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INNOVATIONS IN AUTOMATION, SYSTEM "ANPR"
INOVACE AUTOMATICKÉHO SYSTÉMU ANPR

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Popište podmínky provozování a postup výstavby automatizace využívající systém ANPR.

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Abstract

This bachelor thesis is concerned with the problematic of automatic number plate recognition systems, their purpose, hardware and software features and the process of setting up a properly functioning automatic number plate recognition system.

The topic is relatively new in the field of automation and therefore many challenges have to be dealt with. This thesis focuses on the aspects of a camera suitable for implementation into an ANPR system, the procedures and methods of number plate segmentation and extraction and the recognition of the characters present in a number plate. This thesis also covers the initial steps that need to be followed when setting up a properly functioning ANPR system.

This thesis brings an insight view for those interested in innovations in automation and the challenges which are accompanied by the number plate recognition system functionality.

Keywords

Automatic number plate recognition, ANPR, automation, hardware, software

Abstrakt

Tato bakalářská práce se zabývá problematikou automatických systémů sloužících k rozpoznávání poznávacích značek, jejich účelem, hardwarovými a softwarovými funkcemi a procesem nastavování správně fungujícího systému automatického rozpoznávání poznávacích značek.

Toto téma je v oblasti automatizace relativně nové, a proto je třeba se vypořádat s mnoha výzvami, které na nás v tomto odvětví automatizace čekají. Tato práce se zaměřuje na aspekty kamer vhodných pro implementaci do systému ANPR, postupy a metody segmentace a extrakce poznávacích značek a rozpoznávání znaků přítomných na poznávací značce. Dále potom tato práce popisuje kroky, které je nutné dodržet pro správné nastavení funknčního ANPR systému.

Tato práce nabízí bližší pohled pro všechny, kdo se zajímají o inovace v automatizaci, a na výzvy, které jsou doprovázeny správnou funkčností systému rozpoznávání poznávacích značek.

Klíčová slova

Automatické rozpoznávání poznávacích značek, ANPR, automatizace, hardware, software

Rozšířený abstrakt

Tato bakalářská práce se zabývá problematikou automatických systémů sloužících k rozpoznávání poznávacích značek, jejich účelem, hardwarovými a softwarovými funkcemi a procesem nastavování správně fungujícího systému automatického rozpoznávání poznávacích značek.

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Systém automatického rozpoznávání a čtení poznávacích značek umožňuje další integraci s automatizačními systémy po celém světě. Přestože je historie této technologie a její šíření záležitostí zejména posledního desetiletí, v budoucnu bude bezpochyby možné tuto technologii uplatnit v mnoha dalších aplikacích automatizačních systémů. Jednoho dne by se systémy využívající funkci automatického čtení poznávacích značek mohly stát tak běžné, že i běžný vjezd do domu bude obsluhován takovýmto způsobem. Ostatně již v dnešní době je tato technologie k vidění na mnoha místech od vjezdů do firem, obchodních center a hotelů až po systémy policejní kontroly využívajících tuto technologii. V oblasti policejní činnosti jsou to například systémy pro měření rychlosti v obcích a na dálnicích a kontrolu vozidel při běžném provozu za pomoci integrace s databázovými systémy, kdy posádka policejního vozidla v minimálním čase získá všechny informace o rozeznané poznávací značce.

V této bakalářské práci jsou pokryty nejvýznamnější výzvy, které je třeba překonat při zprovoznění správně fungujícího systému využívajícího technologii automatického čtení poznávacích značek. Je zde také možnost seznámit se s technologiemi, které kamery sloužící k rozpoznávání poznávacích značek musely během svého vývoje implementovat tak, aby mohly překonat problémy nejčastěji způsobeny různými úrovněmi osvětlení. Mezi tyto zmíněné technologie patří například technologie širokého dynamického rozsahu kamery, infračervené světlo pro noční vidění a další. Podrobně je také popsána otázka způsobu implementace softwaru pro čtení poznávacích značek a v daném příkladu aplikace je také uveden přehled celého postupu nastavení systému ANPR.

Všechny popisované kroky zprovoznění správně fungujícího systému využívajícího technologii ANPR jsou podloženy ukázkami ze skutečného administrativního prostředí používaného při nastavení požadovaných parametrů, dále jsou také všechny pojmy, které jsou pro jednotlivé kroky nastavení potřeba znát, detailně popsány. Díky těmto popisům se člověk nejen slepě seznámí s postupem, ale dovede pochopit také pojmy které se k danému postupu vážou a tím pádem lépe pochopit celou funkčnost systému.

Některé z problémů které se mohou objevit při zprovozňování automatizačního systému s využitím funkce automatického čtení poznávacích značek jsou problematičtější a pro jejich řešení je nutná důkladná znalost funkčnosti celého systému na technické i programátorské úrovni. Pro potřeby techniků pracujících s těmito technologiemi jsou však informace obsažené v této bakalářské práci dostatečné a především srozumitelné. Pojmy použité v této bakalářské práci se někdy liší od jejich českých protějšků a je proto obtížné je přeložit způsobem, kterým se zachová jejich naprosto stejný význam. Z tohoto důvodu bylo také jedním z úkolů této práce se pokusit s tímto problémem vypořádat, a to hlavně tím způsobem, že dané překládané pojmy jsou přeloženy více vysvětlujícím způsobem.

Se znalostmi obsaženými v této práci bude člověk schopen lépe poznat fungování a potřeby automatizačních systému využívajících funkce automatického čtení poznávacích značek, a také s pojmy se kterými se při práci s takovýmito systémy bude moci běžně setkat. Informace v práci obsažené jsou podloženy praktickou znalostí těchto systému, jejich nastavováním a kontrolou jejich funkčnosti v reálných podmínkách.

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Prohlášení

Prohlašuji, že svou semestrální práci na téma Inovace automatického systému ANPR jsem vypracoval samostatně pod vedením vedoucí semestrální práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce. Jako autor uvedené semestrální práce dále prohlašuji, že v souvislosti s vytvořením této semestrální práce jsem neporušil autorská práva třetích osob, zejména jsem nezasáhl nedovoleným způsobem do cizích autorských práv osobnostních a jsem si plně vědom následků porušení ustanovení § 11 a následujících autorského zákona č. 121/2000 Sb., včetně možných trestněprávních důsledků vyplývajících z ustanovení § 152 trestního zákona č. 140/1961 Sb.

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INTRODUCTION

1.1 Main purpose of ANPR systems

ANPR, full annotation Automatic Number Plate Recognition is a system that uses ASCII character-based algorithm to read number plates of cars in the view point of a camera. It is used in automation to help with controlled passage to places like parking lots, company sites and other places where only a controlled-amount of vehicles should be able to enter. The system has been widely spread across the whole Europe as well as other continents in the last decade since the first ANPR algorithms have come into existence. The main advantage of this system is reducing the human-work needs in terms of controlled passage, as well as security options because we can observe the passage of a given car in both entrance and exit terminals. Other useful capability of cameras with ANPR system is the connection with barriers and the possibility to control these barriers with the camera itself. When a car comes to the field of reading, the camera (if possible) reads its number plate and it compares it with the given white list (list of cars with passage permission), if the read number plate is successfully compared to a plate in the white list, the camera sends a signal to the relay in the barriers and the barrier then opens for the car to pass through. This mainly comes in handy in places where a high number of cars pass, but only some of them should be permitted to.

1.2 Hardware aspects of automatic number plate recognition system

When a client company wants to implement information technologies into his automation site, for example parking or controlled passage into a company complex to increase the quality of life of personnel dealing with passage control, the easiest way to achieve this is with use of ANPR system. The system can be suited for individual needs

of every client and application with the use of the right hardware components and staying in boundaries given by the supplier of the ANPR system. Individual system installations are differentiate depending on a few aspects such as number of car passages, conditions of the driveway such as length, curvature and light conditions, and other aspects like cable management. Mainly there are two ways of automatic number plate recognition system assembly. The first one, which is most commonly used for small automation sites or places where the speed of the passing cars does not exceed 30km/h or where no further information like time of passage and number of car passages is needed, is done by assembling a camera with a built-in recognition algorithm, therefore no extra computing power is needed for the system to work accurately. Theoretically, using the built-in algorithm cameras the client does not even need a computer to be connected to the cameras to work properly. However, this solution comes with a disadvantage in the question of surveillance, since the user interface of these cameras have a built-in security protocol which forces a logout from the interface every fifteen minutes, The second one is used for applications where more information is needed and/or the passing cars exceed the 30km/h speed limit. This speed is denoted because of conventional shutter capabilities, for example a car passing in the speed of 80km/h under a camera with conventional shutter would cause a motion skew of more than 0.25m and it would therefore make the whole snapshot worthless, since the number plate would not be legible. This assembly is mainly used in big companies where a strict twenty-four-hour surveillance is needed, or it can be even used by units of state power like police departments dealing with traffic surveillance. The second assembly requires bigger investment from the client from the price of the cameras itself to the added cost of a personal computer with desired software and hardware to be able to deal with the process of number plate recognition.

1.3 **History of ANPR systems**

The history of ANPR systems for most people is bounded by the last decade when the system widely spread across the whole world, however the truth is different. Nowadays ANPR systems are more or less part of our everyday lives, from applications such as traffic studies, access control and parking, but surprisingly the creation of the algorithms used by the system is dated way back into the year 1976. “Surprising to most people, the history of ANPR stretches into the last century as it was invented in 1976 in the UK at what was then known as the Police Scientific Development Branch (PSDB) (now titled Home Office Scientific Development Branch) and early systems were developed for use from 1979.” (anpr-international.com/history-of-anpr/). First application of ANPR system was in the United Kingdom in the year 1981, where it was implemented on the A1 road and at the Dartford Tunnel crossing on M25 motorway. It did not take long for the system to show itself worthy when a stolen car number plate was recognised and police officers were able to retrieve the car and arrest the person who had stolen it in a minimal amount of time. And the precise recognition system also helps police departments with decreasing the number of cars exceeding speed limits, since no human interaction is required for the delivery of a ticket, and people respect the regulations much more when they know that a smart software is in control.

2. ASPECTS OF CAMERAS FOR ANPR SYSTEM

Depending on the needs of each application, the cameras that fit the purpose of automatic number plate recognition system need to have some additional technologies implemented, such technologies to help the cameras to be able to correctly and accurately read number plates in the environment where conventional IP cameras with basic capabilities would not meet the desired picture quality, and therefore they would not be able to get the desired performance. These problems are nowadays dealt with thanks to technologies implemented to the camera lenses. The main issues that the ANPR system cameras are dealing with are mainly matters of lighting problems – the environment is too dark or bright on the other hand, the sun shines directly into the lens of the camera or there is a high contrast between the lightest and the darkest part of the snapshot. In the sections below we will take a look at some of the solutions to these problems.

2.1 Wide Dynamic Range (WDR)

WDR, full annotation Wide Dynamic Range is a useful tool implemented to the software of the camera. This software is capable of solving problems with contrast of dark and bright parts of the cameras field of view. So, for example, when a part of a picture is extremely dark but some other part is extremely bright, the conventional camera lens would only be able to focus on the middle are of light between very light and very dark. On the other hand, cameras with WDR have two ways how to deal with this problem. First solution the WDR camera uses is called mapping. Mapping does brighten up dark areas of the view and darkens the light areas, so the final picture we are able to see is somehow balanced. The other solution consists of taking underexposed and overexposed pictures and afterwards join them together using software to reach a balanced light area on the snapshot. These methods require extremely sensitive and fast light-sensitive sensor which is costly, and that is the main reason why only advanced cameras are suited with this technology.

Figure 1 : WDR off

Figure 2 : WDR on

2.2 Using camera with infrared light projector

Number plates in most countries around the world have a retro-reflective surface, and we can take advantage of this type of surface when dealing with automatic number plate recognition. Since it is known that unlike angle or scatter reflection the retro-reflective surface reflects the light straight back to the source, we can use a camera with infrared light projector paired with a filter to obtain an image where the number plate is perfectly visible and distinguished from other parts of the image as shown in Figure 4. This is a very smart approach because without the infrared projector it would not be possible to get a high-quality picture during night time, and since the dawn is quite early in the winter especially in the Czech Republic, this feature is highly demanded. This feature also helps with the number plate segmentation during night time, since when the only reflected and visible light is from the number plate itself the process of extraction of the number plate is reduced just to segmentation and character recognition.

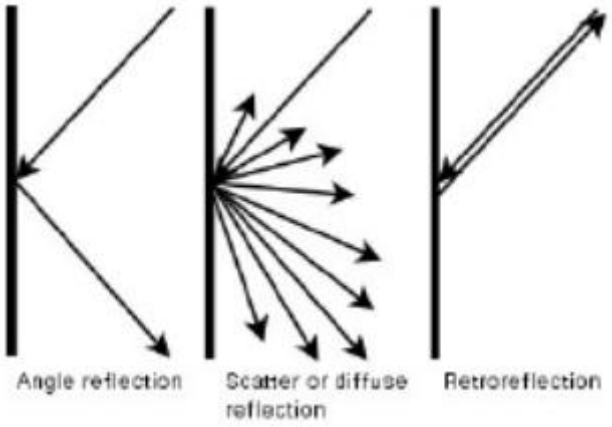


Figure 3 : Lighting reflection

Figure 4 : Picture obtained by an infrared camera

2.3 Number plate extraction

With the knowledge from previous parts we already know what a camera has to be equipped with to be able to successfully read number plates in different environments and daytimes hence we should move on to another chapter in the automatic number plate recognition system. And the next chapter is to extract the number plate from the image. There are number of ways how to approach the extraction of the number plate from the image. These methods are classified in the chapter below.

2.3.1 Global image features

This is one of the most common approaches for extraction of a number plate. This method aims at finding an object within the image that has dimensions similar to a number plate. This method is however time-consuming and the quality of image has to be almost perfect for accurate reading. The most commonly used method is 2D cross-correlation.

2.3.2 Edge features

One of the easiest and most efficient ways of extracting the number plate from an image is by identifying the edges of the number plate. This approach comes from the knowledge of car number plate shape, which has a rectangular shape therefore, searching for the desired edges in the image is one of the fastest and most time-relevant methods that proves to deliver reliable results in quality of the image. There is only one disadvantage for this method, since a close-in view of a car because it is needed to lower the number of random edges in the picture as much as possible. The most commonly used method of edge feature is Vertical Edge Detection Algorithm.

2.3.3 Character features

The last method of number plate extraction worth mentioning is the character features method. The main part of a license plate number is the number itself so this method uses the knowledge of a character-based string and it scans the image and locates the string of ASCII characters in the image and afterwards it extracts it. This method is neither the fastest nor most relevant, for example an error in extraction of number plate can happen when a car has advertisement-stickers on areas near the number plate or any other unexpected characters appear in the image. The most widely used method for character features is using an algorithm for finding regions with ASCII based characters of a given length of string.

2.4 Number plate segmentation

Now, when we have gained a clear high-quality extracted picture of a number plate having used methods mentioned above, we are ready to proceed to the final step of number plate recognition system. And this step is called segmentation. Segmentation of a number plate is nothing else but extracting characters from the number plate one by one. Therefore, we can compare them with ASCII characters and thus we can obtain a successfully extracted number plate.

Like the methods of extraction there are several ways how to proceed the number plate segmentation.

2.4.1 Character contours

This method is the most straight-forward methods of character segmentation. Characters on the number plate have a fixed size and shape, and therefore it is not hard to use an algorithm to approximate a rectangular shape and try to fit in a character from the list that has the same shape and dimensions. This method is very simple and well performing, but a high-quality image with no motion blur is needed to get rid of errors in the process of finding the characters that fit into each segment.

2.4.2 Connectivity of pixels

Using the method of pixel connectivity is another approach on the number plate segmentation. This method uses the known pattern in which pixels relate to other pixels in a given segment of an image, and thus it is possible to employ this knowledge for

number plate segmentation. This method is simple, but it proved not very relevant when the number plate is tilted more than few degrees from the expected position, due to the fact how pixel labelling works.

2.5 Recognition of characters in the number plate

The final step of plate recognition system is the process of recognition of characters of the extracted number plate itself. This process has to deal with issues like zoom factors, focus levels, illumination of the number plate, broken or partly missing characters, amount of dirt on the number plate and fonts of characters used in different countries. It is the most important step of the whole number plate processing, because this is the step where, if successful, a final product of the whole system will be created, and the product is a correctly extracted number plate with a precisely-matched characters. There are several methods of character recognition and amongst the most widely used are these two mentioned below.

2.5.1 Using all the collected data

This method of character recognition takes advantage of all the previously collected data from the whole image like font, dimensions, fixed-size of characters to process it with a template matching method. The most important requirement that needs to be met is the quality of the collected data. This method is not suitable if any errors in the processed data are present, since the time needed for template matching with any errors is exponentially increasing.

2.5.2 Using extracted data only

The other approach on the previously mentioned method of character recognition is aimed on the fact that most of the processed image is not important for number plate recognition. Therefore, this method only uses the pixels of image that proved to be relevant using segmentation and extraction methods. This means that the required time for this method is significantly lower than the previously mentioned ones, however image distortions are affecting this method drastically.

3. AUTOMATIC NUMBER PLATE RECOGNITION SOFTWARE FEATURES

The software responsible for the number plate recognition can be implemented in several ways. The needs and requirements of each application are different, and this feature is also closely related to the budget of each client. There are several ways of setting up an ANPR system, with the main difference in the processing of number plate recognition. The difference in the setup of the system depending on the presence of ANPR software are explained in the parts 3.1 and 3.2.

3.1 ANPR software implemented in camera

The first and the cheapest way of dealing with ANPR system is with no doubt connected with purchasing a camera with ANPR software implemented into the camera's motherboard. This means that no extra computing power is needed and theoretically, after the first initial setup, no computer is needed at all. The price of cameras with on-board ANPR software is higher than the price of conventional IP cameras without any implemented ANPR software, but it is still relatively cheaper than setting up a system where the recognition is dealt with in a computer. When choosing a camera with on-board software the main advantage is price. Simply a camera is purchased and set-up and no extra payments are needed. Most of the times a computer is still needed for maintaining the system, and managing the software inside the camera, but the computer can have the most basic specs and hardware components and it will still be perfectly relevant since the only requirement is a suitable internet browser through which anyone can access the user interface of the camera. The whole process of automatic number plate recognition happens inside the camera with an implemented algorithm combining all the methods from previous parts of this thesis, and therefore only information about the results is transferred into the computer. However, this method of implementation is not suitable when a surveillance is required using the same camera as the ANPR system because the user interface of the camera in which a live stream from the camera can be observed is set to require a re-log into the interface every

fifteen minutes. The time of required re-log cannot be changed since it is a safety regulation for all cameras with ANPR software implemented on-board. This solution is suitable only for basic needs of a client not exceeding three hundred passages per day, since this solution only supports one-lane reading, the speed of the recognition process is about 100ms, and the speed of the passing cars is limited to 30km/h.

3.2 **ANPR software implemented in a computer**

The second way of setting up ANPR system is by implementing special number plate recognition software such as Number OK [3] in a computer paired with conventional IP camera. This way of setup is connected with lower purchase price of the IP camera itself, but on the other hand a personal computer with desired computing power [3] is needed for the proper functionality of the whole system as well as a license for the software itself. The desired computer specifications are: *Intel® Core™* i5-1035G7 or higher, Microsoft Windows 10 64bit, AMD Radeon HD7870 2gb GIGABYTE GTX 660 2gb or higher, 8gb RAM and minimum of 128gb HDD. From the specifications it is obvious that the price of the computer where the ANPR software is installed is much higher than the price of the basic computer that is needed to get into the user interface of cameras with the software implemented on-board. The price of the license is often the biggest expense of the whole system, since some of the most high-end software can easily mark a price of more than a thousand euros. The main advantage of this setup is in the matter of the actual performance of the system. Cameras with on-board ANPR software are capable of basic functionalities such as reading number plates of passing cars in speeds not exceeding 30km/h and storing the information and snapshots of the passages… however the system where the software is implemented in a computer is capable of many other useful features. One of the main advantages of Number OK or similar systems is the limitation of speed of the passage, this system is capable of successfully and precisely reading number plates in speeds up to 240km/h, storing the information of the passages for up to 6 months (depending on the HDD in the computer), computing number of cars that passed in a given time interval, evaluating the number of free parking spots, recognition of the vehicle movement direction, fixation of up to 4 lanes with one camera and much more. This setup is more suitable for clients with bigger parking lots or automatization sites where the number of passages per day can easily exceed five hundred mark.

3.3 Integration of ANPR systems with accounting systems

Using the setup where the number plate recognition happens in a computer opens the door for many practical integrations such as integration with accounting systems. In the last few years a trend of integrating ANPR system with other systems has been on demand, and the most interesting one in the field of automatization sites is with no doubt the integration with accounting systems. The idea of this integration is rather simple, a car passes the entrance to a parking lot, it is parked there for an indefinite time period and then wants to leave. The system mentioned in part 3.2 is capable of computing the exact time period when the car was parked inside and with programming of few equations and conditions the system is capable of computing the price for the time of parking. This feature is extremely helpful and comfortable for users in parking lots of big commercial centres or shopping centres where anyone can park for free for a given amount of time, however when this time is exceeded, a payment is required. It is possible to program the ANPR system to start computing the parking time when a car passes the entrance terminal, and when the car trying to exit through the exit terminal the system compares the parking time with the time period of free parking of the car and if the free parking period is exceeded it will not let the car pass. When the master of the car knows that he exceeded the free parking time and goes to a terminal where payments are made the system will assign a payment with his car's number plate. Afterwards he will get to his car and drive to the exit. There his number plate will be compared to a list of number plates with valid payment and the system will let him pass. The main advantage of this integration is connected with the anti-cheating capabilities, such as getting another ticket from a dispenser to bypass the free parking time. This system is not bounded/tied with a ticket, but with a number plate of a car, so even though he will have a ticket where the free parking time is still not exceeded the system will not let him pass the exit terminal.

4. TYPICAL ANPR SETUP

After the basic pillars of working with ANPR systems were set, it is possible to proceed with an example setup of an ANPR system. This part of the thesis is dealing with typical dimensions for the passage, hardware and software needed for the system to

work properly paired with some of the knowledge that is needed to successfully setup correctly working ANPR system.

4.1 Requirements of the client

The requirements of each client are the most important factors for setting up an ANPR system. In this example the client requires one lane passage control with a white-list of seventy number plates that should be able to pass into the parking lot. History of events and snapshots of the passages should be stored for two months. The main aim of this application is setting up the system to work properly while keeping the cost as low as possible. No extra requirements such as time of parking, integration with an accounting system etc. are not met therefore it is possible to proceed to the planning phase of the project.

4.2 Dimensions of the passage

The first thing that is needed for scheduling the process of building an automation site with ANPR system are the dimensions of the passage. Namely they are the length and width of the lane of the passage. In a given example the lane is 3.5 meters wide and 20 meters long. Knowing this it is possible to choose a suitable camera that will be in control of such a given lane. For the needs of an application like this one a basic ANPR camera with on-board software is chosen, keeping the purchase price for the ANPR system in budget. The chosen camera supports one-line reading, speed of passing cars is limited to 30km/h and the history of passage will be stored on an SD card inside the camera. The SD card should have at least 16 GB of free space to be able to fit in the snapshots of passages for the required time interval, namely two months.

4.3 Scheme of the passage

Below a scheme of the passage can be seen, Figure 5, with all the dimensions and the possible placement of the camera. Cable management is not included since powering of the camera is still a matter of discussion.

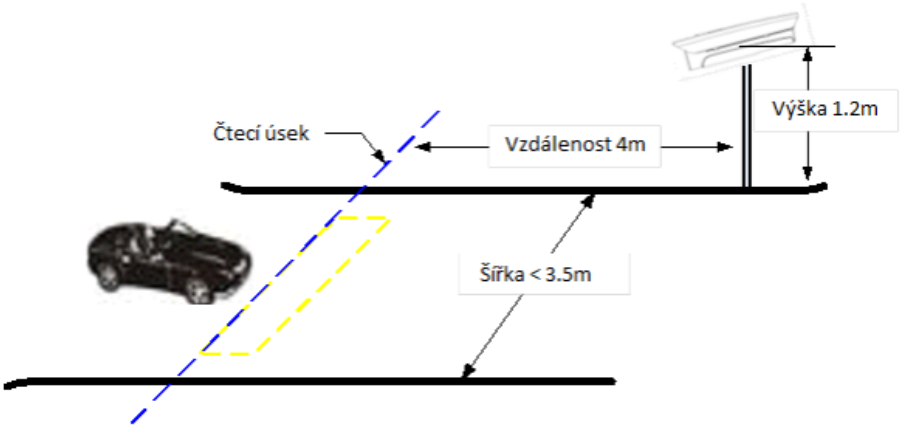


Figure 5 : Scheme of passage

4.4 Requirements for the placement of the camera

The camera that will be in charge of controlling the passage has strict requirements for its placement. The maximum height in which the camera can be mounted on a pole is 2.1 meters. When the camera is mounted in such a height, the ideal field of view should be 8 meters away from the lens of the camera, so the vertical angle between the lens of the camera and the number plate of the passing car will not exceed 30º. The horizontal angle between the lens of the camera and the number plate of the passing car should not exceed 30º for the recognition to work properly. Another thing that is needed to keep in mind is the tilt of the number plate itself. It is important for the tilt of the number plate on any of the cars not to exceed 5 º, otherwise the accuracy of the system can be lower than the expected 99.5% and it will not satisfy the needs of the client.

4.5 Initial setup and testing

When the camera is mounted and powered, it is possible to proceed with the first start-up and testing phase of the project. If all the requirements on the placement of the camera had been met, the system should accurately recognize number plates of passing cars and compare them with the given white-list. If a car is recognized and its number plate is added into the white list, the barrier blocking the passage will be removed and the car will be able to pass. If any errors in reading happen, the placement of the camera must be checked, or the camera has to be placed lower on the pole and the field of view

has to be changed according to the required dimensions of the camera manufacturer. These dimensions differ from one manufacturer to another, but the desired height of the pole where the camera is mounted should be between 1,2 and 2,1 meters. The field of view differs from 4 meters up to 40 meters.

5. SETTING UP A PROPERLY FUNCTIONING AUTOMATION SYSTEM WITH ANPR

This chapter deals with the ways of setting up a properly functioning automation with implemented ANPR system. This combination of automatization technology is very common nowadays since the number of cars owned by people is still on a rise and the need of surveillance and control of passages is on demand. The combination of common passage control techniques such as barriers, gates and so on with ANPR system helps to achieve maximum level of control over a passage, database of each and every car which drives into as well as drives out of the parking lot, square or any other place where the passage control is needed. When thinking about building a new automatization system for a passage we have to consider a number of things - how many lanes are needed to control, what the dimensions of the passage are, whether it is necessary to control only the entrance or the exit as well, if there will there an accounting system which needs to be implemented into the system so it can be possible to require and check payments.

5.1 Most common system for small parking lots

Majority of ANPR systems are used in company parking lots, with a high number of passages and the need of control of the cars entering the company. In this particular example a passage consisting of two lanes, each with one barrier and one camera for ANPR has to be taken into consideration. There also has to be a controlling personal computer, which will meet the minimal requirements for running the ANPR software. In this example a passage without the need of payment for the time spent inside the company parking lot is taken into consideration, since the implementation of the accounting system is very complicated and it should be a matter of in-depth oriented paper. This thesis has the aim to help people interested in innovations in automation to get the basic idea of the system's functionality more than in-depth view on each and every possible solution and possible implementation with other systems. As all the

information needed is stated, it is now the time to look at the scheme of the passage (Figure 6).

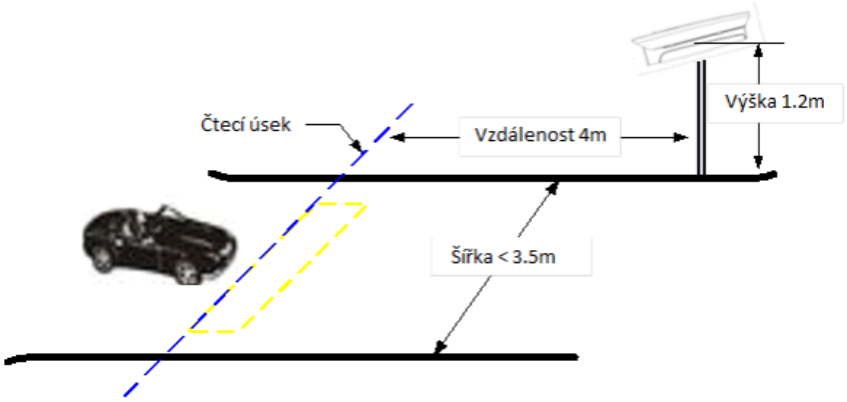


Figure 6 Scheme of the passage

5.2 ANPR software implementation

Before we can proceed to the hardware choice for our example automatization system, it is essential to decide how the ANPR software will be implemented because, as already stated earlier in the thesis, there are two main ways of ANPR software implementation. The first one is when the software is implemented into a computer, and the other one is when the software is implemented in the camera itself. For the needs of this thesis a camera with implemented ANPR software in its motherboard will be chosen. First of all, the price of the camera with implemented ANPR is lower in the final since the price of the licence of the software that would be used is usually about three times higher than the price of the camera itself. Another aspect which affected the choice is the difficulty of the setup of the software in personal computer.

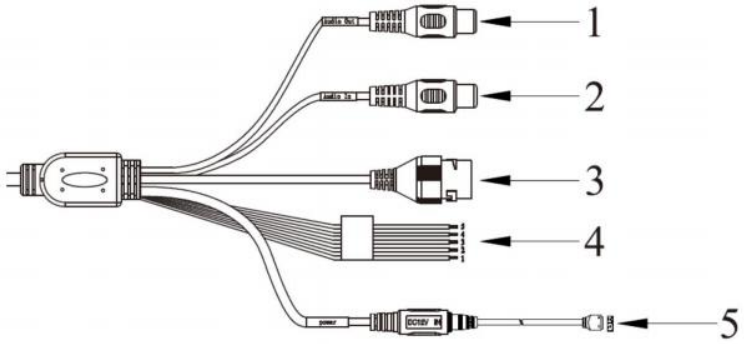
5.3 Hardware choice for the passage control

Each and every application with implemented ANPR system has to be thought of in advance. What type of blockade will be used? What are the specifications of the computer which will be used to manage the system? How many passages per day are expected to take place? Is there a need for light signalization? Answers to all such

question must be clear in advance so that the application will be able to meet all the requirements of each client, it is almost impossible to change the main components later on without interfering the function of the whole automatization and such interference could end up with a very costly service.

5.3.1 Choosing a camera with implemented ANPR software on-board

There are number of companies which in the recent past started to produce ANPR cameras with software implemented on board. The camera chosen to be presented in this thesis is from a Chinese company Dahua, which is one of the leaders in the field of ANPR at the moment. Their cameras are relatively cheap and the ANPR software is very advanced. This comes as no surprise since China is the number one country in the world in the means of CCTV usage. The ANPR camera is called KP802. All the cables and connections are shown in Figure 7. The KP802 is capable of reading number plates of passing cars to speeds up to 30km/h, there is virtually unlimited whitelist and it is easily possible to download each and every passage in form of .CSV file or pictures .jpg. The only disadvantage of this camera is the fact that it is not considered a surveillance camera, and therefore there is a 15 minute auto log-out because of the security reasons. If a 24/7 surveillance is required as well as passage control, another type of camera would have to be chosen.



Číslo	Označení	Konektor	Funkce
1	Audio Out	RCA	Audio výstup
2	Audio In	RCA	Audio vstup
3	Network Port	RJ45	Síťové připojení, PoE+ napájení
4	ALARM_NO	-	Signál pro otevření
	ALARM_COM	-	Signál pro otevření – spínací kontakt
	ALARM_IN1	-	Vstup pro alarm 1 – čtení SPZ po spojení s GND
	ALARM_IN2	-	Vstup pro alarm 2 – čtení SPZ po spojení s GND
	ALARM_GND	-	Zem alarmu
5	Power Port	-	Napájení 12 nebo 24 VDC (podle modelu)

Figure 7 Cable connections of the camera

5.3.2 Barrier

For the needs of this thesis a very commonly used barrier in automatization sites has been chosen, namely the FOX NIUBA 4. When choosing a barrier for passage where ANPR will be used, it is crucial that the barrier does have terminal blocks ready to be connected to the alarm_NO and alarm_COM cables of the ANPR camera. This connection to the barrier's terminal blocks is essential since after reading a number plate the camera has to send an impulse into the barrier's relay to give it a signal to lift the barrier and let the car which was recognized to be in the whitelist of the camera to pass. The main difference between other types of barriers is mainly in price, number of cycles (OPEN-STOP-CLOSE), and the speed of the barrier arm.

5.3.3 Additional signalization – traffic light

When an ANPR system is implemented in a place where no such technology was used in the past, it is sometimes very well required for addition signalization for the passage. In such a case a special traffic light (Green-Red) can be used to help signalize when a car should start to move towards the blockade so the ANPR software can try to recognize its number plate and compare it with the whitelist. This is extremely helpful

but not required as the control of the blockade can be dependant solely on the function of the camera, therefore additional signalization is recommended only for passages where no control was implemented in the past to decrease the confusion of people using the passages.

5.3.4 Personal computer for management of the automatization

It was previously stated what requirements of personal computer are needed for the software implementation in the personal computer, however when ANPR camera with software implemented on-board was chosen for this example it is obvious that the desired specifications of the pc are lower. The desired computer specifications are: *Intel® Core™* i3 or higher, Microsoft Windows 10 64bit, any Intel HD graphics (series of graphic card implemented in the motherboard), 4GB RAM and minimum of 128GB HDD. Nowadays the above mentioned specifications are easily obtainable, it is possible to state that almost any working personal computer's performance will be more than enough for the management of the example automatization. The desired specifications are suited to lower the purchase price of the management personal computer as much as possible. If there is a need to store a high number of passage reports, it is recommended to purchase a HDD with more capacity to prevent loss of reports due to small data storage in the managing computer.

5.3.4.1 Setup with no management computer

There is a possibility of setting up the automatization without the need of management computer. If this possibility of setup is chosen, the cameras have to be configured in advance, and the full list of number plates that are given a permission to pass (called Whitelist) has to be uploaded to the camera in advance as well. All the other configurations have to be made using a notebook or portable computer which will be disconnected from the system when configuration is done. This way of setup however brings in a lot of problems because of the fact that each and every time there will be a need for adjustment of the software, adding or removing a whitelisted number plate or any other interference to the system a technician would have to go to the place of application and connect manually, while on the other hand, if a personal management

computer is present, the technician can use a remote desktop application or any other way of remote control to connect to the management computer and do the required adjustments.

5.4 Cable management

When the hardware for the application is chosen, it is time to proceed with cable management. In this thesis a greater focus will be on the cable management of the cameras, mainly powering the camera and its connection to the network.

5.4.1 Powering up the camera

The first step of installing the camera is to power it up. There are two main ways of powering up the chosen ANPR camera. First one is by using the camera's power port (Figure 8) to connect it to 12 Vdc power supply, which is plugged into a common socket. The second option of powering the camera is to use the PoE+ power supply. It is recommended to use the PoE+ power supply since there is no need for extra cables, as the PoE+ works using a PoE switch and standart UTP cables.

Figure 8 Camera power port

5.4.1.1 Power over Ethernet

Power over Ethernet is a modern technology which let electrical power flow through UTP cables into a device. Its main advantage is in the field of CCTV and cameras generally, since it brought an option which saves both time and money. The use of power over Ethernet is reducing the number of cables which need to be laid, as well as the number of connections of the camera. It is also very efficient for the technician since when powered by PoE only network connection has to be established, as the electronical power is carried by the network cables.

5.4.1.2 PoE 802.3at Standard

This is a standard which allows standard network cables to carry power up to 30W which is convenient for VoIP phones, access points and many types of cameras. This standard is widely used, as in the past the delivery of both power and data which can flow over all four twisted pairs of standard CAT x network cables.

5.4.1.3 Power over Ethernet connection diagram

Setting up a PoE power supply is very straight forward. The connection diagram (Figure 9) shows the simplicity of connection. The only requirement is to have a PoE switch, which can be easily bought, and it is often manufactured by the manufacturer of the ANPR camera.

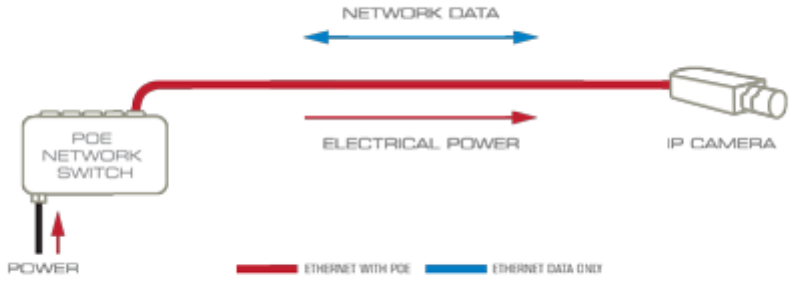


Figure 9 PoE connection diagram

5.4.2 Network cables for camera and PoE power supply

There are a number of different categories of network cables which can be used to connect the camera to the PoE switch and from the switch into the network, however the difference between each category has to be known to choose the right cable for the needs of each application.

5.4.2.1 Categories of cables

When looking for a network cable, one is able to see cables with different “Cat” such as Cat-5, Cat-5e and so on. In the figure below (Figure 10), differences of each category can be seen together with their shielding, transmission speeds and bandwidths.

Categories below Cat 5e are rarely used nowadays because of their speed and discontinuity issues. The most commonly used category of cable is Cat-5e, as most of contemporary home routers are not capable of the transmission speeds of cat 6a and above, and because of the Cat-5e low production cost and support of transmission speeds exceeding the Cat 5 cables.

Category	Shielding	Max Transmission Speed (at 100 meters)	Max Bandwidth
Cat 3	Unshielded	10 Mbps	16 MHz
Cat 5	Unshielded	10/100 Mbps	100 MHz
Cat 5e	Unshielded	1,000 Mbps / 1 Gbps	100 MHz
Cat 6	Shielded or Unshielded	1,000 Mbps / 1 Gbps	250 MHz
Cat 6a	Shielded	10,000 Mbps / 10 Gbps	500 MHz
Cat 7	Shielded	10,000 Mbps / 10 Gbps	600 MHz
Cat 7a	Shielded	10,000 Mbps/10 Gbps	1,000Mhz

Figure 10 Categories of network cables

5.4.2.2 Shielding of network cables

Interferences from power lines are common problem when installing an automatization in company sites with huge electro-motors which use the 380V power supply. This results in high electromagnetic interference (EMI). The amount of electromagnetic interferences is a key factor when choosing the network cable with the right shielding to ensure proper function of the data and power transmission. There are three main types of Ethernet cables which differ in the shielding, Those three types are UTP, STP and FTP.

UTP = Unshielded Twisted Pair

STP = Shielded Twisted Pair

FTP = Shielded Twisted Pair with foil

Normal twisted pair Ethernet cables are working properly in a small scale networks such as at home or in smaller offices, and they could be even usable for the needs of some applications, where close to no EMI is present and the cable would not exceed a length of 100 meters, but generally the usage of STP is recommended to prevent problems connected to high EMI in the place of application. The difference in price between UTP/FTP and STP cables is significant, STP cables often cost twice as much as UTP/FTP cables, but they provide the best possible shielding against EMI. When using a shielded Ethernet cable, it is crucial to establish a ground connection for them, because otherwise the shielding would not work properly. There are known cases where the EMI was interfering with the data transmission from the ANPR camera to the computer, but the PoE powering was unaffected when UTP cables were used, so unless there is a really tight budget for the application one should always use STP cables of Cat5e.

5.4.3 Installation of cable distribution standard ČSN EN 50174

There are standards which have to be followed when installing the cable distribution. One of the most important standards that have to be met is the ČSN EN 50174 in which the essential requirements for the planning operation and installation of cables using symmetrical copper and fibre optic cabling. It is crucial to follow all the instructions in this standard very carefully, because only by following the rules one can be sure that any problems connected to cable management are caused by problems other than the layout of the cables.

5.5 On-site installation of the camera

After the hardware for the automatization is chosen, as well as all the cables that will be needed to power up and connect the camera to the managing computer it is time to focus on the installation of the components on-site. A situation where barriers are connected with all required security measures, powered up and ready to be connected to the ANPR camera is considered.

5.5.1 First connection of the ANPR camera

Before it is possible to proceed with the mounting and connecting the camera into the network, it is required to prepare the camera network settings in advance before mounting it to its desired position. The procedure is described into detail in the following paragraphs.

5.5.1.1 Connect the ANPR camera to a laptop

The first step that has to be made is to connect the ANPR camera to a laptop using any twisted pair cable of at least Cat5e into the laptop's data port. The laptop has to be connected to a Wi-Fi network for the network configuration of the camera. When the twisted pair cable is plugged into the data port of both the ANPR camera and the laptop itself the camera is now being powered and is connected to the laptop.

5.5.1.2 Default IP address range of the ANPR camera

The default IP address range of the chosen ANPR camera is 192.168.1.1-254, namely 192.168.1.108. It is now time to proceed with the network settings, this means changing the network adapter settings of TCP/IPv4. For the better understanding of this step some of the information about the network adapter configuration and DHCP protocol will be introduced.

5.5.1.2.1 DHCP protocol

Dynamic Host Configuration Protocol was specified in 1993 and it was an extension to already existing and used BOOTP protocol. The DHCP is used for allocating MAC addresses of devices to IP addresses in the network. Each and every device in the network has its own MAC address, but further addressing is needed, therefore allocating an IP address to MAC address is an essential step. There are three ways in which the allocation of the IP addresses work.

1) Static - when DHCP is used in such a way, the IP addresses of devices are manually assigned to their MAC addresses. This is done by the administrator of the network.

2) Dynamic - second way of allocation of IP addresses is called dynamic. When used in the dynamic way, an address IP pool has to be chosen by the administrator of the network. Addresses are then assigned for specified time period.

3) Automatic - this way of using the DHCP is similar to the dynamic, however the IP addresses allocated automatically are kept and remembered and there is no specified period of time.

The process of allocating the addresses has strict steps which need to be followed. There are a number of messages between the client and server, and those are "DHCP DISCOVER", "DHCP OFFER", "DHCP REQUEST" and "DHCP ACK". The process is as such:

- DHCP DISCOVER is sent from client to the server to tell the DHCP server to find a suitable IP address for the client
- The server answers the client with "DHCP OFFER" in which the server offers an available IP address to the client
- If the client wants to be given the allocated IP address, "DHCP REQUEST" is sent to the DHCP server
- last step comes when the server acknowledges the client's chosen IP address and sends him the "DHCP ACK"

The client is now given an IP address which is acknowledged and remembered by the DHCP server.

5.5.1.3 Network adapter settings IPv4

It is already known how the DHCP addressing works, and therefore it is time to proceed to the network adapter settings (Figure 11). We need to set up the laptop to the camera's default IP range to be able to connect to its administration interface where the network settings of the camera can be changed. In this thesis, the procedure will be described for Windows 10 home edition. The process of IPv4 network adapter settings is as such:

1) Open control panels.

2) Click Network and Sharing Centre.

3) Click Change adapter settings - now you will be able to see all network adapters in your computer.

4) Find Ethernet, right click it and chose properties.

5) Now it is needed to find the IP protocol version 4 (TCP/IPv4) and go into its properties.

6) In most of the cases, the automatic DHCP allocating is used, however the change of the IP address of the computer to the camera's default IP address range is required, so the IP address will be put in manually.

7) The camera's default IP address is 192.168.1.108, so the chosen IP address for the laptop will be for example 192.168.1.107 (always check if the chosen IP address is available in advance).

8) The laptop and the ANPR camera are now in the same IP address range, therefore the connection into its administration interface is possible.

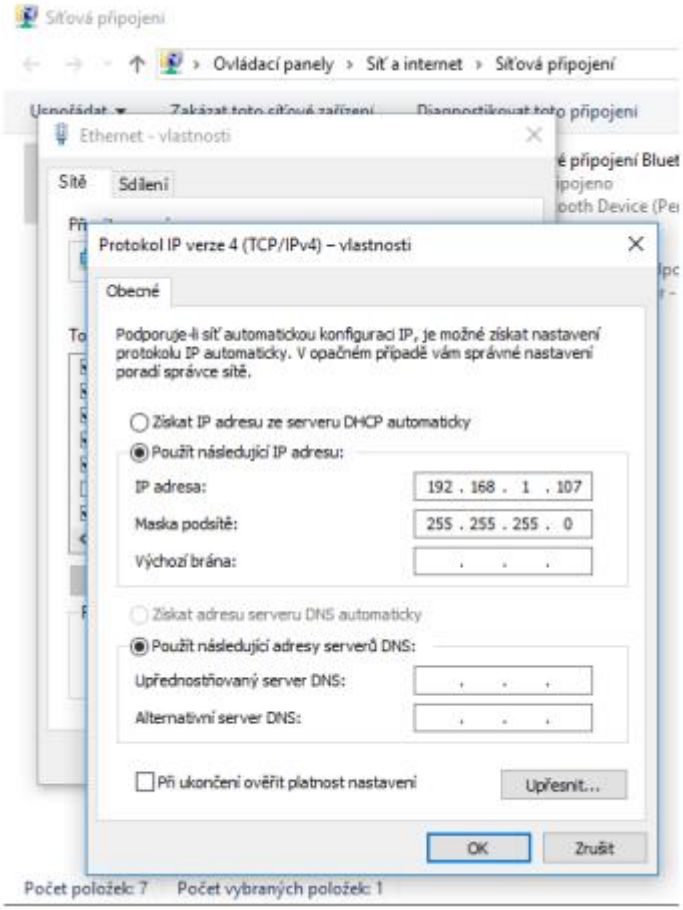


Figure 11 TCP/IPv4 network adapter settings

5.5.1.4 Connection to the administration interface of the camera

The ANPR camera is now connected to the laptop and it is possible to proceed to the network settings of the camera using the administration interface. To connect to the interface the internet browser "Internet Explorer" is required. Usage of different web browsers can lead to problems which may make the connection impossible. The default IP address of the camera will be used in the search bar of the browser. After the IP address is written into the search bar a login window will appear (Figure 12). The default login information is:

-username = admin

-password = admin

After login, a request for password change is shown because of obvious security reasons. It is recommended to set the password to at least 8 characters included at least one capital letter.

Figure 12 Administration interface

5.5.1.5 Changing the IP address of the ANPR camera

For the proper functioning of the ANPR camera, it is essential to change the network settings, namely the IP address of the camera to be in the same range as the network into which the camera will be connected. The administration interface will request the change of the IP address of the camera right after the password change. If for example the network into which the camera will be connected is in the range 10.0.0.0-254. A list of available IP addresses in such given range is required to prevent

interferences of IP addresses. This can be done using the third party applications such as Advanced IP Scanner which is a freeware widely used by network technicians. When a suitable IP address is chosen, it is simply required to fill it into the pop-up window (Figure 13). Subnet mask and default gateway should configure itself automatically.

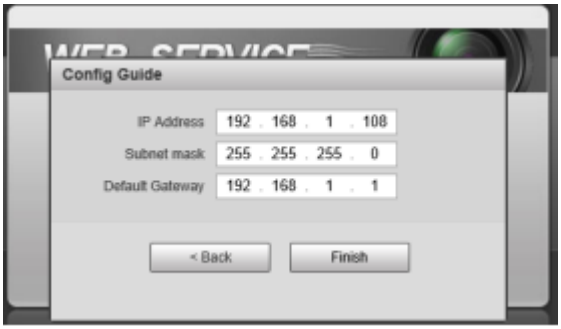


Figure 13 IP address pop-up window

This was the last step that had to be done in advance, and it is time to proceed to the application site and mount the camera into its desired place.

5.5.1.6 Limitations for camera mounting

As previously stated in this thesis, the manufacturer of the camera gives strict rules on the camera placement to prevent miss-reading of the present characters in the number plate. Even though the quality of reading might not be affected by wrong placement of the camera throughout the day, the night time reading is more likely to be problematic since the restrictions in the placement of the camera are made so the IR settings can work properly during the night, when the light reflections from the number plate are the most common issue. The most important restrictions are:

-An angle α with the axis of the lane must not be bigger than 20º, however, the recommended one is lower than 15º

-The height of the camera mount must not be higher than 2 meters, however, the recommended height is 1.5 meters

-The angle β between the ground and the lens of the camera must not be bigger than 20º and at the same time smaller than 8º

When the camera is mounted keeping in mind all the restrictions given by the manufacturer of the camera, it is now time to proceed to cable connections.

5.5.2 Cable connections

The next step that has to be taken for a properly functioning automatization with implemented ANPR is to correctly establish connections between camera, PoE switch, management computer and network.

Connection – network to PoE switch

-a standard UTP cable cat 5e will be used to connect the PoE switch to the company network.

Connection – switch to management PC

-when connecting the switch to a management personal computer a STP cable of Cat 5e will be required to achieve proper grounding of the cable shielding

Connection – switch to camera

-the last part of the connection that needs to be established is the connection between the PoE switch and the ANPR camera itself

-a STP cable of Cat 5e is required

If all the connections are made correctly, a shielded connection for data and power transmission is established, and the camera is now powered up and ready for a further configuration.

5.5.3 Configuration of ANPR software

The camera is not connected, powered, and it is configured into the network, therefore it is time to proceed with the configuration of the ANPR software itself. All configurations are done in the administration interface of the camera. No extra software is needed in this case since the ANPR camera with on-board software was chosen for the automatization.

5.5.3.1 Picture settings and licence plate reading zone

Main page of the administration interface is the "LIVE" page (Figure 14). This page is visible after logging into the interface. When the LIVE page is first visited, there is no visible picture from the camera, and that means that a plug-in installation is required. The installation is automatic. Only one click on the "download plugin" button is needed. After the plug-in is installed, the interface will logout and another login will then be requested.

After the successful login, the "LIVE" page is visible with the picture from the ANPR camera, and it is now time to configure the picture settings.

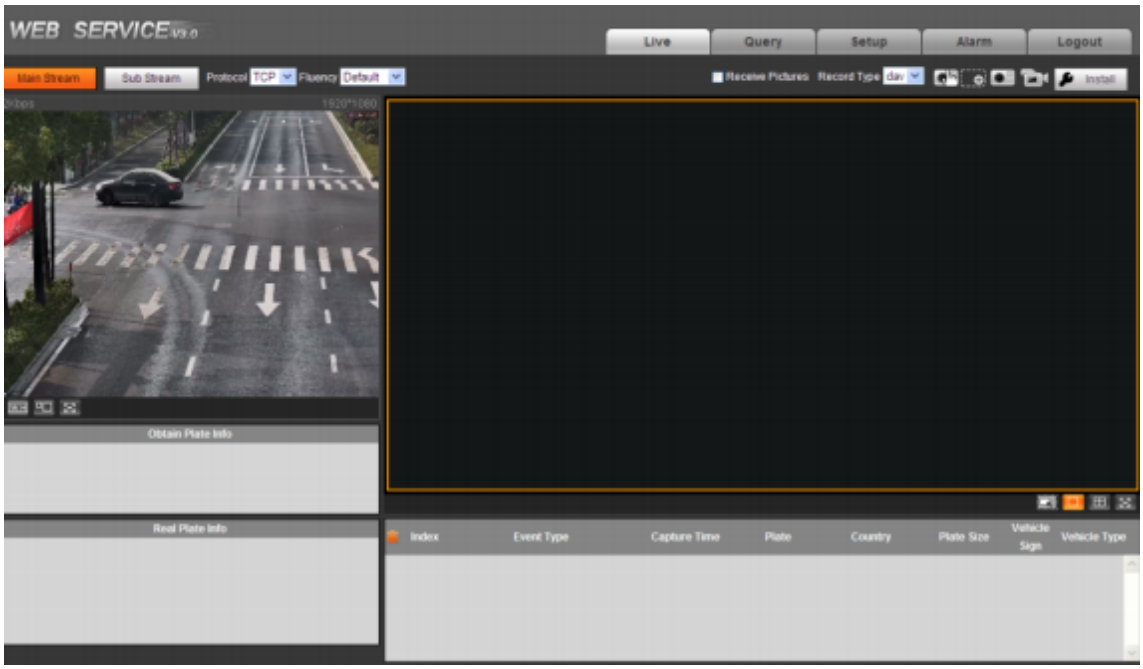


Figure 14 LIVE page

5.5.3.1.1 Picture settings

Picture settings in the chosen camera are made very user-friendly, and no special description is needed. There is a button "Install" (Figure 15), which will open the settings of the picture of the camera, and there is a possibility to configure the reading zone as well as other aspects of picture settings. "Manual configuration" shows the zoom and focus settings of the camera. It is recommended to configure the zoom of the camera so the number plate of the passing car is of a similar size as the reference

number plate (yellow box, Figure 15). After the zoom level is configured, use the "Auto Focus" feature to automatically adjust the level of focus of the camera lens to get a clear sharp image.

Figure 15 Picture settings page

5.5.3.1.2 Licence plate reading zone

There are three aspects that can be configured in the licence plate reading zone (Figure 16). Those are: Region, Detect line and Shield area.

Figure 16 Reading zone configuration

Region - Using four points which are connected by a red line the zone where the camera will look for number plates to read is established. Those four points should cover the whole width of the lane of interest, but it is crucial to prevent the interference

of reading into other lanes. The length of the reading zone should be within the standard of the manufacturer, in this case the zone should cover area of about 6-7 meters, starting at least a meter away from the camera lens and not exceeding the 8 meter length limit given by the manufacturer of the camera.

Detect line - A green line which is made up by connecting two points within the reading zone is used as a trigger for the barrier control relay. When a car enters the reading zone, the camera starts to look for a number plate, afterwards a segmentation of the number plate is made and the characters present in the number plate are read. When the car passes the detect line, the reading is over and the finalized segmented characters are compared with the whitelist and an impulse is sent into the relay of the barrier to lift up the barrier arm.

Shield area - There is a possibility of configuring a shield area, this is established by using four points connected with a grey line, and the shielded area tells the camera to ignore the zone within those four points when reading a number plate. This feature is extremely helpful if the lane is very narrow. There can be a maximum of two shield areas set.

5.5.3.1.3 Night mode picture setting

The ANPR camera is fitted with an IR filter. This allows it to go into IR mode, which is not required during the day, but in the night time it is essential to use it for the proper functioning of the automatic number plate recognition. In the tab Setup, Camera, Attributes (Figure 17) it is possible to use the IRC switch to change the picture mode of the camera from CPL (common picture mode with colours) to IR (infra-red). After the IR is set up, it is possible to change brightness, contrast, hue and saturation of the picture. It is always intended to get a picture as clear as possible, and the configuration of brightness contrast and saturation requires over-time testing to find the best mean values to use. It is possible to configure the IRC switch to work automatically and switch between CPL and IR, however it is better to use only the IR option since the amount of brightness contrast and saturation may differ in CPL and IR.

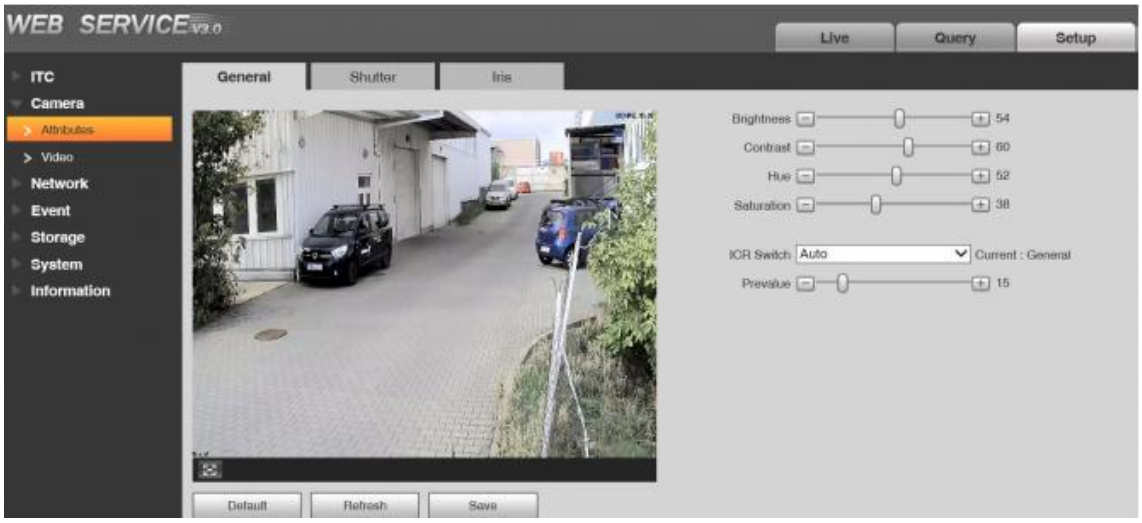


Figure 17 Night mode picture settings

5.5.3.2 Enabling output signal

To allow the camera to send signal to the barrier, one have to go to the tab Setup, BW list, Link Sign Out (Figure 18). To enable the output signal, simply press Enable. In this example setup a control type for the “Traffic Trust List” will be chosen, since when the “All Snap Cars” is chosen the barrier will open to each and every passing car. There is a Hand On button which, after being pressed, sends a test signal into the barrier and opens it.

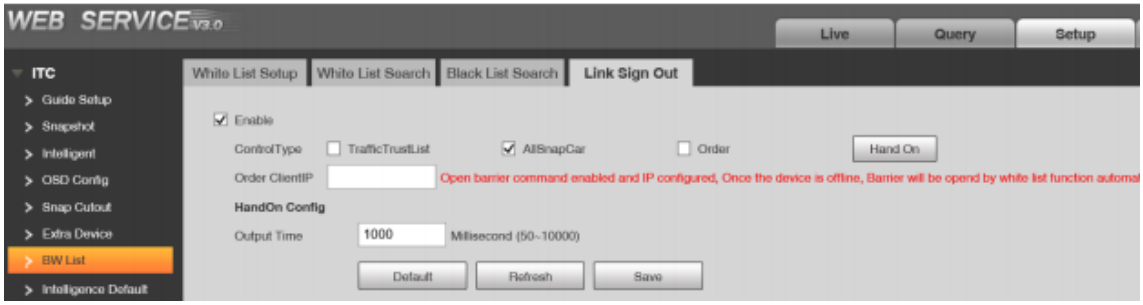


Figure 18 Enabling output signal

5.5.3.3 Mode - open only for permitted number plates, WhiteList

Since the whole system's aim is to secure a passage, a mode when only permitted number plates will be let to pass needs to be configured. In the tab Setup, ITC, BW list and White List Setup (Figure 19) it is possible to enable the WhiteListSetup. The

WhiteList composes of permitted number plates which are written into the Excel sheet. The Excel sheet has to be saved in the .CSV file format which can be uploaded to the camera's memory, or there is another possibility which enables configuration of each permitted number plates manually. After enabling the WhiteListSetup, the software has to be manually told, by a technician using the web interface, what the maximal length of Care Word that will be detected to prevent unnecessary detections is. These unnecessary detections mostly consist of detections of company logos on the bonnets of the cars and trucks.

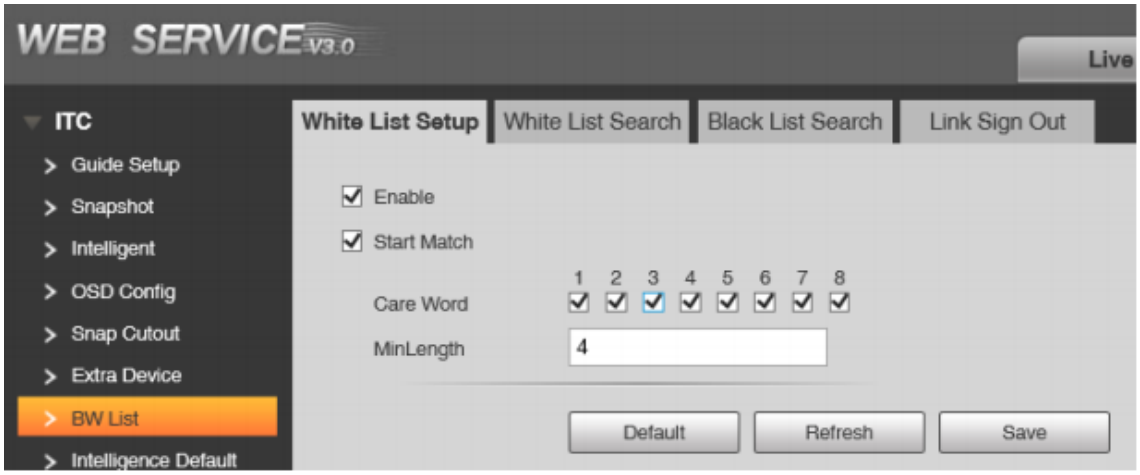


Figure 19 WhiteList setup

5.5.3.4 Mode - open for any number plate except forbidden ones, BlackList

The blacklist is used in applications where the passage should be allowed to anyone except for few number plates. Its configuration is similar to configuration of the WhiteList, it can be uploaded to the camera memory using the Excel sheet in the .CSV file format, or manually for each number plate.

5.5.4 Finalizing the installation and configuration

After the completion of all the above steps, a theoretically fully working application of passage control with automatic barrier control and implemented ANPR system is set up, and the final pre-launch check should be initialized. This pre-launch check should cover all the connections, hardware configuration and network configuration to ensure

the proper functioning of each component and especially to make sure that the ANPR camera is reaching the desired precision of above 95 percent.

CONCLUSION

The automatic number plate recognition system is a very interesting system that allows further integration with automation sites all over the world. Even though its history and spread is a matter of only the last decade, in the future many more applications of ANPR systems will be possible and feasible. One day it might be so common, that even the passage to anyone's house will be suited with recognition software. In the thesis some of the challenges of setting up a properly working ANPR system are covered, there is an in-sight view on the technologies that the cameras that are capable of number plate recognition had to implement over the time to be able to surpass problems with different levels of lighting from wide dynamic range to infrared light projectors for night vision. The matter of software presence is also described into details and there is an overview of the whole ANPR system setup in a given example automation site.

Some of the problems addressed in this bachelor thesis are more problematic and an in-depth knowledge of the functionality of the whole system is needed to solve them, however for the needs of technicians the included information are viable and understandable. The terms used in this thesis sometimes differ from their Czech counterparts and it is difficult to translate them in a way in which the meaning is kept the same, thus it is a challenge for this thesis to try to overcome this by translating the above mentioned counterparts in a more explanatory manner.

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