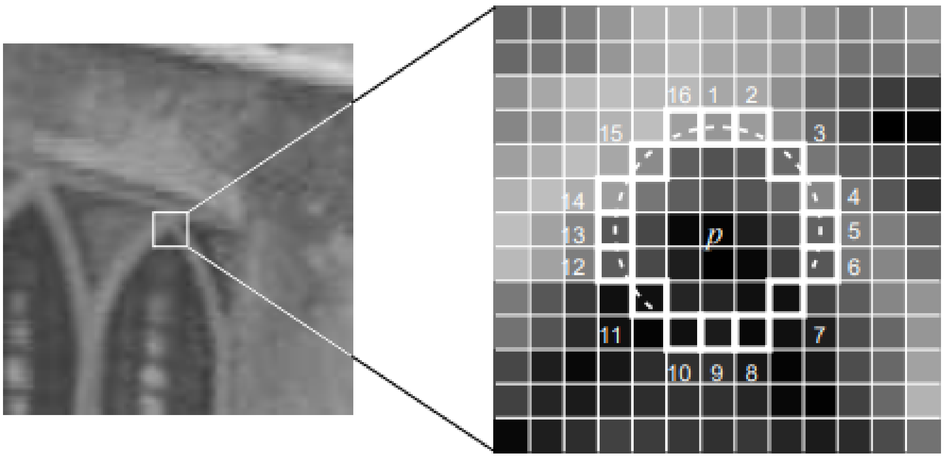


Fig. 4.8. FAST checks pixels using the algorithm

These locations can be found: In order to determine if there exists a continuous section of pixels of length t that are K grades darker (or lighter) than the candidate pixel, FAST creates a circle of radius R around it. The pixel is deemed a "key point" if this criterion is satisfied.

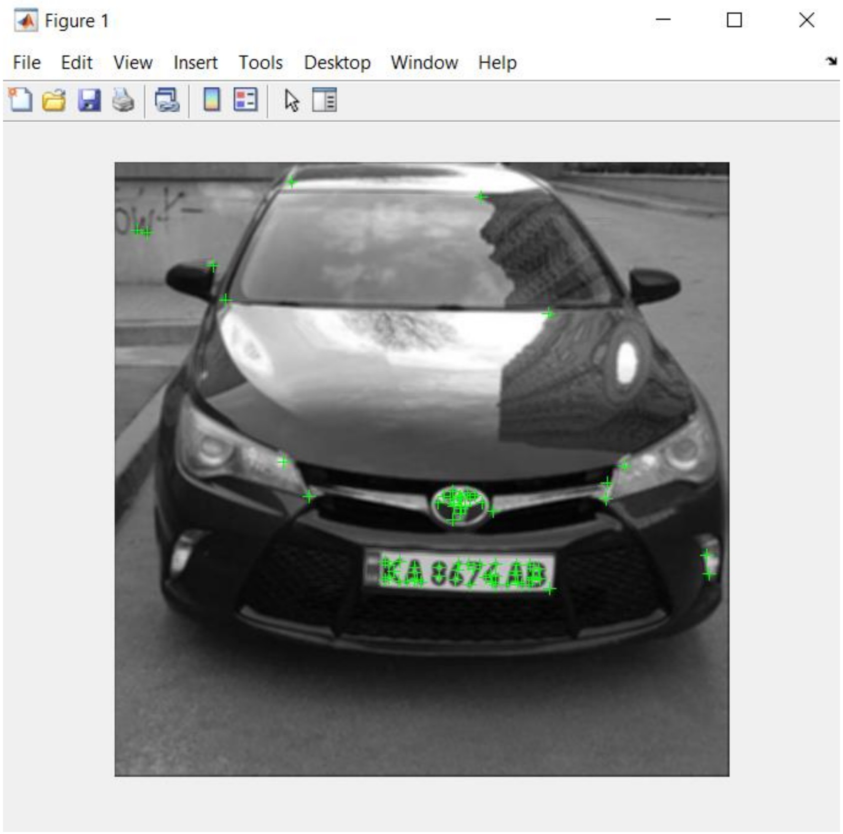


Fig. 4.9. The FAST algorithm identified feature points.

4.2.3. Found feature points filtering

The graphic above (Fig. 4.9) demonstrates that the distinctive points were discovered not solely on the plate number itself, but also in this location, where there is the greatest concentration of them. This implies that they need to be filtered under specific circumstances.

The filtering technique will be based on the understanding that the symbols engraved on the plate number and their edges contain the greatest amount of distinctive points. The functioning of this algorithm will then be gradually explained.

First, use the function *corners.Location()* to record the coordinates *x*, *y* of each typical point in their arrays (Fig. 4.10).

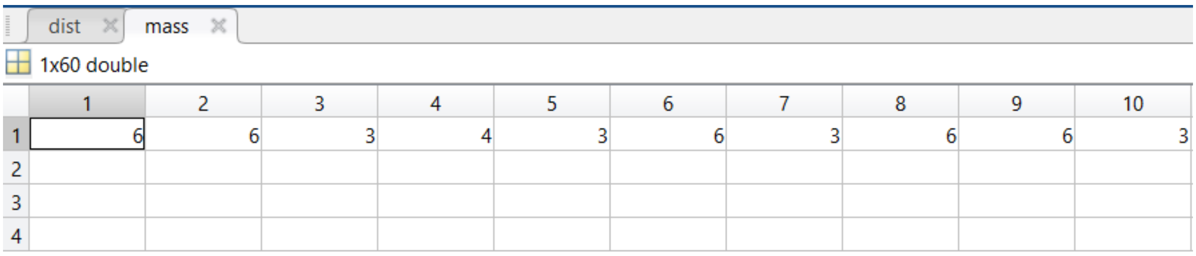
Fig. 4.10. Arrays of feature points coordinates that have been recorded

Remove feature points that are separated by more than 60 pixels from one another after obtaining their coordinates. This value was determined through experimentation to be the best one. Next, use the formula to get the separation between every point and its neighboring characteristic points:

$$D_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{4.3}$$

Where $D_{i,j}$ – the points separation distance; $x_i,\ y_i$ – coordinates for the initial point; $x_j,\ y_j$ – next point's coordinates.

Now, set the variable m, that is equal to the point's weight coefficient, to every point whose neighbor is within 60 pixels of it. In other words, the weight of a feature point will increase in proportion to how many neighbors it has at a distance of up to 60 pixels.



	1	2	3	4	5	6	7	8	9	10
1	6	6	3	4	3	6	3	6	6	3
2										
3										
4										

Fig. 4.12. An array of point-by-point weight values

It is possible to filter data using this criterion when the weights for each feature point are available. The minimal threshold of weight for feature points, m_{min}, is entered for this purpose. Experimental analysis is used to identify the estimated amount of unique points that are found on the license plate. Adjust the minimum weight threshold accordingly by setting it to $m_{min} = 6$ and comparing it to the weight of every point. If $m \geq m_{min}$, the point passes the test and its coordinates x_{1i}, y_{1i} are copied into a new array. Points that failed the check have their coordinates set to 0.

The nonzeros() method is used to delete the locations of the points, which will have a value of 0. This completes the process of filtering points. Now, a collection of points that meet the required standard—those that are located immediately on the license plate—is discovered (Fig. 4.12.).

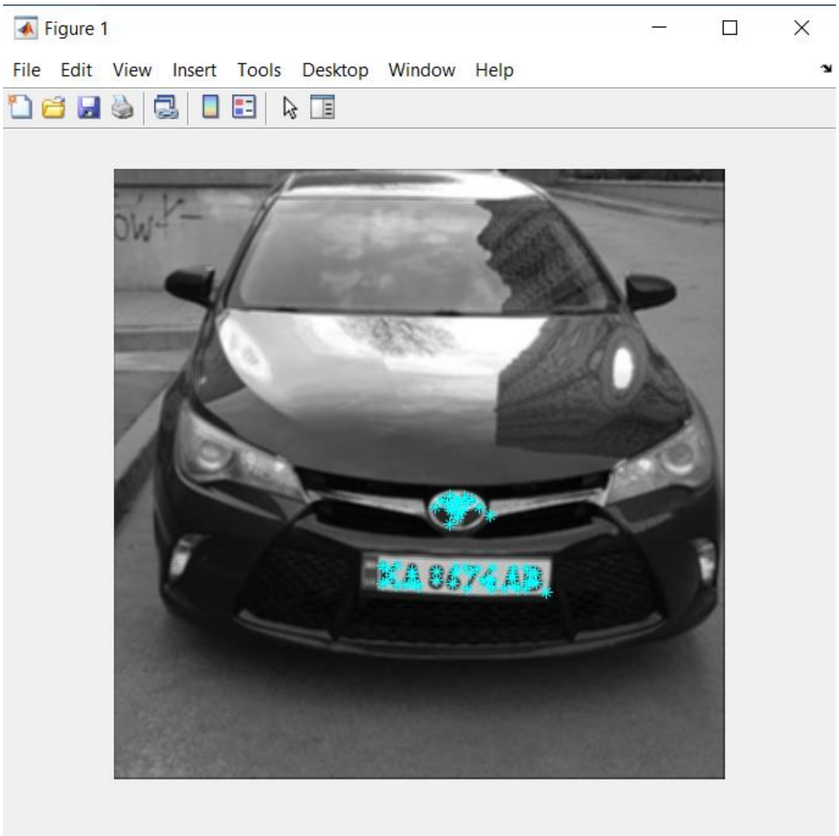


Fig. 4.12. Visualization of the filtered points

Additionally, it is possible that smaller groups of characteristic points that are farther away from the license plate but not too far enough to fail the distance check will fulfill the criteria for the minimum weight of the point. The following code won't function properly in this situation when trying to locate the number plate's location. In this scenario, m_{min} will rise by 1 until the weight limit of the point's threshold value is high enough to eliminate parasitic points, allowing the program to run as intended.

4.2.4. Calculating the license plate's size and location

It is fair to assume that after filtering the feature points, just the license plate remains, and the process may now go on to figuring out its coordinates and size.

It is necessary to obtain information like the coordinates of the upper left corner M_{left} , M_{upper} in order to set the picture cropping boundaries and leave only the image of the plate itself and the width value W and height H of the plate, which has the following formula:

$$W = M_{right} - M_{left} \tag{4.4}$$

$$H = M_{lower} - M_{upper} \tag{4.5}$$

Where M_{left} – the array of point co-ordinates' lowest value x_{1i} (cropping to the left); M_{right} – the highest value from the points' coordinates array x_{1i} (edge of the right crop); M_{lower} – the array of point coordinates' highest value y_{1i} (lower crop boundary); M_{upper} – the least value in the points' coordinates y_{1i} (upper crop boundary).

Knowing the aforementioned values, the license plate's picture is cropped as seen in Fig. 4.13.

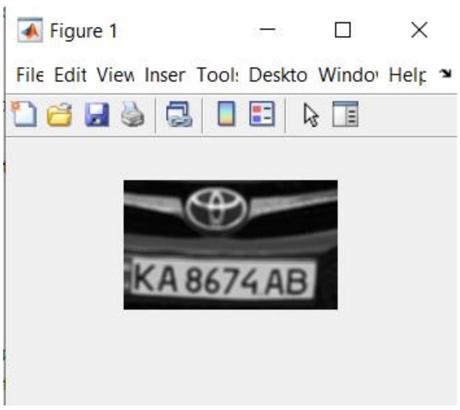


Fig. 4.13. The license plate image after being cropped based on its distinguishing features

The generated image must be converted from grayscale to binary in order to more clearly illustrate the locations of the number frame.

The goal of image binarization is to make the brightest and most important pixels as bright as possible, converting into white points (the color with the highest intensity or brightness), while all other points that are considered to be background become minimally bright, that is, they are transformed into black points (minimum brightness or intensity, absolute absence of color).

The *imbinarize()* function in the Matlab software environment may binarize an image using the Otsu binarization technique (Fig. 4.14.).

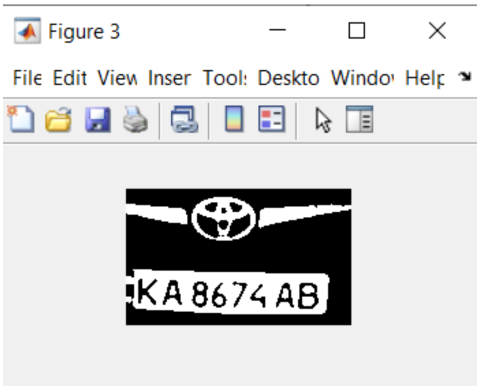


Fig. 4.14. License plate in binary format

Selecting the contours of the image's objects is necessary to further refine the coordinates (Fig. 4.15.). I decided to use the Prewitt operator to choose contours.

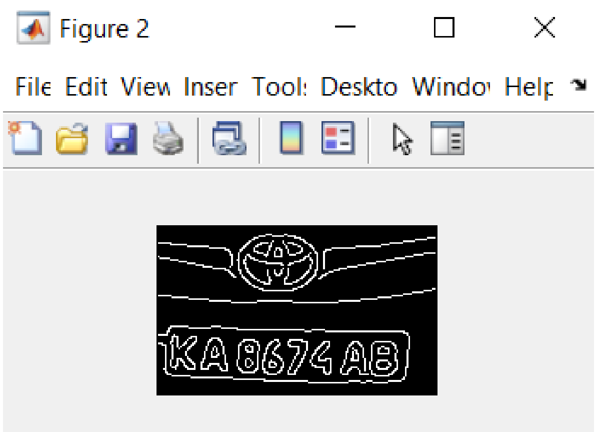


Fig. 4.15. Image with selected contours

Using a mask, the Prewitt operator selects an object's horizontal outlines (Fig. 4.16.).

-1	-1	-1
0	0	0
1	1	1

Fig. 4.16. The Prewitt operator's horizontal mask

The mask is transposed to choose vertical shapes.

Then, in order to finally cropping of the license plate, use the *regionprops()* method to determine the attributes of the resultant binary picture. The parameters Area, BoundingBox, and Image are among them.

Where Area represents the precise number of pixels within the enclosed area; coordinates and measurements of the smallest rectangle enclosing a closed region, or "bounding box"; Binary image of the same size as the BoundingBox that was returned as a binary array is called Image.

The location, width, and height of the greatest BoundingBox are then discovered by comparing the Area with the BoundingBox. This is the last cropping of the license plate (Fig. 4.17.).

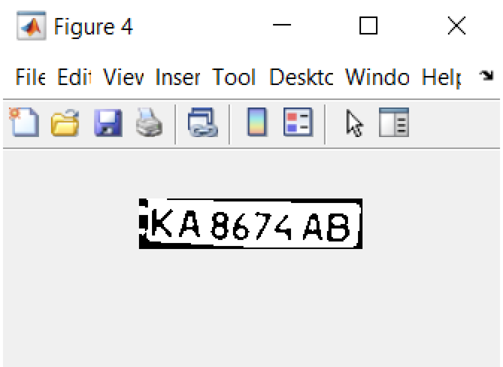


Fig. 4.17. Cutout of the plate's final appearance

4.2.5. Defining the symbols on a license plate

The position and specifications of the registration number have already been identified, therefore the process of identifying the characters on it may begin.

First, invert the generated binary picture by using the *bwareaopen()* method to eliminate any superfluous pixels whose closed region is less than 50 pixels (Fig. 4.18).

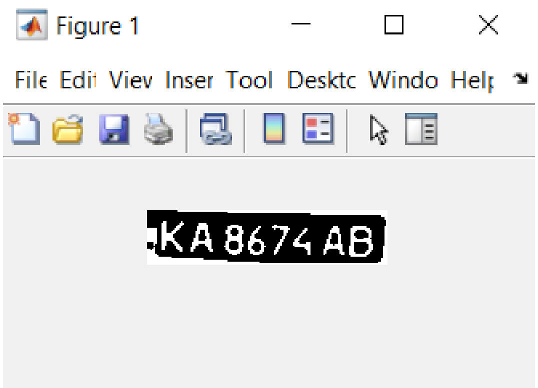


Fig. 4.18. Picture inverted with noise removed

The process of getting ready to recognize letters and numbers has now been completed.

The approach of template matching will be used for letter recognition. Finding the area of the image that most closely fits a template is the basis of this technique. An image's "similarity" is determined using a certain measure. In other words, the picture is "superimposed" with the pattern, and the difference between the two is taken into account. The requested item will be located at the point of the template where this divergence is least.

As a result, a database of templates for pictures of letters and numbers was initially developed and saved in the folder Alpha in order to apply this technique. Each picture is binary, has a resolution of 24 x 42 pixels, and is saved in the.bmp file format (see Appendix B).

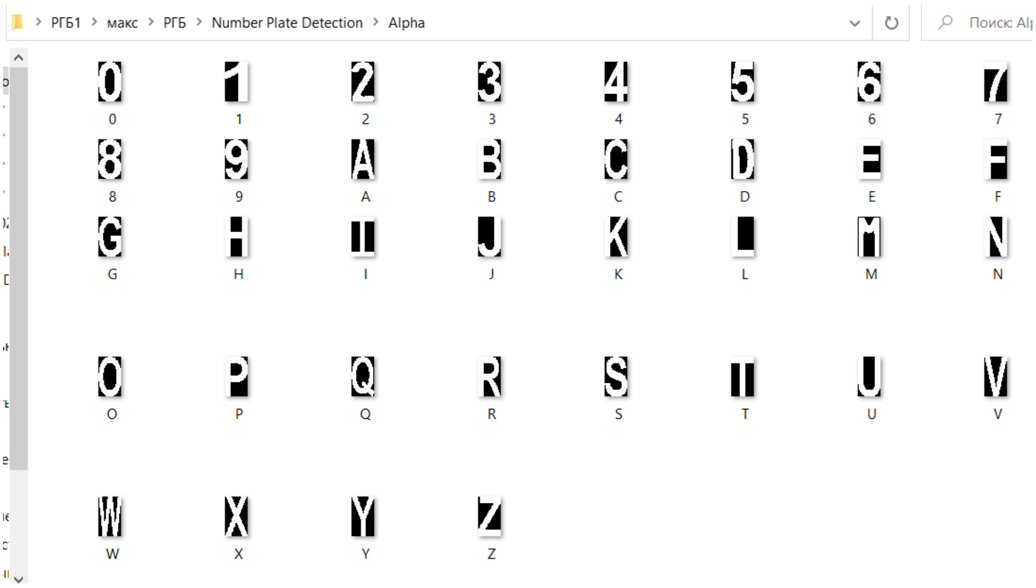


Fig. 4.19. Stored letter and number templates are kept in a folder.

Each picture is assigned to its corresponding variable, which is then assigned to the corresponding arrays letter (for letters) and number (for numbers), that are then inserted into the two-dimensional array NewTemplates.

The resolution of the tablet picture that results after storing the array of images of the letters and numbers is altered in order to match it with the templates. From left to right, every template is contrasted with the final picture of the license plate. The function *corr2()* is used to get the correlation coefficient for each of them using the following formula:

$$r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{m_n} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}} \quad (4.6)$$

Where $\bar{A}$ is arithmetic mean of A; $\bar{B}$ is arithmetic mean B; A is the initial input point array; B is the second input point array; m, n is points in the first and second arrays, respectively.

The more closely the pattern and the input picture match, the higher the correlation coefficient (see Appendix C).

The templates each have a unique allocated index. The letter or number associated with this index is shown when the *find()* method locates the index with the highest correlation coefficient value.

Read characters from the plate are shown as a result (Fig. 4.20).

```
noPlate =

    'KA8674AB'

fx >>
```

Fig. 4.20. Identified symbols on the plate

There is also a check for the amount of characters detected because the algorithm might malfunction occasionally and display more than 8 characters. Additionally, additional characters are dropped if the number of characters is higher.

Additionally, there are instances where inadequate pre-preparation of the image results in the software finding fewer characters than necessary. As a result, until the procedure is successfully carried out, it is repeated if the number of characters obtained is less than 8, then it is repeated once more.

4.2.6. Defining the plate's shape from the source picture and printing the recognized characters

The number plate has to be highlighted for the program's outcome to be seen. The *rectangle()* method, which draws a rectangle using the initial coordinates, width, and height provided, will be used to do this (Fig. 4.21).

It is necessary to carry out inverse calculations—the reverse of what was done earlier—in order to discover these coordinates. Therefore, you can quickly determine the coordinates of the registration plate picture on the original input picture by knowing the number of iterations of the cycle, or how many times the methods for cropping the input image were carried out.

And using the *text()* function, an inscription that replicates the wording of the characters found on the license plate is shown when these locations have been discovered (Fig. 4.21.).

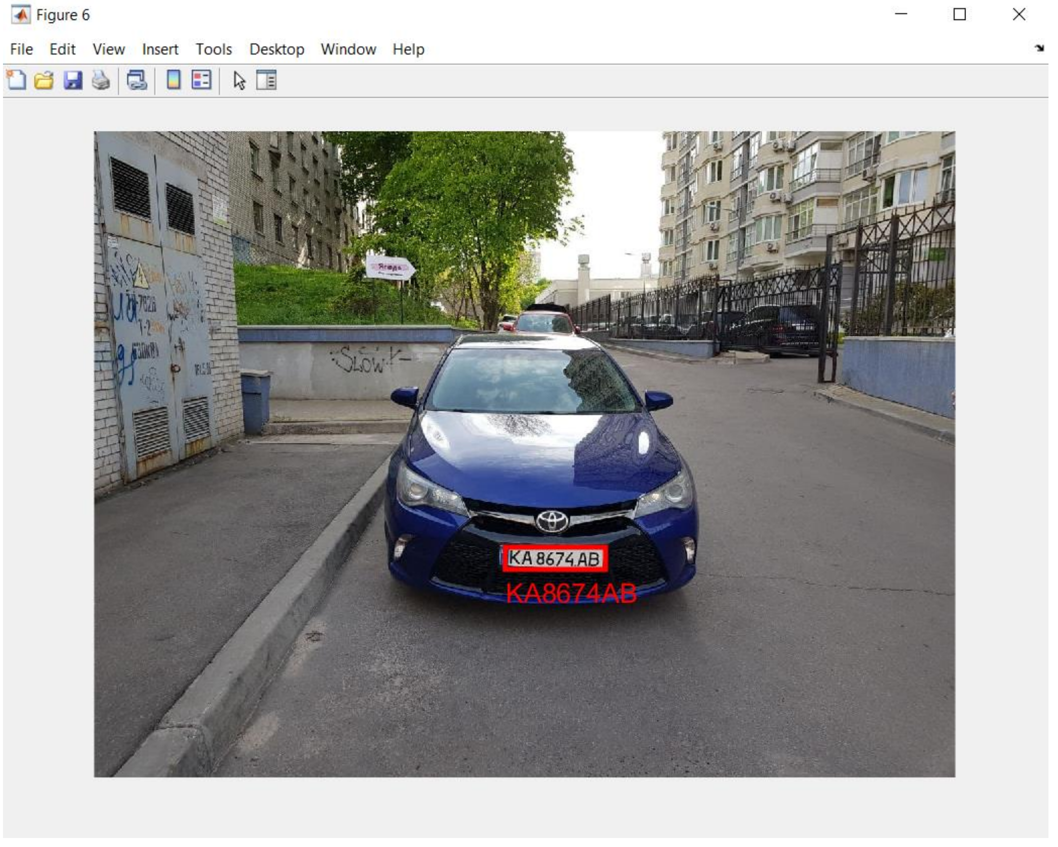


Fig. 4.21. Displayed letters and a number box are highlighted in the input picture

This makes the software effective at tracking license plates and identifying the symbols on them (The working program code is shown in Appendix A).

Naturally, it has its drawbacks, which are evident in the degree of the angle at which the video frame was captured to trace the object's contour. In an experimental study, it was discovered that the system correctly determines the coordinates of the license plate until the angle of view on the vertical and horizontal axes has exceeded about 55 degrees, and that after an angle of 50 degrees, the accuracy of the license plate symbol detection becomes less instructive.

4.2.7. Saving of recognized objects

Once a vehicle's license plate has been identified and recognized, there is a need to preserve it for further analysis or research.

That is why it was decided to save the identified frames in a separate folder using the Matlab function *saveas(fig,filename)*, which will save each non-repeating frame through a built-in loop.

To navigate through the frame database, each of them receives a name with reference to the date and time, using the Matlab function *clock*.

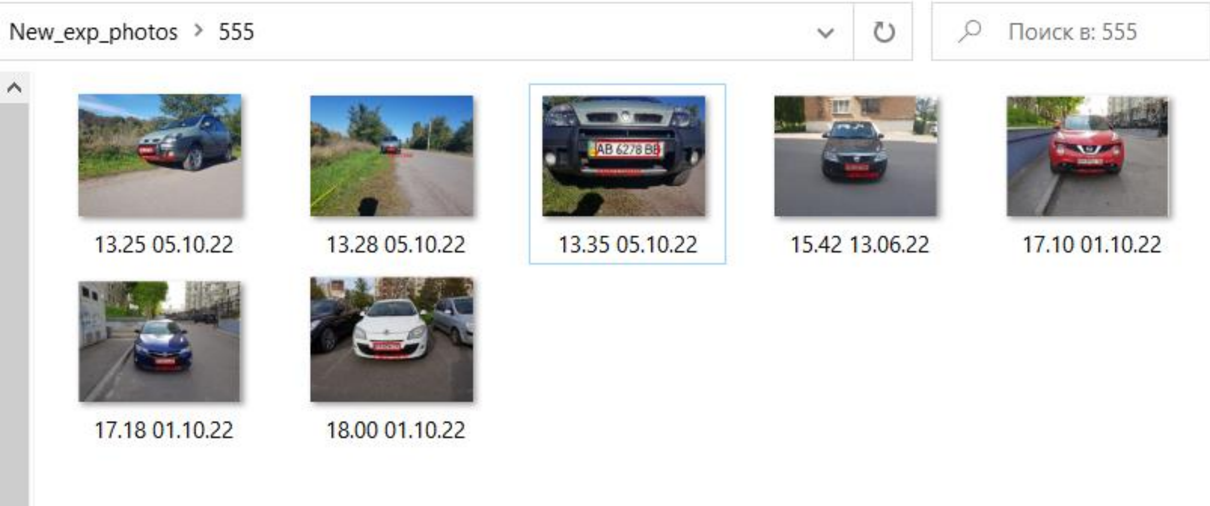


Fig. 4.22. Folder with recognized frames saved

4.3.1. Analysis of the critical values of the recognition range for the installation

The quality of work of visual recognition systems is primarily limited by the quality of the camera matrix. It is clear that for the optimal operation of the system, it should be installed at a comfortable distance from the object of recognition. To find out the optimal range of camera installation distance, you need to find the minimum and maximum permissible installation distance.

That is why experimental work was carried out to identify critical distances for the operation of the installation.

For experiments, the camera was installed at the level of the license plate, perpendicular to it. During their implementation, it was found that the minimum permissible distance to the license plate is 0.5 m.

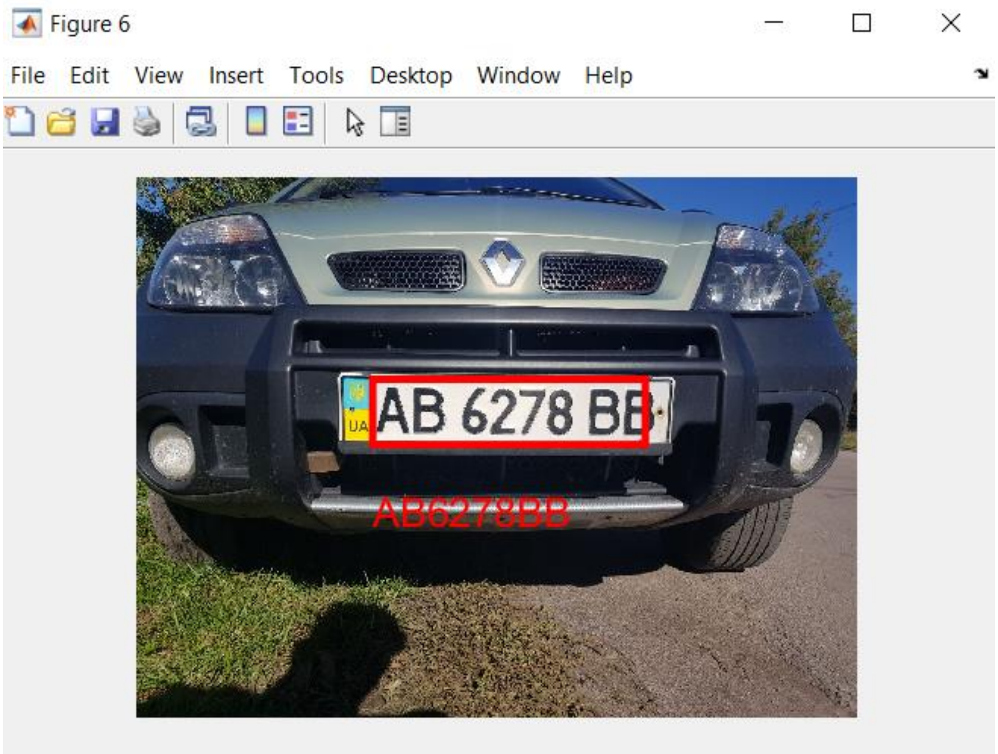


Fig. 4.23. Recognised number plate at minimum permissible distance

If the distance to the object is less than the minimum permissible distance, then the FAST corner recognition algorithm will not be able to correctly find the characteristic points. Due to the large scale of the license plate frame in the photo, the FAST algorithm will find characteristic points on the license plate, but they will be too far apart. Therefore, they will not pass the process of further filtering, and those that pass will be false (Fig. 4.24).

Fig. 4.24. Incorrectly defined characteristic points at a distance smaller than the minimum permissible

After determining the minimum permissible installation distance, the installation was moved away from the plate with the step of 0.5 meters to determine the maximum permissible installation distance (Fig. 4.25).

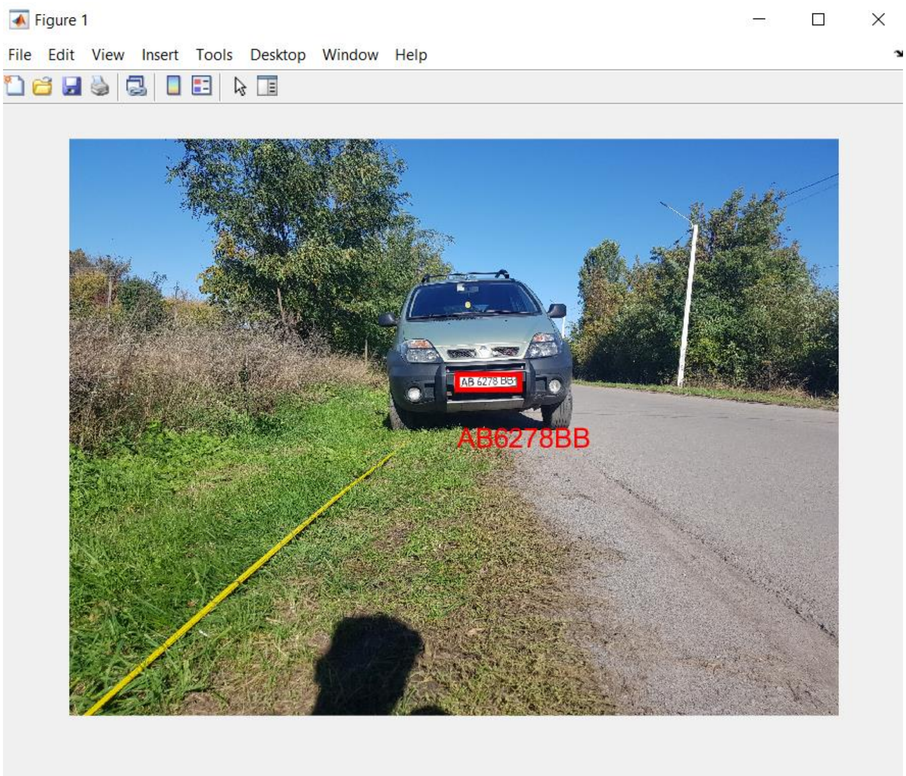


Fig. 4.25. Intermediate result at a distance of 5m

Approaching the 12 m mark, the resolution of the camera began to fall short and the accuracy of plate recognition began to drop. At a distance of 12 m, the recognition accuracy was approximately 80%, and already at a distance of 13 m, it was approximately 50%.

Judging by this experiment, it can be concluded that the maximum permissible distance for installing the camera is 12 m (Fig. 4.26).

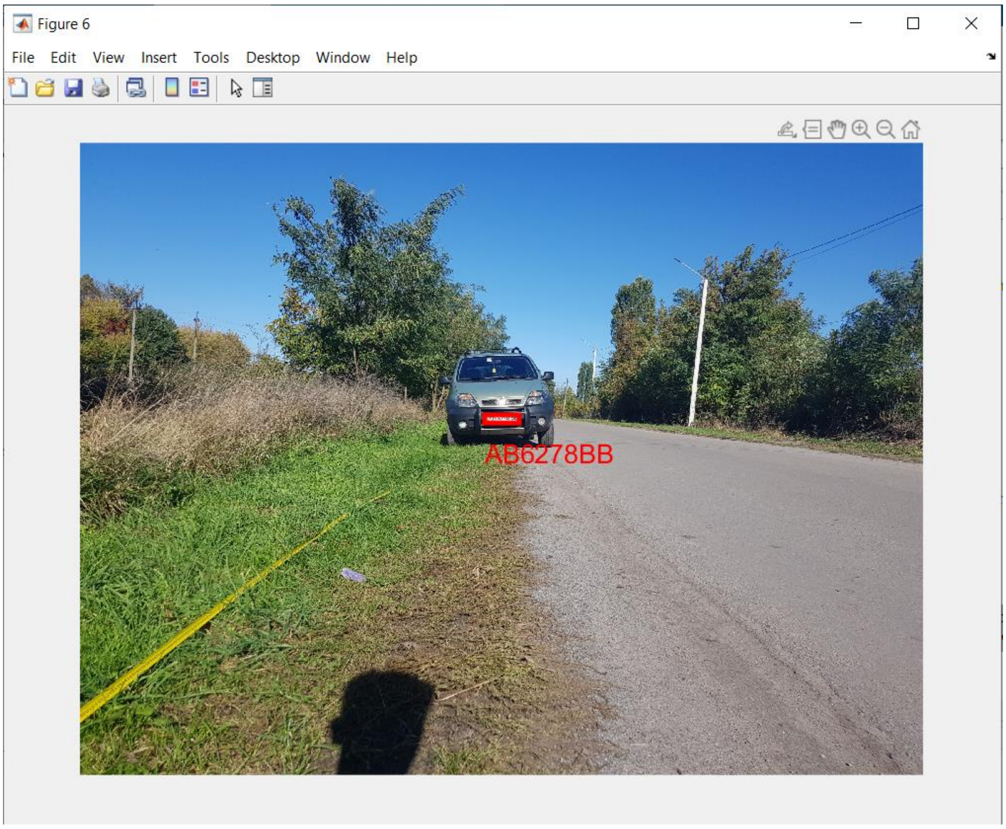


Fig. 4.26. Recognized license plate at a maximum permissible distance of 12 m

4.3.2. Analysis of critical values of detection angles for installation

Usually, license plate recognition systems for cars are installed in parking lots, entrances to private or guarded areas. In such areas, it may not be possible to install the system directly in front of the car. That is, it will be located either on the side of the trajectory of its movement, or below or above.

So, for such an installation that it is necessary to know the critical angles for the stable operation of the installation.

To determine the critical vertical angle of installation of the camera, it was installed step by step at a height of 2.5 m and a distance from 1 to 5 meters.

During the experiments, the critical vertical angle of camera installation was determined, which is ≈60°.

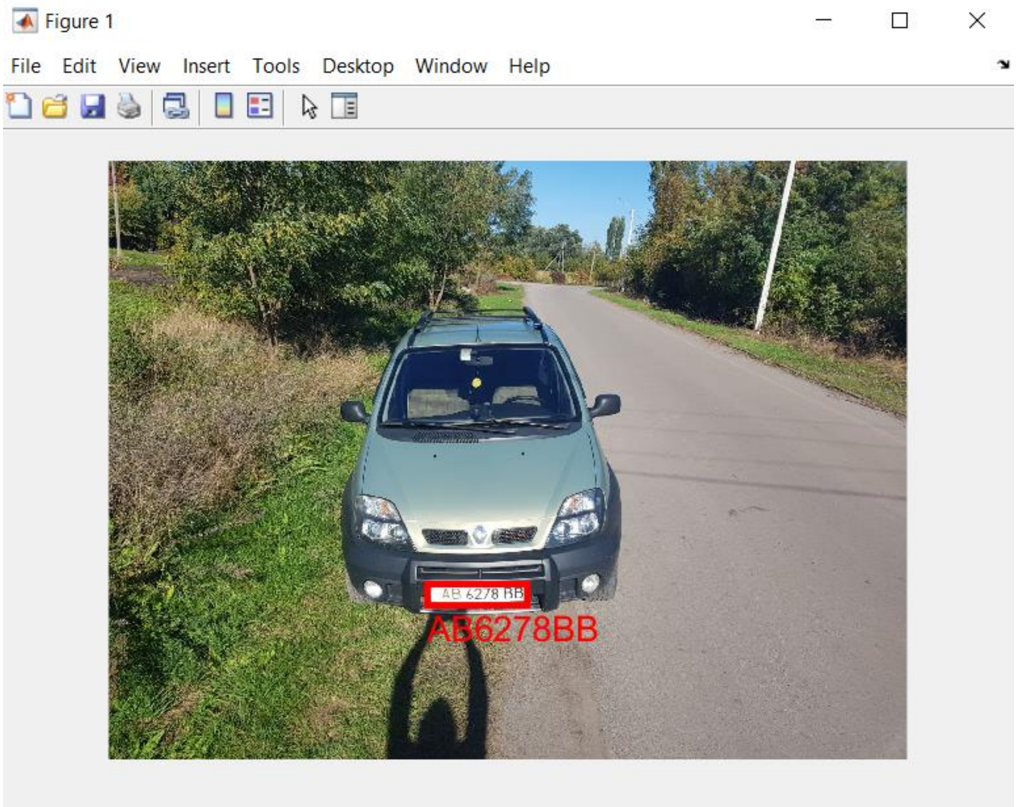


Fig. 4.27. Recognition result at close to critical vertical observation angle

An experiment similar to the previous one was also conducted to determine the critical horizontal angle of camera installation. At a distance of 2 m from the observation object, the camera was moved step by step in the horizontal plane.

After conducting the experiment, the critical horizontal angle of camera installation was determined to be ≈55°.

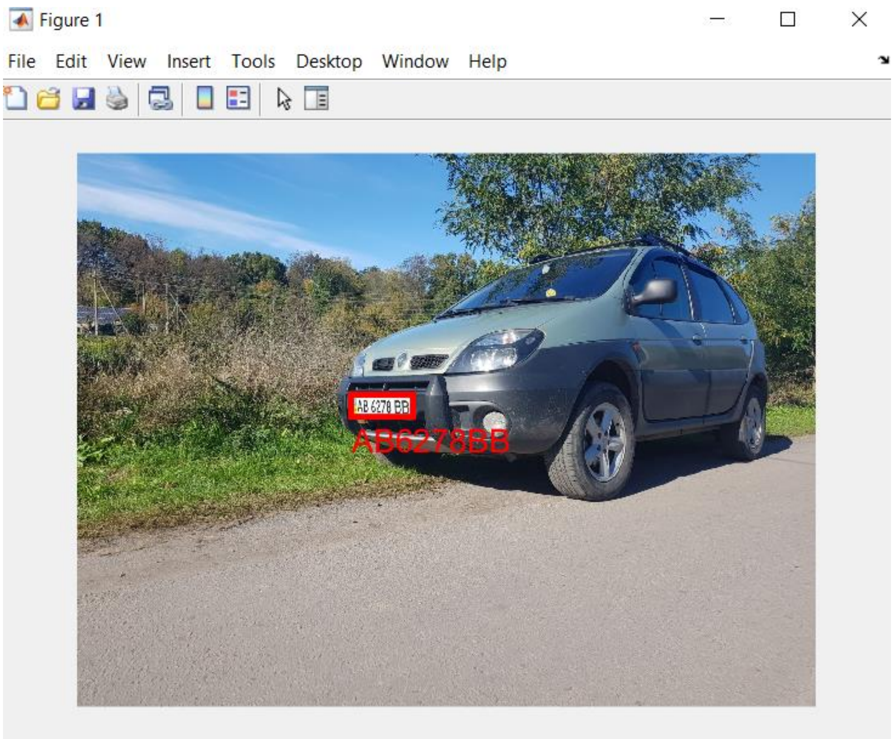


Fig. 4.28. Recognition result at close to critical horizontal observation angle

Therefore, it follows from the conducted research that this system can be installed within such working angles as -60°/+60° vertically and -55°/+55° in the horizontal plane.

4.3.3. Analysis of the impact of the environment on the efficiency of the system

This object recognition system works by identifying characteristic points in the image. It is obvious that ideal situations where only the object of surveillance falls into the camera frame are very rare. That is why it is necessary to create such a system that would not be sensitive to changes in the type of environment, weather conditions, etc.

To analyze this effect, several frames of different cars, at different lighting levels and in different environments were obtained. After conducting the experiment, it was found that the previously mentioned factors, namely the environment (image background), do not affect the quality of recognition. Thus, the object recognition accuracy is 100% under these conditions.

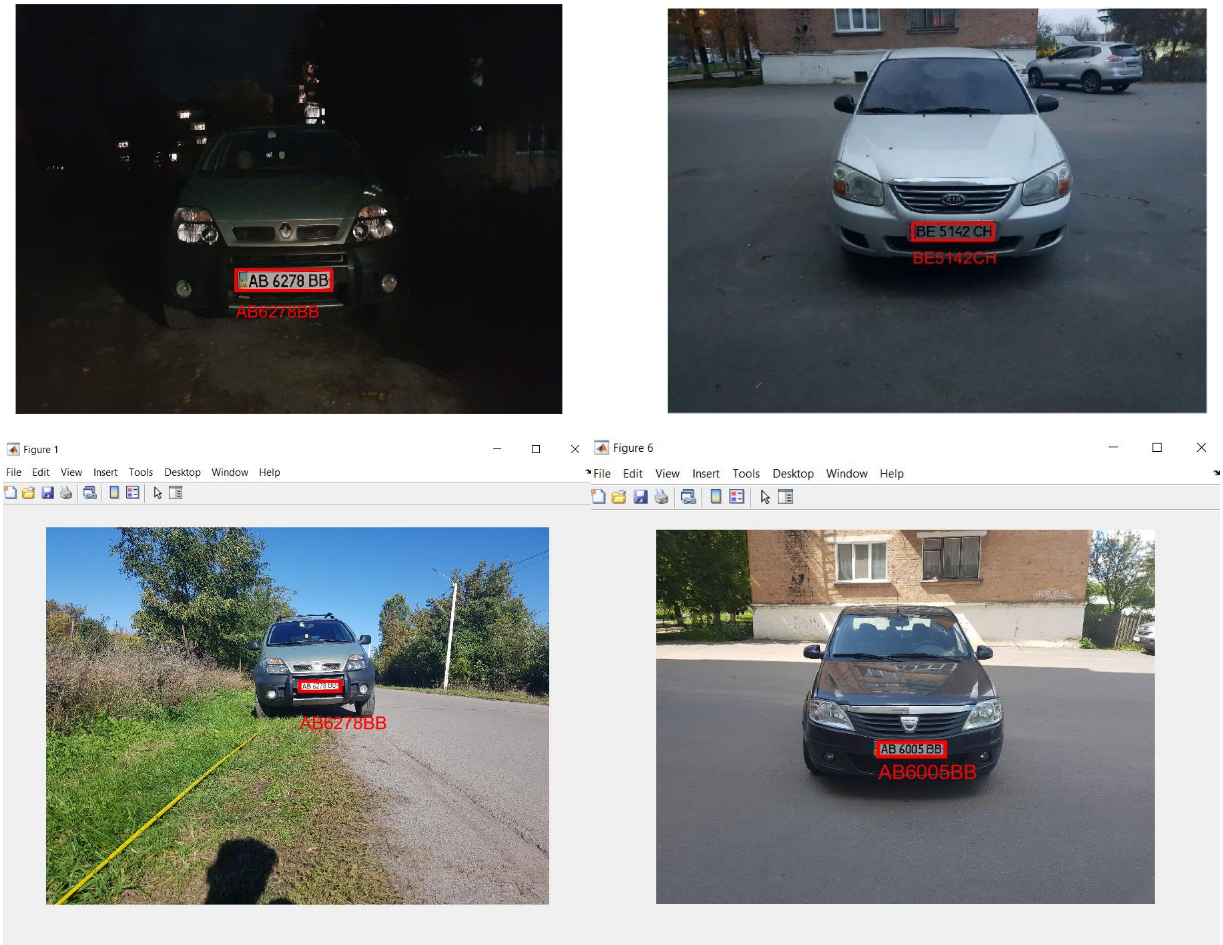


Fig. 4.29. The result of recognizing different cars in different environments

4.3.4. Analysis of the effect of lighting on the efficiency of the system

Like any optical system, this setup can be sensitive to the illumination level of the observation object. In order to find out the working range of illumination for the system, several experiments were conducted under daylight and artificial illumination.

The light sensor from the Samsung Galaxy S8 phone, the TMD4906 lux Sensor and the Physics Toolbox Suite android application were used to measure the level of illumination.

An illumination sensor (dusk sensor) is a specialized technical device for automatic control of light sources that responds to the degree of illumination of a certain space. Ambient temperature and humidity do not affect the activation of the sensor.

The principle of operation is very simple: the device is equipped with a phototransistor or photoresistor, which can register the level of illumination. Speaking from a technical point of view, a photoresistor changes its resistance depending on the light flux, and a phototransistor when illuminated generates a certain amount of electricity.

Illumination measurements are not affected by the range and angle of observation of the research object, if they are within the permissible operating range.

First, experiments were carried out under daylight. They were conducted outdoors on a bright sunny day, in fog, and at dusk, to assess the impact of illumination and determine its minimum value.

At the maximum level of illumination achieved on a sunny day, which is approximately 11,500 lx, the system was found to be working normally (95% accuracy).

Fig. 4.30. System operation at the maximum level of illumination

At normal light levels (namely 925 lx) and with fog, the system works with 100% accuracy.

Fig. 4.31. System operation at normal light level in fog

At dusk, it was possible to find the minimum level of illumination for the effective operation of the system, which is 19 lx.

Fig. 4.32. System operation at the minimum daytime level of illumination

Research has shown that the lower is the level of daylight, the more the contrast of the image drops. Since the FAST characteristic point detection algorithm reacts to changes in the intensity of neighboring pixels, the lower the contrast level, the fewer characteristic points it finds, as shown in Fig. 4.33.

a) b)

Fig. 4.33. Results of detection of characteristic points at the minimum permissible level of daylight (a) and beyond it (b)

Now let's move on to experiments with artificial lighting.

There are 3 main types of artificial light sources, viz:

- Incandescent lamps

  Incandescent lamps (IL) belong to light sources of thermal radiation, their light output is 10...15 lm/W. They create a continuous spectrum of radiation that is richest in yellow and red (i.e., infrared) rays and poorer in the area of blue and green spectrums of radiation than the spectrum of natural light of the sky, which impairs color discrimination. These lamps have a low efficiency, a short service life (up to 1000 hours), and a high temperature on the surface of the bulb (250...300 °C).

- Gas discharge lamps

  Gas-discharge lamps (fluorescent, mercury, high-pressure arc type DRL, etc.) emit light close to natural. The surface of the bulb of these lamps is cold, they are more economical, and allow to create high illumination. According to the spectrum of their radiation, the transmission of colors is of great importance for industry, as it makes it possible to determine the real quality of products, to control raw materials, semi-finished products, and finished products. Fluorescent lamps are 2.5...times more economical than incandescent lamps, work for 5 thousand hours, their light output is 30...80lm/W.

- LED lamps

LED lamps are lighting products for household, industrial and street lighting, in which the light source is LEDs. An LED lamp is a set of LEDs and a power circuit for converting mains energy into low-voltage direct current. LEDs are adversely affected by high temperatures, which is why LED lamps typically have heat dissipation elements such as heatsinks and cooling fins. Their service life and electrical efficiency (they belong to energy-saving lamps) are many times better than those of ordinary incandescent lamps and most fluorescent lamps.

Experiments on the effect of artificial lighting were carried out using an LED flashlight and an LED lamp.

As it turned out during experiments, artificial lighting has a much lower light intensity than daylight. However, in some situations, the system recognizes objects better with it. This is due to the greater contrast between the background of the photo and its foreground, as well as the peculiarities of the paint applied to the license plate. Everything described above facilitates the work of the FAST characteristic point detector, so its effectiveness increases precisely under artificial lighting (Fig. 4.34).

Fig. 4.34. The results of the detection of characteristic points at close to minimum permissible level of artificial lighting

Thus, the minimum permissible level of illumination was 2 lx.

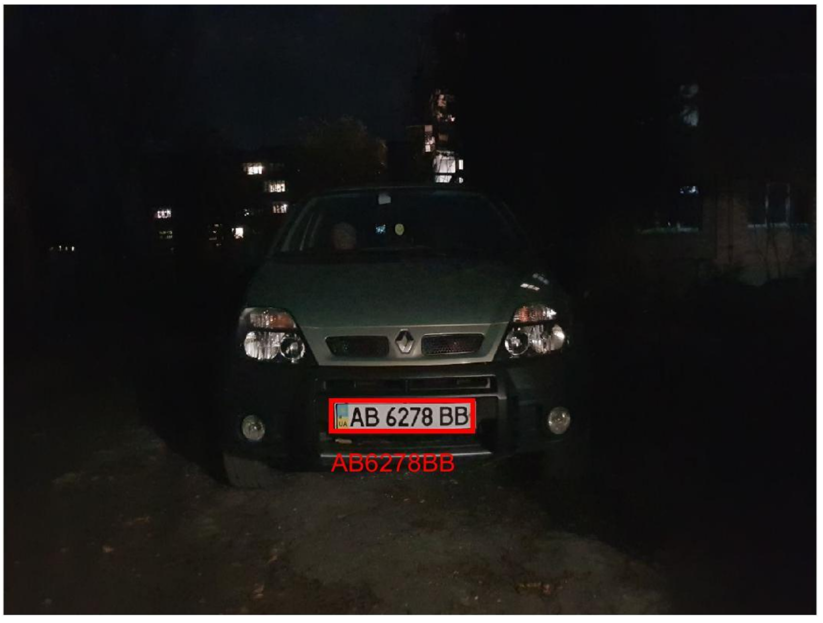


Fig. 4.35. Operation of the system at a minimum level of artificial lighting

With the help of the flashlight, it was possible to achieve a maximum illumination level of 200 lx (for comparison, the illumination level of an ordinary room with three LED lamps is 250 lx on average). At this level of light and close to minimum, the system works great, with close to 100% accuracy.

4.4. Analyzing the computational load

Understanding how much computational power the system requires is crucial for efficient utilization. After all, if the system puts too much strain on the computer, it will negatively affect how quickly it works. Additionally, the system's range of usage may be expanded the less the computer is taxed by it.

Table 4.2 shows how the pc is loaded during the execution of a single-frame application. The program runtime of the cycle for one picture was estimated using Matlab's *tic* and *toc* tools. Additionally, the amount of RAM and CPU consumed for the computations are visible. 4 distinct photos' measurements are shown.

Table 4.2. Experimental results

Frame №	*Resolution, pixels*	*Calculating time, sec*	*Used RAM, Mb*	*CPU load, %*
1	*1280×960*	*0.681325*	*22*	*18.5*
2	*1280×960*	*0.556812*	*18*	*16*
3	*1280×960*	*0.583547*	*19*	*12.3*
4	*1280×960*	*0.512544*	*19*	*15*

The photo with a resolution of 1280 960 was processed in between 0.5 and 0.7 seconds, which is sufficient for the typical program operation. By lowering the frame resolution, the program's speed can be increased if necessary. Halfing the resolution will result in an increase in processing speed. However, such adjustments should be made with caution since if the image's pixel count is decreased, its informational value may be compromised. Which, while not essential for describing the thing under observation, can have a significant impact on how well the symbols are defined on the plate.

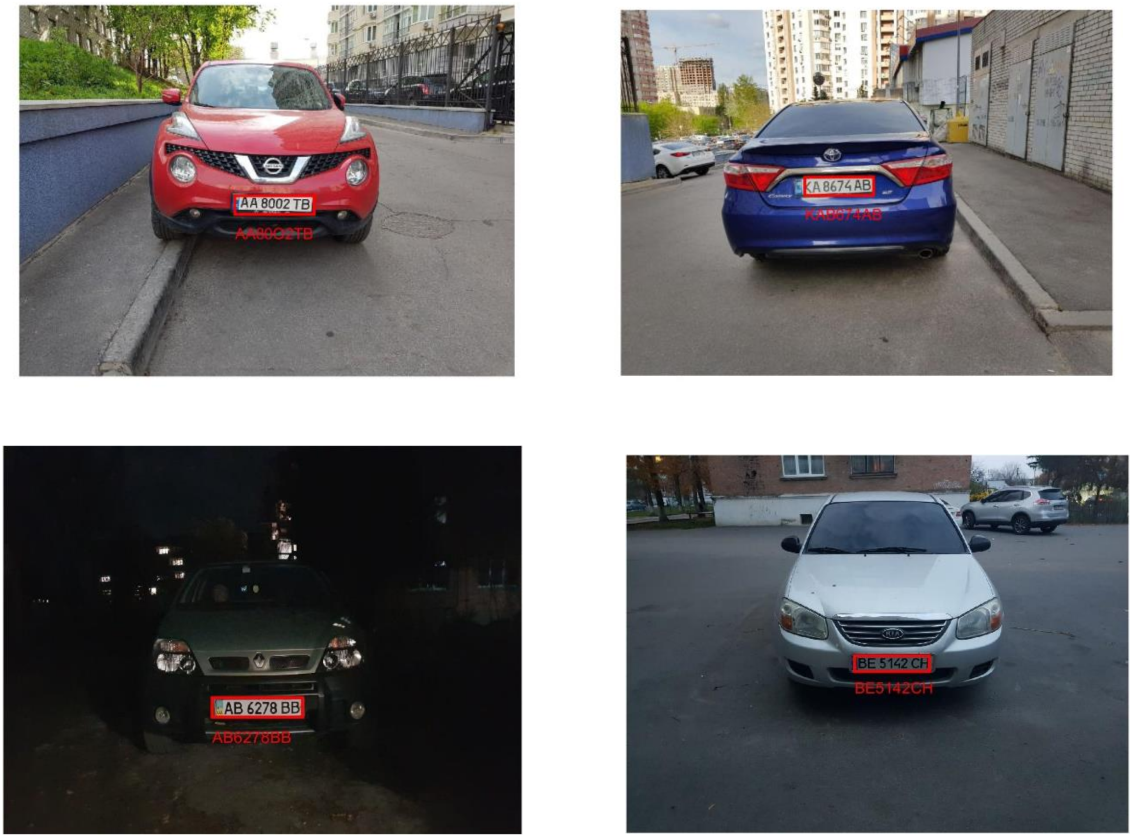


Fig. 4.30. Test-related images

We can thus infer that this system only needs approximately a 2 GB of RAM for reliable operation and doesn't demand a lot of CPU power based on the tests on the assessment of computing expenses. With the help of these characteristics, it may be utilized in more portable configurations that employ a Raspberry Pi microcontroller instead of a PC to do computations.

CHAPTER 5. LABOR PROTECTION

5.1. Introduction

Labor protection is a mandatory element of the organization of any enterprise. Labor protection is a system of legal, socio-economic, organizational-technical, sanitary-hygienic and medical-prophylactic means and measures aimed at preserving the health and working capacity of a person.

The Law of Ukraine "On Occupational Health and Safety", which defines the main provisions for the implementation of the constitutional right of citizens to protect their life and health in the process of work, regulates the relationship between the employee and the administration on occupational health and safety issues. The law applies to all types of activities, in addition, labor protection is based on normative acts.

The Law applies to all legal entities and individuals who, in accordance with the law, use hired labor, and to all employees. The above legal norms regulate the organization of work in the field of labor protection at enterprises (in institutions), planning and financing of labor protection measures; determine the structure of the labor protection service; provide for the organization of supervision and control over compliance with labor protection rules; regulate the procedure for investigating and recording accidents; compensation for material damage; responsibility for violation of labor protection requirements. In modern conditions, the solution of the main problems of labor protection is closely related to the efficiency of economic structures.

State policy in the field of labor protection is aimed at creating proper, safe and healthy working conditions, preventing accidents and occupational diseases. State policy in the field of labor protection is based on principles:

- the priority of the life and health of employees, the full responsibility of the employer for creating proper, safe and healthy working conditions;
- increasing the level of industrial safety by ensuring continuous technical control over the state of production, technologies and products, as well as assisting enterprises in creating safe and harmless working conditions;
- complex solution of labor protection tasks on the basis of national, branch, regional programs on this issue and taking into account other areas of economic and social policy, achievements in the field of science and technology and environmental protection.

When designing a system for visual recognition of objects in buildings, it is important to observe all occupational safety measures. It is necessary to take into account the specifics of the institution when developing labor protection measures.

Studies of working conditions have shown that the factors of the production environment in the work process are:

- sanitary and hygienic environment,
- psychophysiological elements,
- aesthetic elements,
- social - psychological elements.

The subject of the workplace in any room is affected by the following main harmful and dangerous production factors that correspond to GN 3.3.5-8-6.6.1-2002.

Hygienic classification of work according to indicators of harmfulness and dangerous factors of the production environment, difficulty and tension of the labor process:

1. Microclimate of the working area (relative humidity, temperature, speed of movement).

2. Electromagnetic fields and radiation.
3. Natural lighting and artificial lighting.
4. Production noise.
5. Electrical safety.

5.2. Microclimate of the working area

For comparative characteristics, the optimal and actual values of air temperature in the cold season, relative humidity and speed of movement were given.

Table 4.1 Microclimate indicators comparative table

Microclimate indicators	Temperature, (°C)	Relative humidity, (%)	Movement speed, (m/s)
Optimal	21-23	60-40	0,1
Actual	19	50	0,1

After the comparison, it was found that the indicators of the microclimate do not correspond to the norms of DSN 3.3.6.042-99 Sanitary norms of the microclimate of industrial premises.

To improve these conditions, it is proposed to increase the temperature index to the norm by introducing additional heating systems for heating.

5.3. Electromagnetic fields and radiation

The main source of non-ionizing electromagnetic radiation is the PC monitor, the indicators of which have a harmful effect on the person working with it. According to the norms of NPAOP 0.00-1.28-10 Rules of labor protection during the operation of electronic computing machines. Order of Derzhhirpromnadzor dated March 26, 2010. No. 65 [12].

In order to improve workplace conditions and reduce the level of electromagnetic radiation, it is proposed to purchase new equipment that would meet current standards.

5.4. Natural lighting and artificial lighting

To create comfortable conditions for visual work, natural and artificial lighting are used, as well as combined lighting, which is regulated by the building standards of DBN V.2.5-28-2006.

Both natural and artificial lighting are used in the premises of the private security complex.

Natural lighting is provided through windows, and artificial lighting is provided by a combined lighting system. Each of the rooms has a certain type and number of lighting devices. These include: pendant lights, overhead lights, LED strip, table lamps.

5.5. Production noise

Industrial noise is a set of unfavorable sounds that are transmitted to a person and cause unpleasant subjective feelings, reduce work capacity and, in some cases, health disorders.

Fig.5.1 shows the types of noise. Sources of noise are: all types of transport, pumps, industrial facilities, pneumatic and electric tools, machines, construction equipment, etc.

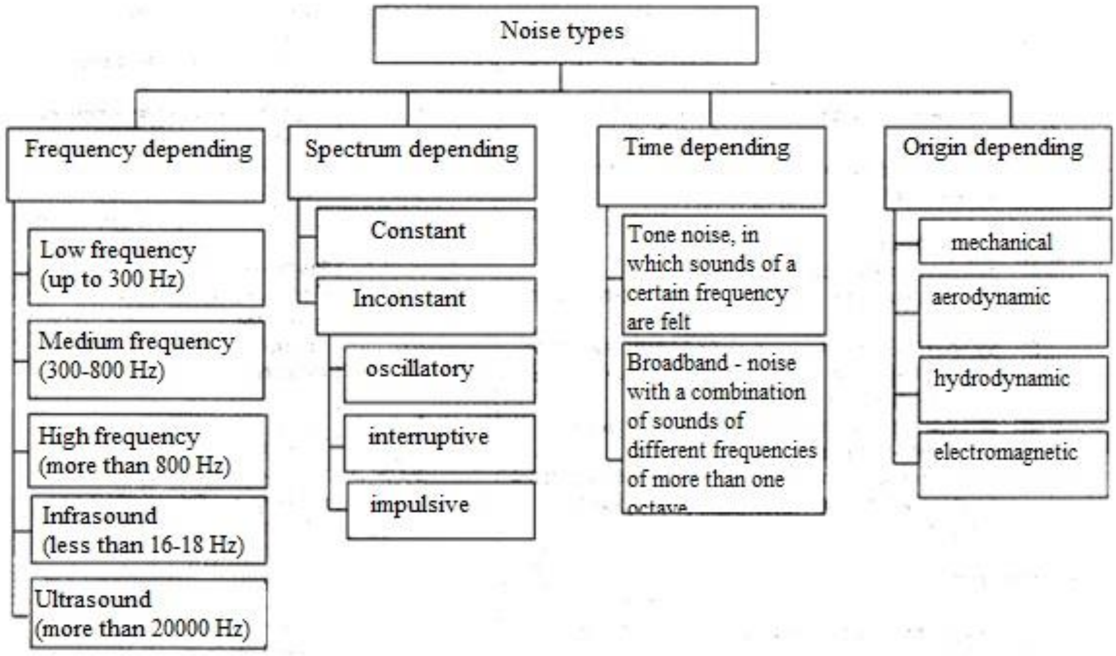


Fig.5.1 Types of noise

In order to ensure acceptable levels of noise at workplaces, it is intended to use sound absorbing means, the choice of which should be justified by special engineering and acoustic calculations.

5.6. Electrical safety

Electrical safety is a system of organizational and technical measures and means that ensure the protection of people from harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity.

Classification of premises according to the danger of electric shock:

- without increased danger (premises in which there are no conditions creating increased or special danger);
- with increased danger (humidity exceeding 75%);
- especially dangerous (humidity about 100%, ceiling, floor, walls covered with moisture).

The premises of the private security complex are without increased danger:

- sockets not located in the immediate vicinity of the risers of the water supply and heating systems.

5.7 Fire safety during operation of the system of visual recognition of objects

In modern radio electronic equipment, a very high density of placement of elements of electronic circuits is noted. Connecting wires and switching cables are located in close proximity to each other. When current flows through them, a significant amount of heat is released, which can lead to an increase in the temperature of individual nodes up to 80-1000 °C, and then to a short circuit and combustion with the formation of sparks of electronic circuits.

To prevent the spread of fire during a fire from one side of the building to the other, fire barriers are provided: ceilings, doors.

Special attention is paid to the safe evacuation of people in case of fire.

An emergency fire alarm system is provided to notify of a fire, which, in the presence of smoke or strong heat release, notifies of the presence of a fire with sound and light signals.

The evacuation routes of the building ensure the safe evacuation of all people in the premises through the evacuation exits.

For the fire safety of the premises, it is necessary to take into account NAPB A.01.001-2004 Rules of fire safety in Ukraine.

Measures to ensure fire safety include:

- develop instructions on fire safety measures for each room;
- the territory and the building itself must be provided with safety signs;
- employees of the facility are obliged to comply with the established fire prevention regime, to comply with the requirements of these rules and other normative legal acts on fire safety issues;

- the territory of the designed complex must be systematically cleaned of garbage, waste, containers, fallen leaves, which must be regularly removed to specially designated places;
- driveways and passages to the building, approaches to external stationary fire ladders, fire equipment, equipment and fire extinguishing means must always be free, kept in good condition, cleared of snow in winter;
- provide lighting for external fire escapes, fire fighting equipment, entrances to the building;
- place fire extinguishers, fire detectors;
- install a fire alarm;
- place evacuation plans for people and evacuation plans for equipment and other valuables in the corridors;
- opening of the door in the direction of evacuation;
- evacuation of people using stairs;
- before the beginning of the heating season, the heating devices must be checked and repaired;
- to provide a view of the halls without the formation of oncoming and intersecting flows in the general part of the complex

The degree of fire resistance of the building is characterized by fire resistance limits and fire hazard classes of building structures. The object has the III degree of fire resistance.

The width of escape routes in the light is at least 1 m, doors - at least 0.9 m. The height of the passage on the escape routes is at least 2 m. The doors on the escape routes open in the direction of the exit from the building. The height of the door in the clearance on the evacuation routes is at least 2 m. The width of the flight of stairs is not less than the width of the evacuation exit to the stairwell. The width of the landings is not less than the width of the march. A gap of at least 50 mm is provided between flights of stairs. Transoms with an area of at least 1.2 m2 on each floor are provided in the light openings of the stairwells. The building is equipped with a CO3 fire alarm.

A fire extinguisher is a technical device designed to stop a fire by supplying the fire-extinguishing substance contained in it under the action of excessive pressure, suitable for carrying and using by one person due to its weight and design.

Fire extinguishers are distinguished by the method of activation:

- automatic — stationary mounted in places of possible fire.
- manual (actuated by a person) — located in specially designed places.
- combined action — have the advantages of both types described above.

Fire extinguishers are divided into five types depending on the injected fire extinguishing agent:

- carbon dioxide;
- air-foam;
- powder;
- water;
- aerosol.

5.8. List of dangerous and harmful production factors in the working area

During the installation, commissioning and repair of fire systems in accordance with GOST 12.0.003-74, the following dangerous and harmful production factors arise:

1) collapsible structures (ladders and other production equipment);

When laying cables, installing and maintaining detectors, video amplifiers, work on a ladder is essential, which can collapse, resulting in a fall and injury to personnel.

2) increased temperature of surfaces of equipment and materials;

It is observed when performing work using a soldering iron, the working surface of which and, accordingly, the soldering element tin, rosin, and flux are heated to fairly high temperatures. Also, the elevated temperature of the surfaces of the equipment and materials is detected when the thermal regime of the equipment is disturbed.

3) increased value of the voltage in the electrical circuit up to 380 V;

An electric shock occurs when touching live parts and when the insulation is damaged, as a result of which the equipment body can be under a voltage of 220 V AC.

4) the location of the workplace at a significant height relative to the ground surface (floor);

As noted above, most equipment is installed at heights of 2 to 2.5 meters.

5) physical and neuropsychological overloads;

The influence of this factor extends to system operators in case of an unsuccessfully developed shift schedule, because the systems issue rather large volumes of operational information during the working hour.

The operation of the designed fire systems assumes a minimum level of risk of dangerous and harmful production factors.

The most likely risk of electric shock remains when touching conductive parts and when insulation is damaged.

5.9. Technical measures to reduce exposure to harmful factors

The listed dangerous and harmful factors to one degree or another have an impact on the health of the employee. The influence of one factor is clearly manifested in a short time and manifests itself in a person as fatigue, dizziness, headache, general malaise. All this reduces the productivity of his work. The constant presence of people in such an environment leads to the emergence of chronic diseases. Other factors affect a person's health instantly, causing him pain, injury, loss of consciousness, and in some cases, death.

5.9.1 Precautions against electric shock

Compliance with the following safety requirements ensures the elimination or maximum reduction of the possibility of electric shock to personnel, as well as exposure to other dangerous factors:

1) installation and operation of systems should be performed only by qualified specialists;
2) compliance with safety requirements when performing electrical installation work;
3) optimal work schedule of the personnel who will serve the system;
4) reliable grounding of the body of system elements powered by a source of alternating current 220 V;
5) during installation and operation, exclude contact of tools with current-conducting dangerous voltages;
6) when performing soldering work, it is necessary to follow the requirements of "Sanitary rules for the organization of soldering processes of small products containing lead No. 952".

According to the "Rules for the installation of electrical installations", all electrical installations are divided into two classes: with a voltage up to 1000 V and with a voltage higher than 1000 V. Measures to ensure electrical safety are developed, first of all, based on which of these classes the designed electrical installation belongs to.

The electrical installation is connected to the internal main line, using copper and aluminum conductors of the type: PEV, PEVD with a cross section of 4-6 mm.

The laying of grounding conductors from strip steel is carried out covered by the structure of the house, with the aim of more affordable maintenance.

The connection of the grounding wire to the parts of the equipment is made by welding.

5.10. Safety, fire and explosion safety instructions

The instruction is written in accordance with "Fire safety of technological processes", "Fire equipment for the protection of objects" and "Fire safety" DSTU78 2272:2006.

People from the engineering and technical staff who know the principle of operation of the concentrator, the technical operation manual, the safety manual and have passed the safety and fire safety test are involved in the work.

5.10.1 Safety requirements before starting work

5.10.1.1 Carefully inspect the workplace, remove all objects that interfere with work.

5.10.1.2 Inspect the equipment, make sure there is no external damage, reliability of grounding, visually check its serviceability. Grounding of the equipment should be carried out regardless of the degree of danger of the premises in which the work is carried out.

5.10.1.3 It is forbidden to turn on the hub in a faulty state.

5.10.1.4 When malfunctions are detected, notify the senior engineer and start work only after their removal.

5.10.2 Safety requirements during work

5.10.2.1 Turn on the system according to the operating instructions.

5.10.2.2 If there is no confirmation of activation or the presence of a malfunction signal, report the malfunction to the senior engineer and proceed with its elimination after turning off the system.

5.10.2.3 As soon as there is a crackling characteristic of a high-voltage breakdown or smoke in the power system or other units, immediately turn off the power supply.

5.10.2.4 When installing portable devices and measurements, it is necessary to exclude touching current-carrying parts with dangerous voltage;

5.10.2.5 It is forbidden to remove the protective elements of the structure that block access to the current-carrying parts.

5.10.2.6 It is forbidden to connect and disconnect modules, connectors that are under voltage.

5.10.2.7 When carrying out routine work, carefully check the operability of all subsystems in all possible modes of operation.

5.10.2.8 In the event of a fire in the hub control unit, first of all, it must be disconnected from the electrical network.

5.10.2.9 In case of fire, call the fire service, report to the shift engineer and start extinguishing the fire after preliminary de-energization of all systems.

5.10.3 Security requirements after the end of the yearбіт

5.10.3.1 Check the performance of the system operating in automatic mode.

5.10.3.2 When changing the duty staff, inform the new staff about all past problems and malfunctions in the operation of the system and record them in the log.

5.10.3.3 Tidy up the workplace after performing regular work.

5.10.4 Requirement in emergency situations

In the event of a fire, call the fire service, report to the senior engineer and start extinguishing the fire after de-energizing all systems.

5.11. Calculation

At the workplace, where the visual object recognition system is operated, both natural and artificial lighting are present. Let's calculate the level of illumination of the room with artificial lighting.

When designing artificial lighting in premises, it is necessary to be guided by the requirements of DBN V.2.5-28-2006 "Natural and artificial lighting". normative value of artificial lighting E = 200-500 lux, natural - KPO = 1.2%.

The calculation of artificial lighting is carried out by the method of the coefficient of use of the luminous flux. The purpose of the verification calculation is to determine the actual lighting in the room.

The main calculation formula of the luminous flux utilization factor method:

$$\Phi_{\text{св}} = \frac{E_{\phi} \cdot k_3 \cdot S \cdot z}{n \cdot N \cdot \eta \cdot \gamma}, \tag{5.1}$$

where E_{ϕ} – actual illumination, lux;

S – the area of the illuminated room, S = 24,96 m^2;

z – coefficient of uneven illumination, z = 1,1;

k_3 – reserve factor, which takes into account dusting of lamps and wear of light reserve sources during operation. For the premises of the display hall, illuminated by fluorescent lamps and provided that the lamps are cleaned at least twice a year, k_3 = 1,4;

N – the number of lamps in a row, N = 5;

η – coefficient of use of light flux of lamps, η = 0,52;

γ – shading factor, γ = 0,8;

n – the number of rows of lamps, n = 2.

The luminous flux of lamps is calculated according to the formula:

$$F_{св} = n_{л} * F_{л} \tag{5.2}$$

where $F_{св}$ – luminous flux of lamps;

$n_{л}$ – luminous flux, the number of lamps in the lamp, $n_{л}$ = 2;

$F_{л}$ – luminous flux of the lamp, $F_{л}$= 2000;

$$F_{св} = 2 * 2000 = 4000$$

The actual illumination is calculated by the formula:

$$E_{Ф} = \frac{F_{св} * n * \eta}{S * k * z} \tag{5.3}$$

$$E_{Ф} = \frac{4000 * 2 * 0{,}52}{24{,}96 * 1{,}4 * 1{,}1} = 108{,}3$$

Conclusion

In this section, the main requirements for labor protection at an enterprise that uses visual object recognition systems were considered.

The following were also determined: the main factors of the production environment in the work process; microclimate of the working area; electrical safety; fire safety during operation of the visual object recognition system; a list of dangerous and harmful production factors in the work area; technical measures to reduce the impact of harmful factors; measures against electric shock; instruction on safety, fire and explosion safety.

As an integral part of the calculation work, lighting calculations were carried out in the room where all stages of planning and modeling of the system were carried out.

As can be seen from the above calculations, the actual lighting does not meet the requirement of DBN V.25-28-2006 "Natural and artificial lighting". It is necessary to increase the lighting at the workplace by increasing the power of the lamp or using local lighting for working with documents.

CHAPTER 6. ENVIRONMENTAL PROTECTION

6.1 Assessment of the impact of the transportation of dangerous goods on the environmental safety of cities

Today, much attention is paid to the assessment of the impact of the transportation of dangerous goods on the environmental safety of cities. For the cities of Ukraine, the issue of environmental safety during the transportation of dangerous goods is very acute. Both cities and regional centers are mostly large industrial centers, and some of them have a unique border location. These conditions are often the reason for laying routes for the transportation of dangerous goods precisely through the urban area, in which the probability of accidents is the highest, because of the high intensity of traffic flows. In addition, there are many objects within the city limits that represent an increased danger in the event of an accident on them. Such attention is also caused by the fact that little attention is paid to this problem in the scientific literature.

Dangerous cargo - substances, materials, products, waste from production and other activities, which due to their inherent properties, in the presence of certain factors, can during transportation cause an explosion, fire, damage to technical means, devices, structures and other objects, cause material damage and damage to the environment, as well as lead to the death, injury, poisoning of people, animals and which, according to international treaties, the consent of which is binding by the Verkhovna Rada of Ukraine, or according to the results of tests in the established order, depending on the degree of their impact on the environment or a person, are classified as one of the classes of hazardous substances.

The conditions of transportation of dangerous goods are determined by legal acts regulating transport activities. In the absence of such acts, dangerous goods are allowed to be transported under the terms of the Law of Ukraine "On Transportation of Dangerous Goods". The transportation of dangerous goods is allowed in the presence of appropriately executed transport documents, the list and procedure of submission of which is determined by the regulatory and legal acts regulating transport activities.

Vehicles used to transport dangerous goods must meet the requirements of state standards, safety, occupational health and ecology, and in cases established by law, have appropriate markings and a certificate of admission to the transportation of dangerous goods.

For the cross-border transportation of hazardous waste, a written consent (notification) for the cross-border transportation of furnace waste is required, which is provided by the central executive body that implements the state policy in the field of environmental protection, within 60 days before the planned date of their first transportation. Written consent (notification) for cross-border transportation of hazardous waste is given in accordance with the procedure established by the Cabinet of Ministers of Ukraine. For violations of the legislation on the transportation of dangerous goods, legal entities and individuals are liable in accordance with the law.

6.2 Environmental safety of the city and its principles

Environmental safety of the city is a state of protection of the population and the environment from various types of natural and man-made hazards.

It is based on the following principles:

- territories are considered polluted if quantitative or qualitative changes are detected in their composition, which occurred as a result of accidental pollution during the transportation of hazardous substances and waste, which can be caused not only by the appearance in the aeration zone of new substances that were not there before, but also by an increase in the content of substances, typical for the composition of uncontaminated soil;

• potential environmental damage during the transportation of dangerous goods consists in determining the total danger of contamination of soils, atmospheric air, surface and underground waters of a certain territory;

• since we are talking about the ecological safety of the settlement, it is advisable to standardize the received amounts of total damages for the statistical assessment of the probability of the population staying in certain areas of the city through which the routes of transportation of dangerous substances pass; when calculating this estimate, the population density of certain districts of the city and the distribution of public facilities of city-wide importance should be taken into account;

• the main determining indicator of environmental danger is the intensity and scale of transportation of dangerous goods. The level of environmental risk when transporting dangerous goods through the city depends not only on the intensity and structure of traffic flows.

For toxic cargoes that are in the liquid phase, another method of assessing the probability of emergency situations on transport highways, as well as the amount of damage caused to environmental components, is proposed. It allows you to calculate the environmental risk of accidents. The risk function for individual highway sections is different.

6.3 Measures to increase the level of environmental safety during the transportation of dangerous goods through the city

In order to increase the level of environmental safety during the transportation of dangerous goods through the city territory, it is recommended to apply the following measures: technical, economic, organizational.

Among the technical measures should be noted:

– increasing the reliability and operational characteristics of rolling stock used for transportation:

- application of the latest technologies in the manufacture of containers for transportation (containers, tanks, etc.);

- disposal of waste at the place of origin.

If we take the level of environmental risk during the transportation of dangerous goods as a starting point, it is influenced by several factors. From the whole set of factors, it is possible to single out some that can be changed, for example, the factor of the intensity of transportation. That is, it can be controlled.

Therefore, the general direction of organizational measures is to manage the intensity (scale) of transportation in individual areas.

Therefore, it is necessary to comply with the necessary conditions for the transportation of dangerous goods, the requirements for the types and equipment of vehicles, the procedure for training, retraining, training, promotion and confirmation of the qualifications of employees who work with dangerous goods, the procedure for obtaining permits for the said transportation. Also, a necessary condition for environmental safety is the prediction of environmental risks and the search for ways to reduce environmental risks during the transportation of toxic waste through the territory of cities is relevant and has great scientific, scientific and economic importance from the point of view of the safety of life and the safety of the region and the state as a whole.

6.4 Designation of goods using ecological labeling

Environmental label— a statement that indicates the environmental aspects of a certain product or service.

Environmental labels can be presented in the form of a wording, symbol or image on a product label or packaging, in product documentation, in technical bulletins, in advertising materials, etc.

The general purpose of Environmental labels is to promote, by conveying verifiable, accurate and truthful information about the environmental aspects of goods or services, the expansion of demand and supply of those goods or services that have the least possible impact on the environment and human health, thereby stimulating using the potential for market-driven continuous improvement.

6.4.1 Types of environmental labeling

The International Organization for Standardization divides environmental labeling and declarations into three main types.

I type of environmental labeling

This type of eco-labeling provides the right to apply the eco-labeling if the products have passed environmental certification.

Certification is carried out by the environmental labeling body for compliance with environmental criteria established for each product group separately.

The criteria establish stricter or additional requirements to state regulations to determine the merits of goods or services in relation to their effects on the environment and human health at all stages of the life cycle.

The concept of "type I environmental labeling program" is defined according to ДСТУ ISO 14024:2002 Environmental labeling and declarations - Type I environmental labeling - Principles and methods (ISO 14024:1999, IDT):

- Type I environmental labeling program (en - Type I environmental labeling program) – a voluntary, multi-criteria, independent licensing program that allows the use of environmental labels on products, indicating the overall environmental advantage of products within a specific product category based on the results of life cycle review cycle
- product environmental criteria for products – environmental requirements that must be met by the product in order for it to be assigned an environmental label.

- ecolabelling body – a body, as a third party and its representatives, which operate the type I ecolabelling program.
- certification – a procedure of written certification by a third party of compliance of products, processes or services with established requirements.

License (in the field of type I environmental labeling) - a document issued according to the rules of the certification system and by which the type I environmental labeling body grants a person or body the right to use environmental labels for their products or services in accordance with with the rules of the environmental labeling program.

Environmental criteria should establish requirements for indicators of improved product characteristics, for example, such as:

- restriction or ban on the use of ingredients or drugs based on risk factors for the environment and human health;
- the level of contamination of natural raw materials with agrochemicals, toxic elements, radionuclides (for example, for food industry products, fabrics, cosmetics);
- consumption of energy and water resources;
- environmental impacts in the production process (environmental pollution indicators);
- volumes of generated production and consumption waste;
- suitability of packaging (containers) and products of individual industrial groups for repeated processing, etc.

Type I environmental certification and labeling is applied to various categories of product groups: construction and finishing materials, furniture, textiles, detergents, cosmetics, toys, food industry products, etc., as well as services: temporary accommodation (hotels), tourist, office organizations type ("green office"), educational institutions ("green classroom").

Specific quantitative requirements for indicators of improved characteristics of raw materials, finished products or services differ for each category.

For food industry products, restrictions are established (in addition to state regulations) regarding indicators of the residual content of toxic elements, mycotoxins, nitrates, radionuclides, pesticides. A ban on the use of GMOs, ingredients of non-natural origin, dangerous and potentially dangerous food additives is introduced.

It is forbidden to use organotin compounds and aromatic amines, lead-based pigments for textiles. The residual content of toxic elements and agrochemicals in fabrics from raw materials of plant origin is limited.

For the production of building materials, the use of carcinogenic substances is prohibited, the content of volatile compounds, heavy metals, radionuclides, etc. is limited.

The user of the ecological certificate gets the right to apply ecological labeling, which will determine the general advantages of the certified products.

Environmental labeling of type I can consist of separate or combined elements in the form:

- statements that indicate the advantage or characteristic of products (in accordance with the ecological criterion);
- graphic image (environmental labeling sign).

Examples of environmental labeling signs belonging to regional and national type I programs recognized at the international level (EU; Northern European countries (Sweden, Norway, Denmark, Finland, Netherlands); Ukraine; USA; Japan; Taiwan; Germany; China; Republic of Korea):

Fig. 6.1. Type I ecological marking signs

The international association that unites regional and national environmental labeling programs of type I (Global Ecolabelling Network, GEN) carries out a certification procedure to confirm competence and international recognition among environmental labeling programs of type I - GENICES.

GEN ensures the development and implementation of basic environmental criteria for type I environmental labeling programs.

This approach allows for harmonization of product requirements between regional and national programs that apply them, as well as mutual recognition of assessment results between environmental labeling bodies, which, in turn, strengthens the potential of exporters-users of environmental labeling according to ISO 14024.

II type of ecological labeling (self-declaration)

This type determines which labeling should be used to determine the specific ecological characteristics of products. The main principles of applying type II environmental labeling are set out in the ISO 14021 standard.

An example of type II environmental labeling can be declarations such as: "recycled material content", "recyclable", "compostable", "demountable structure", etc., or special signs defined by the international standard ISO 7000.

Fig. 6.2. Type II environmental labeling signs

The recycling sign, which is also called the "Möbius strip", means in a shaded version that the product or its packaging contains recycled raw materials (for example, waste paper), and the shaded sign indicates products or their packaging that can be recycled.

Shown in Fig. 6.2 signs mean that the product or packaging material is 100% biodegradable.

The meaning of the third sign is a call not to litter, to hand over used products for re-processing and throw them into separate trash cans for paper, glass, polymer, rags, etc. Such a sign is usually applied together with the inscriptions "Keep your country tidy!" or "Thank you", "Gracias".

For the proper sorting of products for their further processing, a special marking (fourth sign) has been introduced, which allows to distinguish different types of polymers and other packaging materials by their origin. The number in the middle of the sign and the letter code indicate the type of packaging material.

DSTU ISO 14021-2002 Environmental labeling and declarations - Environmental self-declarations (Environmental labeling type II) defines the concept: environmental self-declaration (en - self-declared environmental claim) - an environmental statement made (without independent third-party certification) by manufacturers, importers, distributors, retailers or any other person to whom such a statement may be useful.

According to the requirements of ISO 14021, self-declarations should be accompanied by an explanation if the statement itself could lead to misunderstanding.

The user of type II eco-labelling must be responsible for the assessment and provision of data necessary for the verification of environmental self-declarations.

Therefore, first, in order to achieve reliable results necessary to verify the statement, measures should be taken to evaluate the environmental characteristics of products. The assessment procedure must be fully documented and the label user must ensure that information regarding the validation of the environmental claim assessment results is made public and that such documentation is kept. The duration of storage of supporting documentation should be the entire period while the products are placed on the market, as well as the period after the sale of the products, based on its shelf life (exploitation).

The above-mentioned standards do not provide for the granting of the right to business entities to use such statements as "environmentally clean", "environmentally safe", "environmentally friendly", "friendly to the soil", "non-polluting", "green", "friendly to nature" and "ozone friendly" etc.

Despite the voluntary application of type I and II environmental labeling, the use by business entities of unclear or false environmental labeling, or environmental labeling that cannot be verified or can be misunderstood, is a sign of violation of current legislation in the field of consumer rights protection, advertising and competition protection in entrepreneurial activity.

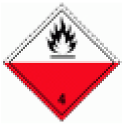
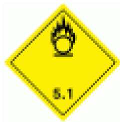
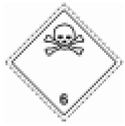
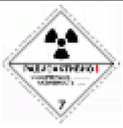
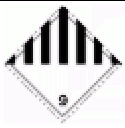
6.5 Designation of vehicles using markings

To increase the attention of other road users, vehicles carrying dangerous goods are marked with orange plates and large danger signs.

Transport units carrying dangerous goods must have two orange dangerous goods plates placed in a vertical plane. One of these plates must be fixed at the front, and the second - at the back, and both - perpendicular to the longitudinal axis of the transport unit.

Orange dangerous goods plates and large danger signs also provide important information to emergency services in the event of an accident.

Table 6.1 Images of danger signs

 1st class of danger Explosive substances and products	 2 class of danger Gases	 3rd class of danger Flammable liquids
 4th class of danger Flammable substances and materials	 5th class of danger Oxidizing substances and organic peroxides	 6th class of danger Poisonous and infectious substances
 7th class of danger Radioactive materials	 8th class of danger Corrosive substances	 9th class of danger Other dangerous substances and products

Signs and marking of dangerous cargo

Danger signs are placed on dangerous cargo, packages and other means of keeping dangerous goods, and also, in some cases, on vehicles transporting dangerous goods.

The system of danger signs is based on the classification of dangerous goods and is designed as such:

— to make dangerous goods easily recognizable from a distance by the general appearance of the danger signs on them (symbol, color and shape);

— to provide, with the help of the colors of the danger signs, the first useful indication regarding loading and unloading operations, stacking of loads and their distribution.

Marking vehicles, containers and tanks with danger signs, the signs are placed on:

— on both sides and on each end face of the container, multiple gas container, tank container or portable tank. When a tank-container or portable tank has several compartments and carries two or more dangerous goods, the appropriate danger signs shall be placed on each side where the respective compartments are located, and one danger sign of each type present on each side shall be placed on both end sides.

— on both sides and at the rear of tank cars, vehicles with removable tanks, battery vehicles and vehicles transporting dangerous goods in bulk. If a tank truck or demountable tank carried on a vehicle has several compartments and two or more dangerous goods are carried in them, the appropriate danger signs must be placed on each side where the respective compartments are located and one danger sign of each type available on each side, must be placed at the rear of the vehicle. However, if the same danger signs are required for all compartments, they must be placed one on each side and on the rear of the vehicle. If more than one information board is required for the same compartment, they must be placed next to each other.

Danger signs that do not belong to the dangerous goods being transported or their parts must be removed or covered up.

In ADR, the concept of "orange plates" is used for marking vehicles during the transportation of dangerous goods.

Fig. 6.3 Labeling of vehicles during transportation of dangerous goods

Transport units transporting dangerous goods must have two dangerous goods information tables located in a vertical plane. One dangerous goods information table must be attached to the front, and the other - to the rear of the transport unit, and both - perpendicular to the longitudinal axis of the transport unit. These dangerous goods information tables must be clearly visible.

On tank trucks, battery vehicles or transport units with one or more tanks in which dangerous goods are transported, dangerous goods information tables must be additionally installed on the sides of each tank, each tank compartment or located parallel to each longitudinal axis of an element of battery vehicles. These dangerous goods information sheets must include the hazard identification number and UN number assigned to each substance carried in the tank, tank compartment or battery vehicle unit. These dangerous goods information tables must be clearly visible.

On the side surfaces of vehicles and containers in which dangerous goods are transported in bulk (bulk), information tables of dangerous goods located parallel to the longitudinal axis of the vehicle must be additionally installed. These dangerous goods information sheets must show the hazard identification number and the UN number assigned to each of the dangerous substances transported in bulk / in bulk in a transport unit or in a container. These dangerous goods information tables must be clearly visible.

6.6 Application of the developed system to reduce the impact of transportation of dangerous goods on the environment

The developed visual object recognition system, when properly configured, can recognize different plates, images and text on them with high efficiency and under a variety of conditions. When installing such a system at checkpoints at the entrances to cities and in warehouses, it will provide an opportunity to control the types of cargo being transported and various goods in storage.

Such automation of the process will help to systematize and establish logistics and control over the transportation of dangerous goods, which has a positive effect on the ecological situation of the environment. Next, we will consider the features of using such a system.

6.6.1 How checkpoint automation can benefit from automatic checks

For new terminals, automated data collection is not difficult. When modernizing existing terminals, visual object recognition systems can accelerate the path to digital transformation.

The first step in terminal automation is usually the automation of checkpoint processes. Information about arrivals and departures is important for the organization of terminal operations. Checkpoint automation includes a portal with cameras or OCR truck portal for trucks, also known as a video gate: when approaching the terminal checkpoint, trucks arrive, pass through the truck portal for trucks and register using license plate recognition cameras, while other cameras read the container or semi-trailer number, ILU number, ISO code, yellow plate, IMDG dangerous goods marking, presence of seals, container weight, etc. Some terminals only need the container number, while others need more data for tailored operations at later stages.

The registered data is instantly transferred to the terminal operating system (TOS) and checked in the Truck Appointment System (TAS), if the vehicle pre-booking system is installed. Depending on the capacity of the terminal, one or two truck portals are usually enough to register the incoming flow of trucks. As drivers proceed to the terminal entrance gate along one of the truck lanes, a new set of LPR cameras at the check-in kiosk immediately associates the truck with the relevant container data. After the truck driver is identified, he is allowed access to the terminal and receives an Electronic Routing Ticket (ERT), which contains exact information about where to drop off or pick up the container or trailer. The Gate Operating System (GOS) also controls the traffic light and barrier at the checkpoint. When everything is ready, the driver gets the green light and the barrier opens automatically.

6.6.2 Railway solution at intermodal terminals

Intermodal terminals must process incoming and outgoing trains as quickly as possible. Faster processing means processing more trains in the same time frame. And as freight integration becomes more important, tracking trains and cargo requires fast and accurate data. The rail camera portal automatically registers every rail car, platform and container / semi-trailer when trains pass through the portal. A train list can be checked in minutes, while manual checks require operators to travel several miles per day to fully register the inventory. When part of the required data is not visible, the train manifest serves as a backup to fill in the data. The Rail Portal comes with a software application, providing intuitive handling of out-of-state situations and providing additional photos for status logging.

Fig. 6.4 An example of a railway car labeling

6.6.3 Integration with the operating system of the terminal

The image analysis solution is a recognized industry standard, offering the highest accuracy rates, significantly reducing the number of freelance situations when processing data at checkpoints, cranes or rail operations. All hardware solutions come with intuitive software applications for handling freelance situations and easily integrate with your own Terminal Management System or TOS.

CONCLUSION

In order to implement this work, an investigation of the algorithm's existing implementation techniques was carried out. It was found that none of them could entirely satisfy the conditions for the target contour's video monitoring system on their own:

- while despite being relatively straightforward, the correlation detection approach has a significant likelihood of mistakes (false identification or missing objects), which is explicable given that the qualities of noise were ignored when creating the image processing algorithm;
- The process of identifying an object in a picture by its contour is not particularly quick and occasionally detects incorrect contours;
- Because the feature points for the new numberplate will vary appropriately, the method of identifying the item in the image by feature points does not allow for the precise determination of the number plate's coordinates.;
- Although neural networks can recognize objects pretty well, they need a lot of computer power, a graphics accelerator, and a lot of practice photographs.

As a result, a custom algorithm for the system was created using a number of different techniques. Additionally, a custom method for filtering characteristic points was created, ensuring that the position of the licence plate on the picture could always be determined with accuracy. Character recognition for license plates has been introduced with the use of the Template Matching approach.

The created system, which uses a simple camera and a Raspberry Pi microcomputer with MATLAB programming software installed, reliably recognizes the object of tracking, operates rapidly, and can be compact in comparison to other systems that use deep learning.

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APPENDIXES

Appendix A. Code of the program for highlighting the number plate contour and displaying the characters.

```
close all;
clear all;
tic
im = imread('C:\Users\Admin\Desktop\РГБ1\макс\РГБ\gg3.jpg');

 im3 = im; % save variable with input image
imgray = rgb2gray(im); % conversion of the image to gray
halftones
imgray = imcrop(imgray, [400 300 500 500]); % crop image pixels

G = fspecial('gaussian',[4 4],2); % Blur image with Gaussian
filter
 %# Filter it
imgray = imfilter(imgray,G,'same');

corners = detectFASTFeatures(imgray); % determination of
characteristic points by the FAST detector
% imshow(imgray); hold on;
% plot(corners.selectStrongest(200)); % Display points with
selected mass
% pause(2);


for i=1:length(corners.Location) % Record the coordinates of x,
at each characteristic point
    x(i)= corners.Location(i);
    y(i)= corners.Location(i,2);
end
for i=1:length(corners.Location) % Calculation of the mass of
each characteristic point for the distance between them
    mass(i)=0;
    for j=1:length(corners.Location)
    dist(i,j)=sqrt((x(i)-x(j))^2+(y(i)-y(j))^2); % equation for
determining the distance
    if  dist(i,j)<=60 % comparison of the distance between
points with a certain threshold
        mass(i)= mass(i)+1;
    end
    end
end
masso=6;    % Record the initial threshold of the mass of points
num_of_iter=1; % initialization of the cycle iteration count
variable
```

```
while(1) % Start of the number plate definition cycle and the
symbols on it

for i=1:length(corners.Location) % Cycle of elimination of
characteristic points with too little mass
    if mass(i)<=masso
        mass(i)=0;
    else
        x_1(i)=x(i); % coordinates of points that have been
checked
        y_1(i)=y(i);
    end
end
x_1=nonzeros(x_1)'; % screening points with 0 coordinates
y_1=nonzeros(y_1)';
% imshow(imgray); hold on;
% plot(x_1,y_1,'c*'); % Display of characteristic points that
have passed all checks

Mleft = min(x_1)-0;%left crop edge point
Mright = max(x_1)+20;%right crop edge point
Mupper =  min(y_1)-10;%upper crop edge point
Mlower =  max(y_1)+10;%lower crop edge point

X=400+Mleft*(num_of_iter); % calculation of the trimming edge
after each iteration
Y=300+Mupper*(num_of_iter);

num_of_iter=num_of_iter+1; % cycle iteration counter

imgray = imcrop(imgray, [Mleft Mupper Mright-Mleft Mlower-
Mupper]); % Crop image at extreme characteristic points

imbin = imbinarize(imgray); % image binarization

im = edge(imgray, 'prewitt'); % Select contours on the cropped
image using the Prewitt method
% figure, imshow(im);
% figure, imshow(imbin); % binary cropped image
%Below steps are to find location of number plate
Iprops=regionprops(imbin,'BoundingBox','Area', 'Image'); %
finding image properties: coordinates and dimensions of the
smallest rectangle, actual number of pixels in the region,
binary image of the same size as BoundingBox returned as a
binary array
area = Iprops.Area; % actual number of pixels in the region
count = numel(Iprops); % number of elements of the array
maxa= area;
boundingBox = Iprops.BoundingBox;
```

```
for i=1:count                      % Frame definition
   if maxa<Iprops(i).Area
       maxa=Iprops(i).Area;
       boundingBox=Iprops(i).BoundingBox;
   end
end

im = imcrop(imbin, boundingBox);%crop the number plate area
%figure, imshow(im);
im = bwareaopen(~im, 50); %remove some object if it width is
too long or too small than 50
%figure, imshow(im);
 [h, w] = size(im);%get width and height

%imshow(im);

Iprops=regionprops(im,'BoundingBox','Area', 'Image'); %reading
the letter
count = numel(Iprops);
noPlate=[]; % Initializing the variable of number plate string.

for i=1:count
   ow = length(Iprops(i).Image(1,:)); % image height
   oh = length(Iprops(i).Image(:,1)); % image width
   if ow<(h/2) && oh>(h/3)
       letter=Letter_detection(Iprops(i).Image); % Reading the
letter corresponding the binary image.
       noPlate=[noPlate letter] % Appending every subsequent
character in noPlate variable.
   end
end
masso=masso+1; % increase in the threshold mass of the points
with each cycle
if masso > 13 % Limit the value of the mass of points
    masso_err = 0;
    break
end

if length(noPlate)==9 % Corrects the incorrect definition of
the first character
    if isnumeric(noPlate(3))==0

    noPlate(1)='';
end
end
if length(noPlate)==8 % output of characters read from the
plate
    masso_err = 1;
    noPlate
```

```
    break
end
close all
end
toc
% Frame the area of the number and display the read characters
on
% to the original image
if masso_err == 1
imshow(im3); hold on;
rectangle('Position',[X+boundingBox(1) Y+boundingBox(2)
boundingBox(3) boundingBox(4)],'EdgeColor','r','LineWidth',3);
text(X+boundingBox(1),Y+boundingBox(2)+2*boundingBox(4),noPlate
,'Color','red','FontSize',16);

 end
```

Appendix B. Program code that creates templates of alphabets and numbers.

```
%CREATE TEMPLATES
%Alphabets
A=imread('alpha/A.bmp');B=imread('alpha/B.bmp');C=imread('alpha
/C.bmp');
D=imread('alpha/D.bmp');E=imread('alpha/E.bmp');F=imread('alpha
/F.bmp');
G=imread('alpha/G.bmp');H=imread('alpha/H.bmp');I=imread('alpha
/I.bmp');
J=imread('alpha/J.bmp');K=imread('alpha/K.bmp');L=imread('alpha
/L.bmp');
M=imread('alpha/M.bmp');N=imread('alpha/N.bmp');O=imread('alpha
/O.bmp');
P=imread('alpha/P.bmp');Q=imread('alpha/Q.bmp');R=imread('alpha
/R.bmp');
S=imread('alpha/S.bmp');T=imread('alpha/T.bmp');U=imread('alpha
/U.bmp');
V=imread('alpha/V.bmp');W=imread('alpha/W.bmp');X=imread('alpha
/X.bmp');
Y=imread('alpha/Y.bmp');Z=imread('alpha/Z.bmp');

%Natural Numbers
one=imread('alpha/1.bmp');two=imread('alpha/2.bmp');
three=imread('alpha/3.bmp');four=imread('alpha/4.bmp');
five=imread('alpha/5.bmp'); six=imread('alpha/6.bmp');
seven=imread('alpha/7.bmp');eight=imread('alpha/8.bmp');
nine=imread('alpha/9.bmp'); zero=imread('alpha/0.bmp');

%Creating Array for Alphabets
letter=[A B C D E F G H I J K L M N O P Q R S T U V W X Y Z];
%Creating Array for Numbers
number=[one two three four five six seven eight nine zero];

NewTemplates=[letter number];
save ('NewTemplates','NewTemplates')
clear all
```

Appendix C. Code for comparison of input image with templates.

```
function letter=readLetter(snap)

load NewTemplates
snap=imresize(snap,[42 24]);
rec=[ ];

for n=1:length(NewTemplates)
    cor=corr2(NewTemplates{1,n},snap);
    rec=[rec cor];
end

ind=find(rec==max(rec));
display(ind);

% Alphabets listings.
if ind==1 || ind==2
    letter='A';
elseif ind==3 || ind==4
    letter='B';
elseif ind==5
    letter='C';
elseif ind==6 || ind==7
    letter='D';
elseif ind==8
    letter='E';
elseif ind==9
    letter='F';
elseif ind==10
    letter='G';
elseif ind==11
    letter='H';
elseif ind==12
    letter='I';
elseif ind==13
    letter='J';
elseif ind==14
    letter='K';
elseif ind==15
    letter='L';
elseif ind==16
    letter='M';
elseif ind==17
    letter='N';
elseif ind==18 || ind==19
    letter='O';
elseif ind==20 || ind==21
    letter='P';
elseif ind==22 || ind==23
```

```
    letter='Q';
elseif ind==24 || ind==25
    letter='R';
elseif ind==26
    letter='S';
elseif ind==27
    letter='T';
elseif ind==28
    letter='U';
elseif ind==29
    letter='V';
elseif ind==30
    letter='W';
elseif ind==31
    letter='X';
elseif ind==32
    letter='Y';
elseif ind==33
    letter='Z';
    %*-*-*-*-*
% Numerals listings.
elseif ind==34
    letter='1';
elseif ind==35
    letter='2';
elseif ind==36
    letter='3';
elseif ind==37 || ind==38
    letter='4';
elseif ind==39
    letter='5';
elseif ind==40 || ind==41 || ind==42
    letter='6';
elseif ind==43
    letter='7';
elseif ind==44 || ind==45
    letter='8';
elseif ind==46 || ind==47 || ind==48
    letter='9';
else
    letter='0';
end
end
```