COMPUTER VISION

PROJECT REPORT

Development of Computer Vision Application for Car License Plate Detection

Rafael Andreu Roselló

Mar Martín Díaz

David Redondo Quintero

Patricia Rodríguez Peña

TABLE OF CONTENTS

EXECUTIVE SUMMARY

OVERVIEW OF THE PROJECT

The project aimed to develop a sophisticated computer vision application for the detection of license plates in images, employing various techniques such as image preprocessing, segmentation, and optical character recognition (OCR).

The multidisciplinary team was organized into four key areas: management, technological, documentation and programming. In addition, the manager of the technological area performed the functions of validation and testing of the developed code. Each area had specific competencies and responsibilities, contributing to the successful execution of the project.

OBJECTIVES

The objectives of the project are detailed below:

- Evaluate state-of-the-art techniques in image preprocessing, segmentation, optical character recognition (OCR), and for their applicability to license plate detection.
- Develop a computer vision application that can precisely identify license plates in various image datasets.
- Facilitate collaboration among team members from diverse areas, including management, technology exploration, documentation, programming, and testing/validation.
- Implement efficient project management practices, including work planning, progress evaluation, conflict resolution, and clear communication with stakeholders.
- Documenting the project in a detailed and organised way, collecting the results, and drawing the main conclusions, as well as indicating possible future directions.
- Develop a dedicated project website to serve as a centralized platform for sharing project information, updates, and documentation.
- Conduct thorough testing and validation procedures to assess the accuracy, reliability, and generalization of the developed license plate detection system.

KEY RESULTS

The main results of the project are shown below:

- Algorithm 1 for the first dataset provides an accuracy of 85% for license plate detection and 14% for license plate reading.
- Algorithm 1 for the second dataset provides an accuracy of 33.3% for license plate detection and 10.5% for license plate reading.
- Algorithm 2 gives poor results in general.
- Algorithm 3 (a mixture of algorithms 1 and 2) provides an accuracy of 77.5% for license plate detection and 37.9% for license plate reading, being the best algorithm among those developed in the project.

INTRODUCTION

PROJECT CONTEXT

The demand for automated license plate detection has increased due to the rise of smart cities, intelligent transportation systems, and heightened security concerns. This technology is crucial for traffic management, law enforcement, and surveillance applications.

The project is based on the use of advanced computer vision techniques, including segmentation algorithms, OCR methodologies, and image preprocessing techniques. By incorporating cutting-edge technologies, the system is made more competitive and adaptable.

This project also holds educational and research significance. It offers students the opportunity to engage in real-world problem-solving, explore emerging technologies, and contribute to the academic discourse surrounding computer vision and image processing.

In essence, the project is focused on addressing current challenges, leveraging advanced technologies, and contributing to the evolving landscape of computer vision applications. By focusing on license plate detection, the project aims to make a meaningful impact on various sectors, fostering efficiency, security, and innovation.

IMPORTANCE OF LICENSE PLATE DETECTION

License plate detection is a crucial technology with numerous applications that significantly contribute to public safety, security, and streamlined operations across various sectors. The significance of license plate detection is highlighted by the following factors:

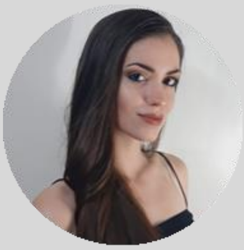
- **Crime prevention and law enforcement**: License plate detection is crucial in preventing crime and enforcing the law. It allows for the quick identification of vehicles linked to criminal activities, helping authorities to locate stolen vehicles, apprehend suspects, and investigate incidents.
- **Automated surveillance for public spaces**: In public spaces, license plate detection systems provide automated surveillance. This not only helps monitor traffic but also enhances security by identifying vehicles of interest and alerting authorities to potential threats or suspicious activities.
- **Electronic toll collection**: License plate detection is crucial for electronic toll collection systems, enabling fast and automated toll payments. This reduces traffic congestion at toll booths and enhances the efficiency of toll collection processes on highways and expressways.
- **Fleet management and logistic**: In the field of logistics and fleet management, license plate detection improves tracking and management capabilities. Companies can monitor their vehicles efficiently, optimize delivery routes, and ensure the security of transported goods.
- **Integration with the initiatives of smart cities**: Integrating license plate detection technology aligns seamlessly with the broader vision of smart cities. It enhances public safety, reduces traffic congestion, and creates a more connected and intelligent urban environment.

METHODOLOGY

DIVISION OF TASKS AMONG TEAM MEMBERS

Although each member is responsible for a particular area, an equal division of tasks has been sought. Thus, the tasks carried out by each of the members are detailed in Table 1.

Table 1 Division of tasks among team members

Team member	Tasks
 Rafael Andreu Roselló *Technical Manager*	• Coordinate the technological exploration, evaluation of technical progress. • Development of the OCR algorithm. • Test performance and results validation.
 Mar Martín Díaz *Documentation Manager*	• Document the entire project and generate deliverables in the appropriate format. • Design and create the web page that collects all the results.
 David Redondo Quintero *Programming Manager*	• Coordinate and supervise code development. • Development of the initial segmentation algorithm and implementation of the convolutional network.
 Patricia Rodríguez Peña *Project Manager*	• Coordinate the work of the entire team and communicate with the professor. • Development of the image pre-processing, license plate segmentation and tilt correction algorithms.

STAGES IN PROJECT DEVELOPMENT

Developing an effective license plate detection system requires a systematic approach that involves several stages, from data collection to model evaluation. The following section outlines the key steps and methodologies used in creating the license plate detection system.

Problem definition and scope

This stage seeks to define the objectives and requirements of the license plate detection system, including the scope, the types of images to be processed, the desired output of the system, and any constraints or limitations.

Data collection

This stage seeks to collect a diverse dataset of images containing vehicles with different license plate characteristics. Ensure that the dataset represents the actual situations expected, including different lighting conditions and vehicle angles.

Code development

The design specifications are translated into executable code during this stage. The source code is written, tested, and refined to create a functional and efficient software application.

Testing and optimization

This stage seeks to conduct rigorous testing to ensure seamless functionality, address any integration issues, and verify the system's performance in real-world conditions.

Results and comparison

In this stage, the results are analysed and the different alternatives that have been implemented are compared.

Documentation and reporting

This stage seeks to document the entire development process, including a description of the algorithms used, as well as any information that may be needed to aid future development, troubleshooting and possible improvements to the system.

Website development

This stage seeks to design and create a web page to collect project results. It must be ensured that the page have an attractive interface for the public and use language that is understandable to both, computer vision experts and non-experts.

PROJECT DEVELOPMENT

MANAGEMENT AREA

The management area is crucial in overseeing and coordinating the project's overall development. Below is an overview of the project's development within the management area:

- **Planning:** Establish milestones to be met in order to complete the project on time. Define which activities must be completed first in order to be able to start subsequent activities.
- **Team Coordination:** Organise regular team meetings to foster collaboration and ensure that everyone is aligned with the project objectives. The minutes of the meeting are included in Annex 1 of this document.
- **Communication with stakeholders:** Communicate with the teacher, who is the main stakeholder, to ensure that the project requirements are met.
- **Progress tracking and evaluation:** Implemented a structured progress review system to evaluate the status of each phase of development.
- **Time management:** To ensure that the time spent by team members is sufficient to complete the tasks assigned to them. The work control is shown in Annex 2.

TECHNOLOGICAL AREA

The project aims to achieve license plate detection through the use of advanced technologies. Here is an overview of the project's technological development:

- **Technology exploration**: Explored and selected the license plate detection theme based on its technical complexity and relevance. Conducted an in-depth exploration of existing technologies related to computer vision.
- **Algorithmic Approach**: Evaluated various algorithms suitable for license plate detection, considering factors like accuracy, speed, and adaptability.
- **Dataset selection**: Identified and acquired relevant benchmarks for training and testing the license plate detection system.

DOCUMENTATION AREA

Project documentation

The project documentation area aims to systematically capture and present the entire journey of license plate detection development. Below is an overview of the project's development within the documentation domain:

- **Create document templates for the various deliverables**: Establish a single format for all documents, achieving continuity in the presentation of the documentation submitted.
- **Gather information from the different areas**: Keep track of the progress and results achieved in the different areas.
- **Generate deliverables**: Review documents, correct possible errors, adapt the format and generate deliverables.

Website

The project website presents the development journey of license plate detection in a clear and concise manner. The link to access it is available below: http://upmetsii.125mb.com/.

The project website has been meticulously crafted to provide an immersive and visually engaging experience, presenting a comprehensive overview of the efforts undertaken in the development of the license plate detection system. The design is optimized to ensure accessibility and provides an informative and eye-catching exploration of the ins and outs of the project.

PROGRAMMING AREA

For the development of the license plate detection system, it has been decided to use two different algorithms, so that the results can be compared. The scheme of the steps carried out in the development of each of the algorithms is shown in Figure 1.

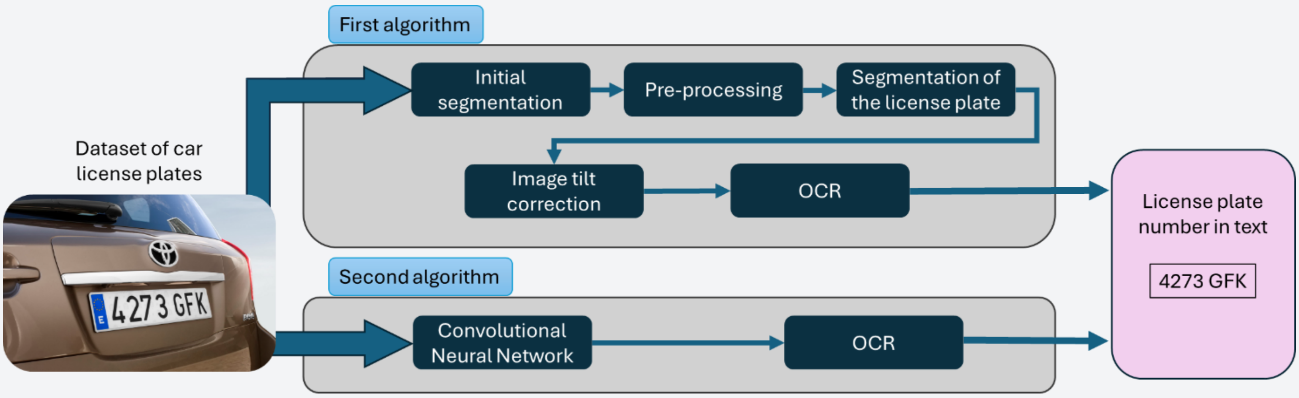


Figure 1 Schematic of license plate detection system

The algorithms implemented are explained in more detail below.

First algorithm

Initial segmentation

The first step in the development of this first license plate detection algorithm is to perform an initial segmentation to facilitate subsequent work. For this purpose, the ORB[1] (Oriented FAST and Rotated BRIEF) algorithm was used.

ORB is an efficient substitute for SIFT or SURF, which are two commonly used algorithms for feature extraction and matching in computer vision and image processing. It combines the FAST key point detector and the BRIEF descriptor with several modifications to enhance performance. It uses FAST

[1] OpenCV: ORB (Oriented FAST and Rotated BRIEF) [Internet]. Disponible en: https://docs.opencv.org/4.x/d1/d89/tutorial_py_orb.html

to identify key points and then applies the Harris corner measure to determine the N best points between them. Additionally, it employs pyramiding to generate multi-scale features. However, one drawback is that FAST does not compute orientation. The orientation is determined by calculating the intensity-weighted centroid of the patch with the corner located at the centre. In order to improve the invariance to rotation, the moments are computed with x and y, which have to lie in a circular region of radius r, where r is the size of the patch. For its descriptors, ORB uses BRIEF descriptors.

The implementation of this algorithm is described below. Characteristic points are obtained from a test license plate, as well as from the image in which the license plate is located. The *"cv2.BFMatcher"* function is used to obtain the image features that best match those obtained from the test license plate. The matching process uses the Manhattan distance between the points as a criterion. By limiting the number of descriptors, the algorithm can guide the identification of the license plate.

Limiting the number of features is crucial in avoiding widely distributed points in the image. If the limit is too low, the points will be concentrated around the car. On the other hand, if the limit is too high, most of the points will appear in other parts of the image, such as the background, trees, grass, and traffic. After a process of experimentation, the number of features was limited to 50.

Subsequently, a clustering process is applied which divides the whole descriptors cloud into subgroups according to their distance from each other. For this purpose, the function "*hcluster.fclusterdata*" is used. This function implements hierarchical clustering, a grouping technique that organizes data in the form of a tree or dendrogram.

First, it performs the calculation of distances between all pairs of points in the dataset. This calculation is based on the Euclidean distance metric. These distances are used to create a map of the relationships between the points called the linkage matrix.

The dendrogram is then constructed. This dendrogram is a visual representation in the form of a tree that illustrates how points are grouped at different levels of similarity. Next comes the cut-off step of the dendrogram. Here, the process depends on the specified threshold value, 20 in the case of this project, and the clustering criterion, "inconsistent" in this case. It is decided to cut the dendrogram at a specific level, thus creating groups or clusters of classified points.

Considering the largest sets of grouped points (over ten points), coordinates are obtained on the image to construct an array with a bounding box that encompasses the marked points plus a size margin for each group of points.

If fortunate, multiple points will be concentrated around the number plate area, and the clipping will include the entire plate and a portion of the car. The main purpose of this step is to remove contours and elements that may interfere with the segmentation of the license plate. If this step fails, the rest of the process will fail as well. Therefore, it is necessary to validate its efficiency by means of testing and to decide whether it is worthwhile to include it as a pre-processing step prior to segmentation.

Image pre-processing

Once the cuttings have been obtained, since its size is significantly reduced, the image is resized to facilitate the rest of the operations (Figure 2). The next phase is filtering.

Figure 2 Image resized

First, the image is converted to black and white using the “*cvtColor*” function and setting the color space to grayscale (shown in Figure 3).

Figure 3 Grayscale Image

Next, the generated image is edge-detected using the “*cv2.Canny*” function, which uses the “*cv2.Canny*” algorithm, a popular method for identifying abrupt changes in pixel intensity, which generally corresponds to the presence of edges in an image can be seen in Figure 4.

Figure 4 Canny Image

Figure 5 shows a Gaussian filter applied to the detected edges in order to reduce noise and smooth the transition between image pixels. The result is stored in the variable “gaussian”.

Figure 5 Gaussian Image

Then, the function “*cv2.adaptiveThreshold*” is used to apply an adaptive threshold to the smoothed image. This method adapts the thresholds locally according to the characteristics of the region. The result is stored in the variable “*thresh*” can be seen in Figure 6.

Figure 6 Thresh Image

Subsequently, a dilation operation is applied to the thresholded image using a square kernel of size (5.5). This operation is performed in order to join close regions and close gaps at the edges, since in many cases the contours of the license plates, not being thick, do not join and can cause difficulties when segmenting the image. The result is stored in the variable “*dilated*” (shown in Figure 7).

Figure 7 Thresh Image

An erosion operation is applied to the enlarged image. Erosion aims to reduce the size of the regions of interest and to remove small details that are better left unnoticed. Three iterations are performed. The result is stored in the variable “*eroded*”.

Finally, the function “*cv2.findContours*” is used to identify the contours in the eroded image. The contours are stored in the variable “*contours*”, and the contour hierarchy is stored in “*hierarchy*”.

Segmentation of the license plate

For the segmentation operation, a copy of the original image (“*imagR*”) is created, and the contours found at the previous stage are used to draw green lines around the areas identified as contours. The result is stored in the variable “*result*”.

Figure 8 Contours Image

For each contour stored in the variable “*contours*” of each clipping (shown in Figure 8), the following segmentation conditions are set that will help distinguish the license plate area. It must be fulfilled that:

- The approximate polygon that forms the outline should have approximately four edges and be of sufficiently large area.

- The approximate polygon has to be a rectangle, so width and height will be compared so that the ratio between them is between 1.5 and 6. This difference in values is due to the fact that the image does not have to be correctly placed in perspective.

Image tilt correction

Once the image has been segmented, the next step is the perspective transformation. This involves straightening the image from 3D to 2D. To do this, the "*minAreaRect*" function is used, and an additional adjustment is made to ensure that the image is positioned so that the height is less than the width and ensuring that it is in a proper rotation. Homography is calculated with the "*findHomography*" function, a geometric transformation that maps points in one image to corresponding points in another image and applied to the image using the "*warpPersPective*" function.

Optical Character Recognition (OCR)

The pre-processed and segmented images from the previous steps were analysed to determine the best method for converting the image of the license plate number to text using OCR (character recognition).

The most effective approach was chosen after considering several options, including *EAST* OCR and *Aspose*. One issue with some of the alternative options is that they require a license and are not just simple OCR tools. They perform independent image processing, which is unnecessary in this application since it has already been completed in previous steps, resulting in a loss of computational efficiency.

On the other hand, *EasyOCR* has been implemented, which is a very intuitive and easy to use OCR. However, this method is outdated for current Python versions as it uses an old library that does not function correctly.

Additionally, *PyTesseract* OCR has been implemented. While it can be run directly on Linux, an .exe must be installed to run it on Windows. *Tesseract* has been used in various research labs under license and was finally released after 10 years without modification. The system is currently funded by Google and enables training with languages that were not initially available. It can also detect the language if it is in its database.

Finally, the Matlab OCR function has also been implemented. The algorithm takes the pre-processed license plate image as an input parameter, which was previously saved in the workspace. In addition, the regions of interest (ROI), where only characters are present, were defined and a more precise search was performed in this area. An example of the definition of these regions of interest is shown in Figure 9.

Figure 9 ROI for the OCR

Second algorithm

Convolutional Neural Network (CNN)

A pre-trained network called YoloV8 specialized in segmenting and identifying objects in images has been chosen. This network alone is not able to identify that an object is a number plate, but it is able to identify that the number plate is an object.

Through a process of "fine tuning", the architecture of the pre-trained network (which has already learned patterns and features from a larger dataset) is taken, and the weights of its layers are adjusted to better suit the specific task of number plate detection. This is done through a back-propagation process in which a loss function is minimized relative to the dataset.

It is important to note that the success of customized training will depend on the quality and quantity of data in the dataset, as well as the choice of network architecture and other hyperparameters. The selected training set consists of approximately 400 photos. The training setting was 100 epochs.

Once the network tuning process is finished, it is sufficient to save it in the directory. As the Yolo network has its own library, the use of the model is immediate. The predict function is used to obtain the points that delimit the contour box detected by the network, which is, hopefully, the number plate. These points are used to crop the image and apply the OCR.

It should be noted that the network will only return matches with a hit rate of more than 80%, thus reducing false positives.

Optical Character Recognition (OCR)

In order to convert the already processed and segmented image into text, the same recognition method was used as in the first recognition algorithm, so its explanation can be consulted in the corresponding section of this document (First algorithm: Optical Character Recognition (OCR)).

TESTING AND VALIDATION AREA

During the testing and validation phase of the project development, the robustness and reliability of the license plate recognition system is ensured through a systematic approach. This phase is crucial in affirming that the algorithm and components meet the defined performance criteria. Below is an overview of the testing and validation processes.

To perform the tests of the algorithms, the previously selected benchmark has been used. Before introducing the images, the dataset was reduced to eliminate the photos in which the license plates did not appear, since these images would affect the results. In addition, images considered very difficult to detect were extracted.

On the other hand, it has been decided to apply the algorithm to images taken by the developers of the present project, with the idea of observing the performance of the algorithm for the detection of Spanish license plates.

A total of two tests have been carried out. The first test focused on the effectiveness of license plate detection, while the second focused on the system's ability to read license plates using OCR.

RESULTS AND DISCUSSION

The results of the license plate detection system are presented below. Since the results of the second algorithm were not very accurate, it was decided to implement the second part of the first algorithm in the second one, in order to improve the accuracy of the system. The scheme of this modification can be seen in Figure 10.

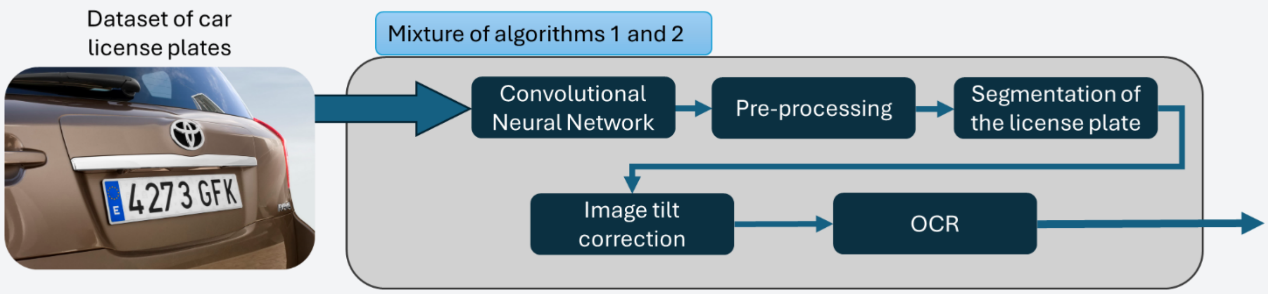


Figure 10 Scheme of the new algorithm (mixture of algorithms 1 and 2)

RESULTS OF THE FIRST ALGORITHM

The results of the application of the first algorithm for license plate detection are shown below.

First dataset

The results obtained for the application of the algorithm to the first dataset are shown in Figure 11. As can be seen in the image, in this case the accuracy obtained in the reading of license plates is 14%. On the other hand, the accuracy in detecting license plates is 85%. This implies that the implemented OCR does not correctly perform the conversion to characters, due to a lack of precision or a poor resolution of the processed images. For future implementations it would be interesting to improve the processing and segmentation stages, as well as the OCR.

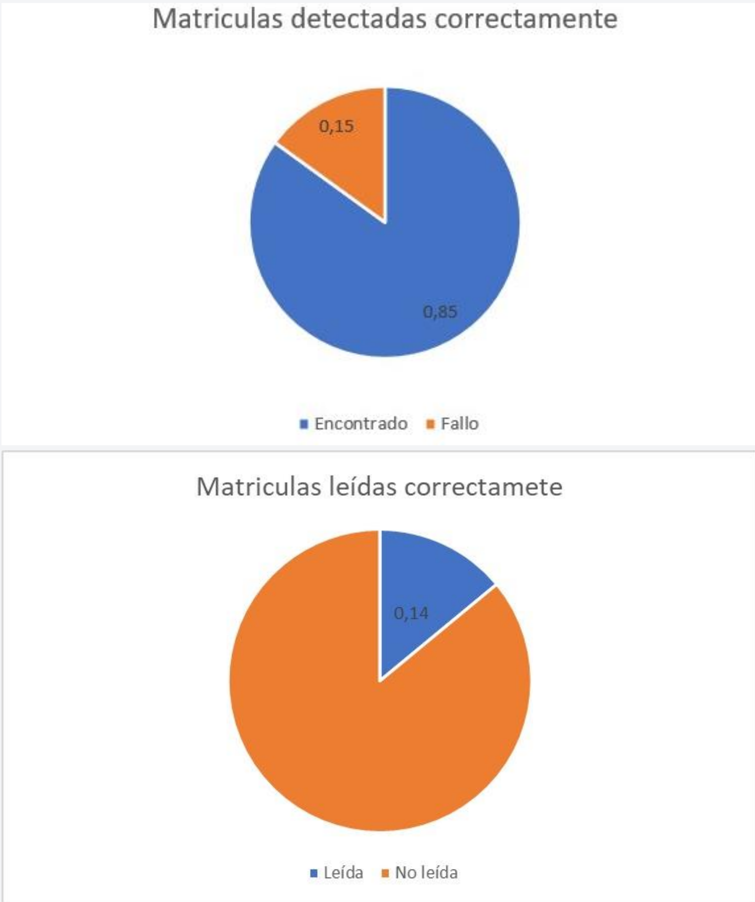


Figure 11 Results of applying the first algorithm to the first dataset

Second dataset (Spanish license plates)

Figure 12 shows the results related to the application of the algorithm to the Spanish dataset. As shown in the image, an accuracy of 10.5% is obtained.

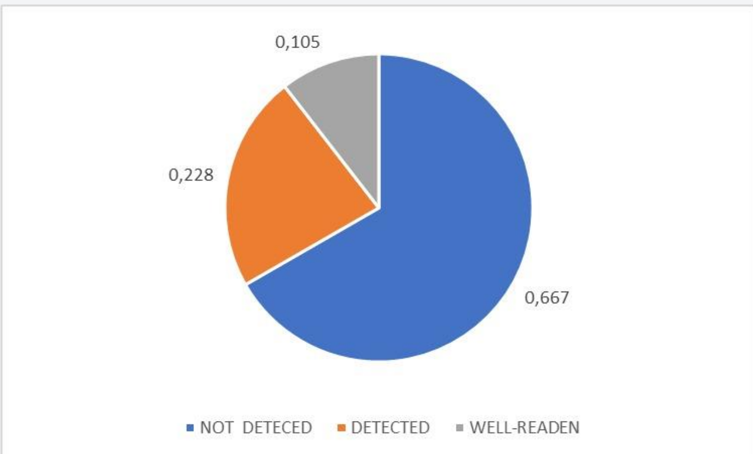


Figure 12 Results of applying the first algorithm to the second dataset

RESULTS OF THE SECOND ALGORITHM

Since the implementation of this algorithm without performing the processing and segmentation phase has not yielded good results, only the results corresponding to the training and validation of the neural network are included in this section. It should be noted that the results of the complete system are shown in the following section (*"Results of the mixture of the first and the second algorithms").*

Convolutional neural network

The results of the neural network training are presented below. Figure 14 shows the results of the neural network training with an estimation of the prediction confidence. On the other hand, Figure 13 shows the most relevant metrics obtained during the learning phase.

Figure 13 Neural network training results with an estimation of the prediction confidence

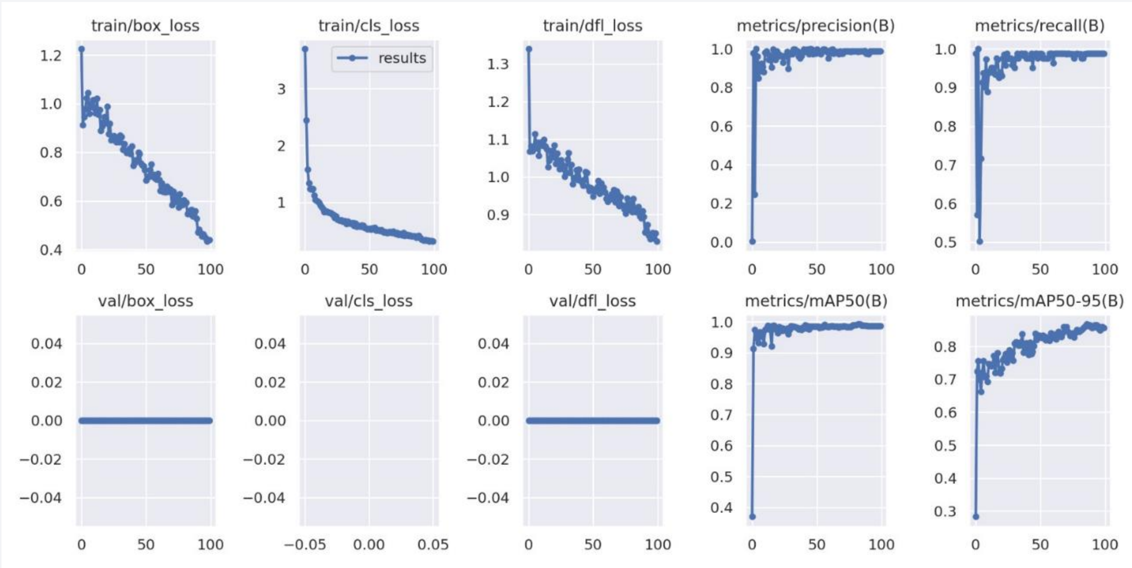


Figure 14 Metrics of the learning phase

In the figure 14, the horizontal axis of the graphs indicates the number of epochs, where each epoch signifies one complete iteration of the training data set through the neural network. While increasing the number of epochs improves the training of the model, too many epochs can result in overfitting.

The vertical axis corresponds to the loss value. The loss serves as a metric to evaluate the performance of the model during training. Lower loss values mean superior model performance, while higher values indicate inferior performance. The main objective during training is to minimise the loss value[2].

"box_loss: Denotes the bounding box regression loss, which measures the disparity between the predicted bounding box coordinates/dimensions and the reality on the ground. A smaller "box_loss" indicates more accurate bounding box predictions.

"cls_loss": Represents the classification loss, quantifying the error in the predicted class probabilities compared to the ground truth for each object. A lower cls_loss implies a more accurate model in the prediction of object classes.

"dfl_loss": A distinctive addition to the YOLOv8 architecture, this refers to the loss of the deformable convolution layer. It measures the error in the deformable convolution layers, designed to improve the model's ability to detect objects with varying scales and aspect ratios. A lower dfl_loss suggests improved handling of object deformations and appearance variations.

The recall is calculated as the ratio between the number of possitive samples correctly classified as Positive to the total number of Positive samples. The recall measures the model's ability to detect Positive samples. The higher the recall, the more positive samples detected.

[2] Source: https://stackoverflow.com/questions/75809415/yolo-v8-result-grap

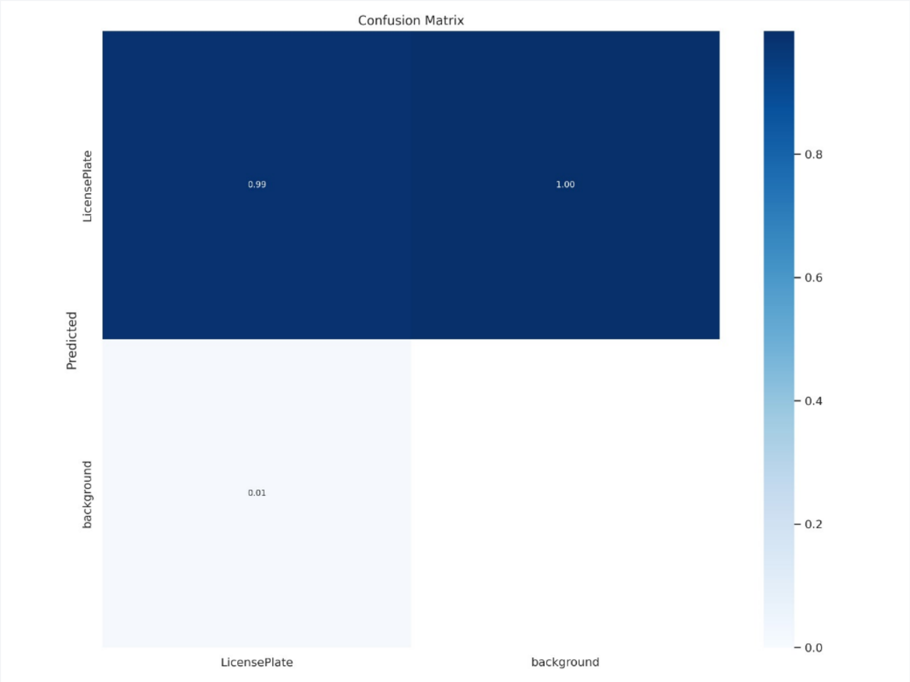


Figure 15 Confusion Matrix

RESULTS OF THE MIXTURE OF THE FIRST AND THE SECOND ALGORITHMS

First dataset

In the image, you can see how it identifies the license plate. Starting from a reference license plate, it identifies the segment of the photo that most closely resembles it (shown in Figure 16).

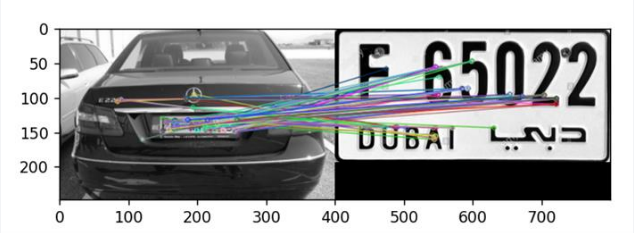


Figure 16 Reference license plate

The next step is to crop the image, obtaining the region of interest (shown in Figure 17).

Figure 17 region of interest

In the processing, it first converts it to black and white can be seen in Figure 18.

Figure 18 Grayscale Image

Next, it detects the contours of the figures can be seen in Figure 19.

Figure 19 contours of the figure

From the contours, a white image with the contours and a black one are obtained (shown in Figure 20).

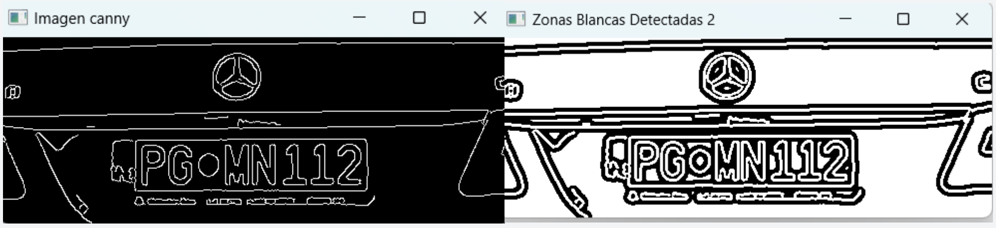


Figure 20 contours black and white of the figure

Finally, the rectified region with the license plate is obtained so that the OCR (Optical Character Recognition) can read it (shown in Figure 21).

Figure 21 Rectified region to OCR

Final image, with the license plate correctly read can be seen in Figure 22.

Figure 22 License plate and the lecture

In the terminal, it can bee seen the matrices used in the transformation and processing of the image, as well as the detected license plate number (shown in Figure 22).

```
box [[131.99998 147.      ]
 [131.99998  99.      ]
 [355.99994  99.      ]
 [355.99994 147.      ]]
[[   3.5714293     0.         -471.42861327]
 [   0.            4.16666667 -412.5        ]
 [   0.            0.            1.        ]]
si3:
9
cargray 8
PLACA:  PG MN112
```

Figure 23 Transformation Matrix and license plate number

Second dataset (Spanish license plates)

Mixing the license plate detection algorithm of the second algorithm, using the neural network) with the image processing proposed in algorithm one, the results obtained for the second dataset are improved. With the same OCR used as in algorithm one, an increase in success cases can be seen. In the previous case, only 33,3% of the license plates were detected and 10,5% were read, while in this case they increase to 77,5% and 37,9% respectively (shown in Figure 24).

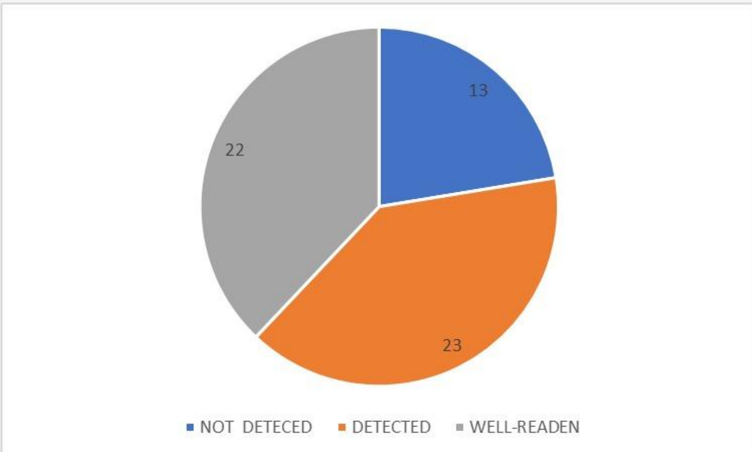


Figure 24 Results of applying the mixture of algorithms to the second dataset

CONCLUSIONS

The following are the conclusions that have been reached after the completion of this project.

The initial algorithm, which relied on ORB segmentation and subsequent processing and OCR steps, achieved moderate success with an accuracy rate of 14% on the first dataset and 10.5% on the second.

The second algorithm, which used a pre-trained neural network without image processing, produced suboptimal results, prompting the exploration of alternative strategies.

Incorporating the neural network from the second approach into the initial segmentation and processing pipeline resulted in a hybrid algorithm that showed promising results. The hybrid algorithm achieved a 22% precision rate for license plate recognition on the second dataset, indicating a significant improvement over the individual algorithms.

The project team's commitment to overcoming challenges and refining the system is exemplified by the iterative development and integration of a hybrid solution.

The main challenge is the transition from detected license plates to individual letters, which poses a significant hurdle in achieving higher precision rates. Further investigation into the underlying causes and potential solutions was prompted by this challenge.

Extracting individual letters accurately can be difficult due to factors such as font style variations, image quality, and diverse backgrounds. Character recognition in real-world scenarios can also add to the complexity of the issue.

FUTURE DIRECTIONS

The project's future trajectory focuses on refining and optimizing the algorithm for real-time license plate detection. This includes implementing sophisticated techniques such as adaptive frame rate adjustment to dynamically manage computing resources, integrating temporal information to improve tracking accuracy, and exploring advanced deep learning architectures adapted to video analytics. The goal is to create a robust system capable of handling dynamic scenes.

To improve computational efficiency, dynamic Region of Interest (ROI) adjustment strategies could be implemented. These strategies would focus on relevant areas within each frame, adapting to the movement and positions of vehicles. Kalman filters and other Multiple Object Tracking (MOT) algorithms could be integrated to associate license plates across successive frames and maintain accurate track identities.

On the other hand, to tackle the challenges related to different viewing angles and perspectives, it is recommended to investigate cross-view techniques for license plate recognition.

Finally, the integration of semantic segmentation techniques can improve the contextual understanding of the scene. This can help refine license plate localization in complex backgrounds and manage occlusions in real-time video.

The objective of these future directions is, once developed, to improve the project's license plate detection system, making it more robust and capable of responding to the demands of various environments and usage scenarios.

ANNEXES

ANNEX 1: MEETING MINUTES

Annex 1 contain the minutes of the meetings held during the project. This information is of great interest for the knowledge of the status of the project of the different members. It also serves as a guide to mark the deadlines for the different tasks.

ANNEX 2: WORK CONTROL

Annex 2 contain the work control.

ANNEX 1: MEETING MINUTES

MEETING MINUTES

Date: 28/09/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Team roles assignment: discussion and distribution of roles among team members for effective collaboration. • Topics for algorithm development: brainstorming and exploration of various topics and areas to focus. • Scheduling Future Meetings: agreement on the frequency and timing of upcoming team meetings for project updates and coordination.

UPDATES	ACTION ITEMS
• Role distribution among team members.	• Rafael Andreu Roselló: search for other topics, apart from those presented at the meeting. • Mar Martín Díaz: search for other topics, apart from those presented at the meeting. • David Redondo Quintero: search for other topics, apart from those presented at the meeting. • Patricia Rodríguez Peña: search for other topics, apart from those presented at the meeting.

MEETING SUMMARY

The meeting started with a warm welcome to all team members. The primary agenda was the distribution of roles among team members to ensure a well-organized workflow. The following roles were assigned:

- Rafael Andreu Roselló: Technical Manager
- Mar Martín Díaz: Documentation Manager
- David Redondo Quintero: Programming Manager
- Patricia Rodríguez Peña: Project Manager

A brainstorming session was then conducted to consider different alternatives before starting with the development of the project.

Finally, each member of the team explained his or her time availability in order to plan the following meetings and the milestones to be met. In addition, action items were assigned to each team member to facilitate progress in project development.

MEETING MINUTES

Date: 02/10/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Choice of topic. • Tasks assignments. • Scheduling of the next meeting

UPDATES	ACTION ITEMS
• Project topic: license plate detection.	• Rafael Andreu Roselló: search license plate benchmarks. • Mar Martín Díaz: prepare the first deliverable. • David Redondo Quintero: search and think about options on how to implement the system. • Patricia Rodríguez Peña: make an initial planning.

MEETING SUMMARY

With a friendly welcome and thanks for the team's commitment, the second meeting began. Following a collaborative discussion, the team unanimously chose 'License Plate Detection' as the project topic, recognizing its relevance and potential impact.

Based on their role in the project, each team member was assigned specific tasks. Rafael Andreu Roselló was responsible for finding license plate benchmarks. Mar Martín Díaz was tasked with preparing the first deliverable, which would set the foundation for subsequent project milestones. David Redondo Quintero's focus was on researching and presenting various options for implementing the license plate detection system. Patricia Rodríguez Peña was responsible for creating the initial project plan, which included identifying key milestones and timelines.

The team concluded the meeting with a shared vision, clear responsibilities, and a sense of enthusiasm for the license plate detection project.

MEETING MINUTES

Date: 04/10/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz	• Introduction and welcome. • Selected benchmark. • Tasks assignments.

UPDATES	ACTION ITEMS
• Benchmark selected.	• Mar Martín Díaz: include information on the selected benchmark in the first deliverable.

MEETING SUMMARY

With a friendly welcome, the third meeting began. In this third meeting Rafael Andreu Roselló played a key role in communicating the chosen benchmark to Mar Martín Díaz.

Mar, responsible for preparing the first deliverable, was tasked with incorporating information about the selected benchmark into the document.

The meeting concluded with a sense of accomplishment.

MEETING MINUTES

Date: 06/10/2023

ATTENDEES	AGENDA
• Mar Martín Díaz • Patricia Rodríguez Peña	• Introduction and welcome. • Review of the first delivery • Tasks assignments.

UPDATES	ACTION ITEMS
• First delivery ready to be sent.	• Patricia Rodríguez Peña: submit the first delivery.

MEETING SUMMARY

With a friendly welcome, the fourth meeting began. In this fourth meeting Mar Martín Díaz presented the final document of the first delivery to Patricia Rodríguez Peña.

Patricia was in charge of the upload of the delivery to Moodle.

The meeting concluded with a sense of accomplishment.

MEETING MINUTES

Date: 11/10/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Determining the contents of the next delivery. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Distribution of tasks for the next delivery.	• Rafael Andreu Roselló: search the state of the art of OCRs. • Mar Martín Díaz: start preparing the next deliverable. • David Redondo Quintero: search for the state of the art of license plate identification in an image. • Patricia Rodríguez Peña: search the state of the art of image preprocessing and segmentation.

MEETING SUMMARY

The meeting started with a warm welcome to all team members. The primary agenda was determining the contents of the next delivery. Once the contents to be included were established, the tasks were distributed.

Rafael was assigned to search for state-of-the-art OCR techniques. Mar was tasked to start with the preparation of the next deliverable. David was assigned the task of researching the state of the art of license plate detection techniques in images (initial segmentation, convolutional networks). Patricia had the task of researching the state of the art of image preprocessing and segmentation.

Finally, each member of the team explained his or her time availability in order to plan the following meeting.

MEETING MINUTES

Date: 22/10/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Presentation of results in the search of the state of the art. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Knowledge of the state of the art applicable to the project.	• Rafael Andreu Roselló: start implementing the OCR algorithm • Mar Martín Díaz: integrate the information sought by the rest of the members and start with the design and creation of the web page. • David Redondo Quintero: start implementing the initial segmentation algorithm. • Patricia Rodríguez Peña: start implementing the preprocessing and the segmentation algorithms.

MEETING SUMMARY

The meeting began with a cordial greeting to all team members. The main topic was the presentation of the results of the state-of-the-art search by the team members. After the information was presented, various tasks were assigned.

Rafael was assigned to start with the development of the OCR algorithm. Mar was tasked to integrate the information in the final deliverable and generate the document for submission, as well as start with the design and creation of the web page. David was assigned to start implementing the initial segmentation algorithm. Patricia was assigned to start implementing the preprocessing and the segmentation algorithms.

Finally, each member of the team explained his or her time availability in order to plan the following meeting.

MEETING MINUTES

Date: 04/12/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Presentation of the website. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Website with the basic contents ready to be delivered.	• Patricia Rodríguez Peña: delivering the website.

MEETING SUMMARY

The meeting began with a cordial greeting to all team members. The main topic was the presentation of the website created by Mar. After presenting the design of the website and the agreement of the different members, Patricia was commissioned to deliver it.

Finally, each member of the team explained his or her time availability in order to plan the following meeting.

MEETING MINUTES

Date: 16/12/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Progress in code development. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Knowledge of project status.	• Rafael Andreu Roselló: complete the OCR algorithm. • Mar Martín Díaz: start with the final documentation. • David Redondo Quintero: complete the initial segmentation algorithm and begin the implementation of the neural network. • Patricia Rodríguez Peña: complete segmentation and preprocessing algorithms.

MEETING SUMMARY

The meeting began with a cordial greeting to all team members. The main topic was the presentation of the progress in code development. After presenting it, tasks were assigned to the different team members.

Rafael, David and Patricia were tasked with completing the development of their respective algorithms. On the other hand, Mar was tasked with starting to prepare the final documentation.

Finally, each member of the team explained his or her time availability in order to plan the following meeting.

MEETING MINUTES

Date: 26/12/2023

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Presentation of developed algorithms. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Knowledge of project status.	• Rafael Andreu Roselló: optimize the OCR algorithm. • Mar Martín Díaz: write the final documentation for the developed algorithms and include the progress on the website. • David Redondo Quintero: optimize the initial segmentation algorithm and finish the implementation of the neural network. • Patricia Rodríguez Peña: optimize segmentation and preprocessing algorithms.

MEETING SUMMARY

The meeting began with a cordial greeting to all team members. The main topic was the presentation of the developed algorithms. After presenting it, tasks were assigned to the different team members.

Rafael, David and Patricia were tasked with optimizing of their respective algorithms. On the other hand, Mar was tasked with including the information gathered during the meeting in the final documentation and update the website.

Finally, each member of the team explained his or her time availability in order to plan the following meeting.

MEETING MINUTES

Date: 04/01/2024

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz • David Redondo Quintero • Patricia Rodríguez Peña	• Introduction and welcome. • Presentation of final algorithms. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Code ready for validation.	• Rafael Andreu Roselló: validate the code. • Mar Martín Díaz: update possible changes in the final documentation and on the website.

MEETING SUMMARY

The meeting began with a cordial greeting to all team members. The main topic was the presentation of the final algorithms. After presenting it, tasks were assigned to the different team members.

Rafael was tasked with testing and validating the different algorithms. On the other hand, Mar was tasked with update possible changes in the final documentation and on the website.

Finally, each member of the team explained his or her time availability in order to plan the following meeting.

MEETING MINUTES

Date: 11/01/2024

ATTENDEES	AGENDA
• Rafael Andreu Roselló • Mar Martín Díaz	• Introduction and welcome. • Presentation of code validation. • Assignment of tasks. • Scheduling next meeting.

UPDATES	ACTION ITEMS
• Completed system development.	• Mar Martín Díaz: include test and code validation information in the final documentation and update the website.

MEETING SUMMARY
The meeting began with a greeting among the attendees. The main topic was the presentation of code validation. After presenting it, tasks were assigned to Mar. She was tasked with including test and code validation information in the final documentation and updating the website. The meeting was then concluded.

MEETING MINUTES

Date: 20/01/2024

ATTENDEES	AGENDA
• Mar Martín Díaz • Patricia Rodríguez Peña	• Introduction and welcome. • Presentation of final documentation. • Assignment of tasks.

UPDATES	ACTION ITEMS
• Project prepared for delivery.	• Patricia Rodríguez Peña: submit the final delivery.

MEETING SUMMARY
The meeting began with a greeting among the attendees. The main topic was the presentation of the final documentation. After presenting it, Patricia was assigned to submit the final delivery. The meeting was then concluded.

ANNEX 2: WORK CONTROL

CONTROL DE TRABAJO

Miembro	Tareas realizadas	Horas empleadas por tarea	Horas totales por miembro	Porcentaje comparativo
Rafael	Búsqueda del banco de imágenes adecuado	3	57	100%
	Exploración de OCRs	6		
	Implementación de OCRs	36		
	Realización de los tests de validación y las estadísticas finales	12		
Mar	Recopilación de la información	7	57	100%
	Desarrollo y revisión de los entregables	30		
	Diseño de la página web	20		
David	Exploración de entornos y lenguajes de programación	5	61	107%
	Desarrollo del código de filtrado y ajuste de imágenes	26		
	Desarrollo del código relativo a redes neuronales	30		
Patricia	Realización de la planificación inicial	3	58	101%
	Control de progreso y comunicaciones con el profesor	4		
	Desarrollo del código de preprocesamiento de imágenes	17		
	Desarrollo del código de segmentación de imágenes	34		
Total			233	102%

El porcentaje comparativo se realiza comparando las horas empleadas totales con respecto a las restricciones de tiempo asignadas, de 57 h/persona.

Al ser cuatro miembros, la suma de horas totales trabajadas óptimas grupales es de 228 h.