Version 3.0

License Plate Recognition Cameras Selection

Setup and Installation Guide

vit
raising technologies™

Introduction

This user guide is designed for specialists in charge of selecting and installing license plates recognition cameras. At all stages of process (from equipment selection to its setup and installation) the conditions for the best possible quality of the resulting image should be met. This can be achieved by following the instructions presented in this guide, thus providing high-quality video material for processing and therefore higher recognition rate.

The license plates are detected and recognized on the frame-set (video) using **AutoSDK** – a group of dynamic libraries and header files of C/C++.

Legend:

- – requirement;
- – recommendation.

1. Requirements for license plate image in the frame

License plate recognition is different from other types of video analytics in having specific requirements for an essential part of the frame – the image of a license plate.

AutoSDK is designed based on the fact, that the license plate to be recognized was created in accordance to the requirements of **Vienna Convention on Road Traffic** for registration plates and signs of all cross-border vehicles and trailers (Convention on Road Traffic – Annex 2)[1].

AutoSDK will recognize the license plate if it's contrasted enough and fully visible in the frame (Fig. 1).

Figure 1 – Examples of license plate images that may be fully recognized by AutoSDK

The images should not be:

- unequally lit;
- overexposed;
- blurred (due to incorrect shutter speed settings for the speed of the vehicle);
- distorted (due to incorrect placement of the camera);
- interlaced;
- dirty.

To determine whether or not the image of a license plate is contrasted enough, two values should be set: license plate symbol brightness and license plate background brightness.

[1] Source: http://www.unece.org/fileadmin/DAM/trans/conventn/crt1968e.pdf

A license plate image is considered contrasted enough if the difference between license plate symbol pixel brightness and license plate background pixel brightness is more than 20% of the higher value. This correlation may be represented by the following formula (1):

$$|Is - Ib|/\max(Is, Ib) > 0,2 \qquad (1)$$

Where:

Is is value of symbol brightness,

Ib is value of background brightness.

For example, the value of license plate symbol brightness is 48 and the background brightness is 128. Such an image is considered contrast and therefore the license plate is suitable for recognition since the difference between the brightness values is more than 20%:

$$|48 - 128|/128 = 80/128 = 0.63 \ (63\%)$$

Additionally, there is a requirement for minimal height of license plate symbol in the frame (that allows for it to be recognized):

- when cameras with no hardware video compression (analog, machine vision) are used, the minimum height is 16-20 px;
- when IP-cameras (with hardware compression) are used, the minimum height is 30-40 px.

If the camera is installed outdoors, natural noise may be present in the frame due to weather conditions that aren't suitable for recognition (snow, rain). Larger license plate image in the frame may increase recognition rate under such conditions.

2. Requirements for camera specifications.

2.1. Framerate

When AutoSDK is working in “parking” mode (Table 1), a videostream with about 6 fps (frames per second) is enough for license plate recognition.

When AutoSDK is working in “freeflow” mode, a videostream with up to25 fps might be used for license plate recognition.

CPU usage during the recognition process is contingent on a product of framerate multiplied by frame size in pixels. It’s worth mentioning that video decoding significantly raises CPU usage. Regardless whether AutoSDK is working in “parking” or “fleeflow” mode, the whole stream is decoded (Table 1). For example, if the module is recognizing license plates at 6 fps, the whole video stream received at 25 fps will be decoded.

Table 1 – Correlation between AutoSDK operation mode and vehicle speed in surveillance zone

Mode	Video processing speed, fps	Speed of vehicles in video surveillance zone, km/h
“Parking”	6 or less	20 or less
“Freeflow”	up to 25	300 or less

2.2. Camera color mode

This feature definitely depends on particular country LPR rules and regulations. Some requires color mode recognition only (color features on number plate gives additional information), some just monochromatic.

Monochromatic (black and white): preferable

Monochromatic camera allows video surveillance to be conducted under poor lighting conditions when infrared (IR) illumination is required. Moreover, cameras of this kind often have higher sensitivity than color cameras (when other specifications are practically the same) providing higher level of details in resulting images.

Color: allowed

When the license plate is recognized using AutoSDK, color frames are converted to greyscale. Therefore color cameras may be used only when it’s important to capture the color of the license plate (aside from recognition) or vehicle color, if necessary.

Read more about this at chapter 2.

2.3. Image Settings

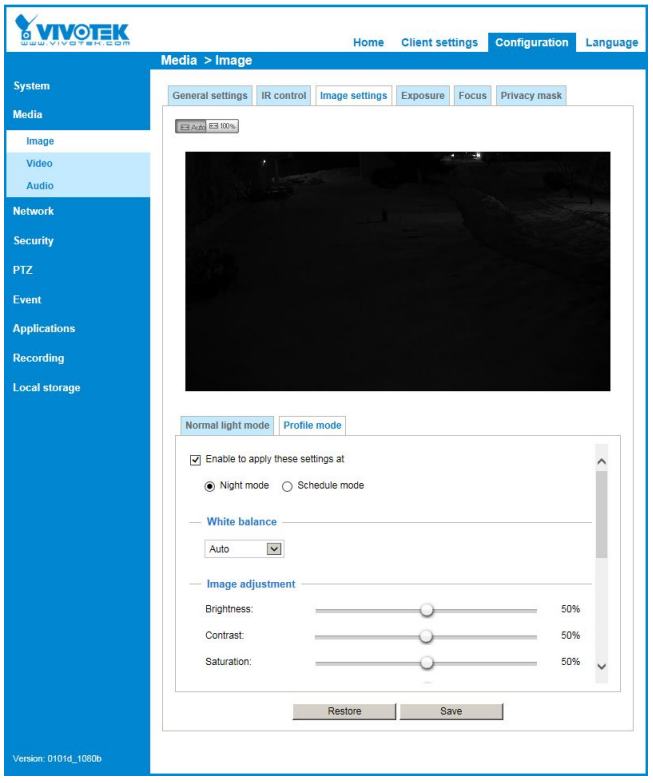
In order to configure camera for proper LPR sometimes we need to change image settings:

- White balance – use “auto” by default. This depends on illumination type you have.
- Brightness, contrast, saturation, sharpness – use 50% values by default. Try to enhance image by external features, not this (meaning add extra light if needed but not push brightness feature)
- Gamma curve – you can try for limited cases to extend\change dynamic range to make number plate \ vehicle shapes visible.
- Defog - disabled
- 3D-noise reduction – disabled

You can see all settings on Fig. 2.

For more flexible approach you can configure image settings for each camera profile personally.

Figure 2. Configuration → Media → Image → Image settings



2.4. Exposure mode

Cameras with exposure control (where exposure options may could be configured depending on conditions and requirements) should be used for license plate recognition.

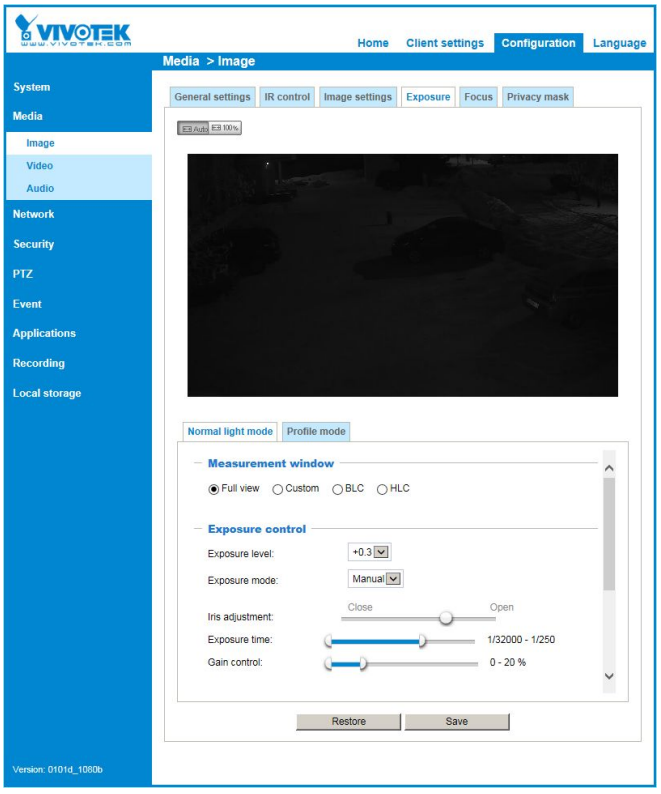
However, it's vital to keep in mind that longer exposure may cause motion blurring of license plate symbols on the image. They may seem sharp on the video, but a frame-by-frame view will uncover the defects.

We recommend to use following settings in Vivotek cameras:

- Exposure level – 0.0 (or +0.3 , this will add some light from IRIS value if needed)
- Exposure mode – shutter priority (we can control shutter range and longest shutter value to avoid motion blur)
- Exposure time – range from minimal value (1/16000) to maximal acceptable value from tables 3 and 4
- Gain control – up to 20%
- WDR – disabled both options

You can see example on Fig. 3

Figure 3. Configuration → Media → Image → Exposure settings



For each AutoSDK operation mode ("parking" or "freeflow") there is a range of values for shutter speed that should be set depending on the speed of vehicles in surveillance zone (Tables 2 and 3).

Table 2 – Correlation between shutter speed and speed of vehicles ("parking" operation mode)

Exposure, s	Max. speed of the vehicle in surveillance zone, km/h
1/200	18
1/250	22

Table 3 – Correlation between shutter speed and speed of vehicles (“freeflow” operation mode)

Exposure, s	Max. speed of the vehicle in surveillance zone, km/h
1/500	45
1/750	68
1/1000	90
1/1500	136
1/2000	181

Moreover, if the camera is installed at horizontal angle of more than 10 degrees to the surface of a license plate, it is recommended to lower the shutter speed by half. This should be done in order to increase the sharpness of images since the license plate in the frame is blurred along multiple axes.

2.5. Lens iris

Table 4 – Requirements for iris specifications

Characteristic	Requirement/Recommendation
1. Lens aperture	A high-aperture lens (1.0, 1.2, 1.3, 1.4, 1.8 aperture) is required.
2. Aperture control type	Automatic aperture control is used under changing lighting conditions. P-iris is recommended. It allows avoiding diffraction (blurring of the image) by not letting the aperture become too narrow under strong light. This effect is achieved by cooperation of sensor-managing software that adjusts sensitivity and built-in stepper motor that work simultaneously. The range of automatic aperture control may be set via user interface. Furthermore, sharpness of the image is increased allowing for surveillance to be carried out under various lighting conditions and from various distances - from parking lots to highways. DC-iris is allowed. Unlike P-iris, it only manages the exposure of the sensor. When DC-iris is opened, the sharpness is affected and auto-tuning of this image quality option is not available (Fig. 4). Fixed or manual aperture can only be used for surveillance under more or less constant lighting conditions (e.g. at parking lots) when there is no need for constant aperture adjustment. When fixed iris is used, the exposure is set by adjusting shutter speedand AGC – this is acceptable, but not as flexible as aperture tuning.

Figure 4 – Comparing sharpness of images taken with and without P-iris

The back focus should be adjusted when under maximum aperture.

Maximum aperture should be achieved in order to decrease depth of field allowing for easy and fine adjustment of back-focus. The adjustment should be carried out under low (in the evening or at night) or manually decreased lighting conditions using an external ND filter (usually placed in front of the lens).

When the depth of field is low and a vehicle crosses the surveillance zone, few (3-5) images of a license plate will be taken. Based on the fact that most images will be out-of-focus, internal AutoSDK algorithm may recognize the number incorrectly even if one of the resulted images is sharp.

Lenses with automatic iris (fixed and adjustable focal length) have two settings:

- Level – allows setting the average value of the iris.
- Auto Light Control (ALC) – controls the automatic iris control board sensitivity in variable lighting conditions.

Level setting should be adjusted when the lens is exposed to a maximum amount of light. However, it's prohibited to point the lens at direct sunlight, as it will damage the sensor.

After that, level value should be decreased until the image becomes visible and then the lens should be closed for 5 seconds. When the lens is opened again, the image should reappear. If that did not happen, the adjustment procedure should be repeated.

ALC setting should be set to the average value.

2.6. Day/Night modes

You must consider that at night (sunset, sunrise as well) there could be not enough light (not enough exposure)
to see number plates. So we must use external illumination to give more light to our ROI.
There are 2 general types of illumination:

- IR wavelength illumination.
- Visible wavelength illumination (white light)

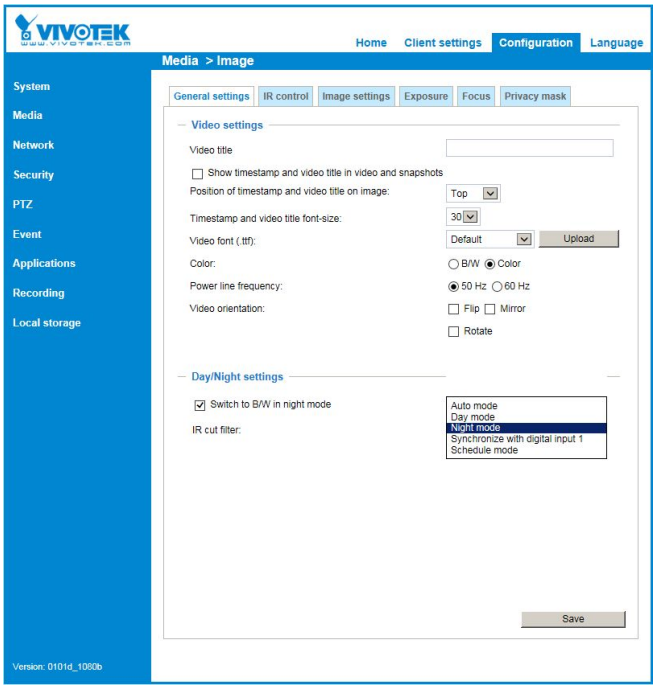
IR usage implies 2 different camera modes: Day (when camera sensor works in color mode) and Night (when camera sensor disable special IR-cut filter but goes B\W mode). See Table 5.

For the cases when we need to save colors (due to special project requirements or general region of installation requirements) we can't use IR illumination and have to use white light (visible wavelength light).

Vivotek camera has next Day/Night mode options (check Fig.5):

- Auto mode. Day/Night modes switch depending on embedded light sensor sensitivity. You can also configure sensor sensitivity levels.
- Day mode. Continuous day (color) mode
- Night mode. Continuous night (B/W) mode. This is preferable for most cases.
- Synchronize with digital input 1. Works same to Auto mode but decision to switch makes external sensor connected to input 1.
- Schedule mode. You can create timetable for "day" and "night" time.

Figure 5. Configuration → Media → Image → General Settings



If IR-projector is used, a lens with infrared correction is required (IR light compensation).

Lenses of the kind usually have "IR" index in their marking.

Table 5 – Requirements for IR-projector specifications

Characteristic	Requirement/Recommendation
1. IR illumination range	850-880 nm is suitable for license plates recognition. It has sufficient recognition distance and generates a comparatively low amount of visible illumination.
2. Angle of illumination (if stand-alone IR-projector is used)	Should be the same as the camera angle of view. If illumination angle of IR-projector is lower than camera angle of view, an exterior light source or well-lit object may get captured in the field of view making the shutter work under the average frame lighting value and thus lower the exposure (equal to forced decreasing of the camera sensitivity). Balancing illumination angle of IR-projector and angle of view of the camera is especially important for long-distance surveillance when the camera works at the limit of its sensitivity.

Infrared light has longer waves and lesser angle of refraction compared to normal light, therefore the focused image plane is slightly behind the sensor.

This is the reason it's recommended to have the camera back-focused under IR light – in this case the depth of field will be at minimum and the objects will be in focus. During the day, the depth of field increases to make up for the difference between focus under IR and normal light.

3. Installation of license plate recognition cameras

This section contains requirements and recommendations for camera installation that should be met in order to provide recognition in control area. Each place of installation (surveillance object) has individual features which is why this section contains master schemes for camera installation. Along with individual parameters of the object, they should be accounted for during planning stage of designing a traffic surveillance system.

3.1. General requirements

Correct camera installation should provide the following:

- Meeting the requirements for license plate images provided at the beginning of this guide.
- Maximum time in frame for the license plate.

Therefore, when installing the camera (either on highway or in access point), it is necessary to follow general requirements provided in this section.

3.1.1. Minimizing false triggering during recognition

It is important to install the camera in a way that no high-contrasted objects (e.g. billboards, trees, wire fences) are visible in the frame.

This causes an increased number of false triggering during recognition. Additionally, the camera should not be pointed directly at light sources (sun, streetlights) or reflecting surfaces.

3.1.2. Setting camera angle

It is necessary to set the optimal angle (Table 6) to avoid distortion of symbols on a license plate image – only then can they be recognized by AutoSDK.

Table 6 – Requirements for camera angles

Camera angle	Value range
Vertical (Fig. 6)	Recommended: 18-20 degrees Maximum allowed: 30 degrees
Horizontal (Fig. 7)	Recommended: 5-10 degrees Maximum allowed: 20 degrees

Figure 6 – Recommended vertical camera angle

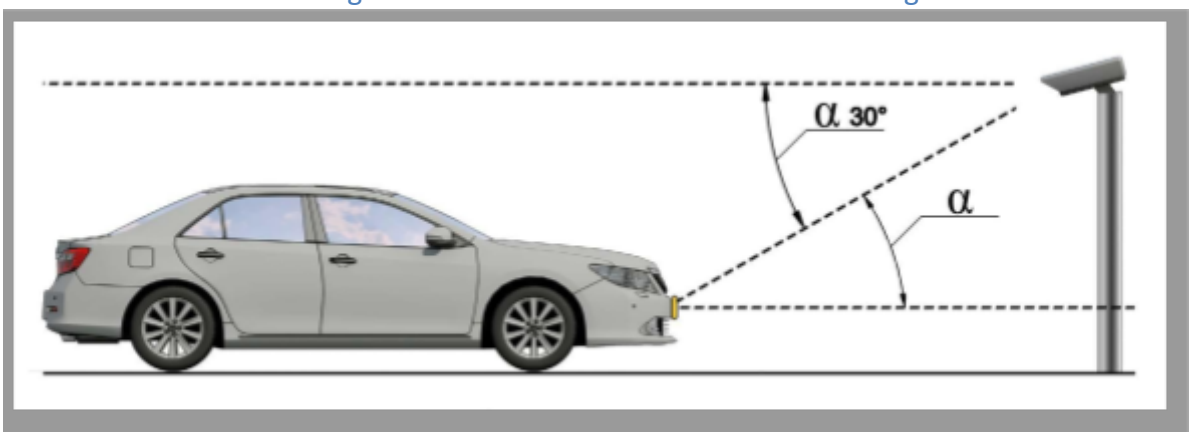
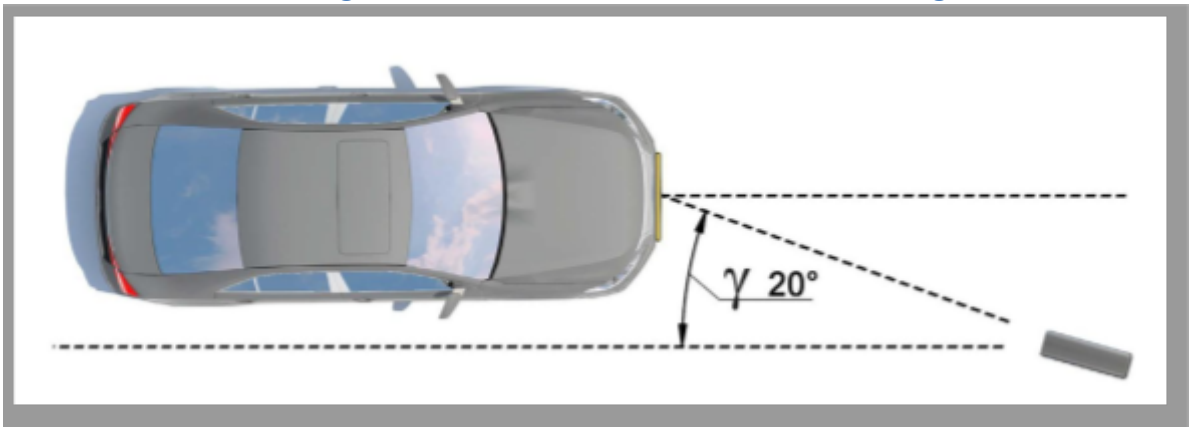


Figure 7 – Recommended horizontal camera angle



Road incline should be taken into account when the camera is installed.

If the camera is to capture a vehicle moving down the incline (Fig. 8), the maximum allowed vertical angle is to be determined by the following formula (3):

$\alpha \leq 30° - \beta$ (3)

Where:

α is vertical camera angle in degrees, β is road incline is degrees.

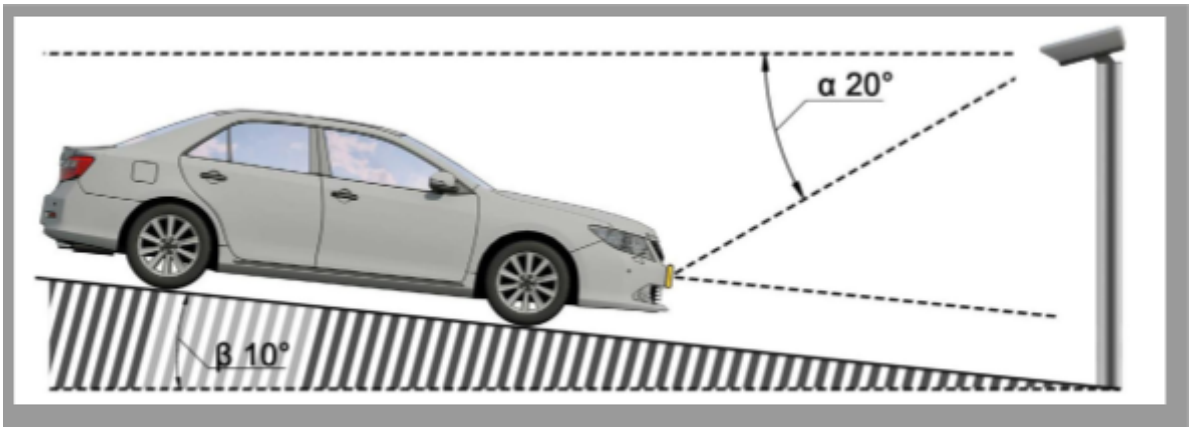


Figure 8 – Placing the camera for surveillance on an inclined road

During the installation, the conditions should be provided for the angle of the license plate on the image to be 5 degrees or less against the surface of the road (either clockwise or counterclockwise). This applies to both single- and double-line license plates.

During a single-line license plate (with at least six symbols) recognition, camera angle may be tested using the "rule of one line": an imaginary horizontal line must cross both the first and the last symbol on the license plate (Fig. 9).

Figure 9 – Determining allowed tilt of the license plate ("rule of one line")

3.1.3. Determining the distance between place of installation and surveillance area

The distance between place of installation and surveillance area is determined by focal length of the lens.

And vice versa, if the distance between place of installation and the center of surveillance area is known, it's necessary to provide respective focal length proportional to sensor diagonal (Table 6).

Examples of such calculations for both highway and access point surveillance are provided further in this guide.

3.1.4. Setting IR-projector angle

When a stand-alone IR-projector is used, the angle of IR-projector should be the same as camera angle of view. It's especially important during long-distance surveillance when the camera is working at maximum sensitivity.

3.2. Camera installation for access-point surveillance

The camera for surveillance at secured areas access points is usually installed at the edge of the lane:

- Installation height must be over the headlights level.
- Distance between place of installation and focal point must be 3 meters or more.

Placing the camera too close to supposed license plate detection point (as well as using short-focus lenses) causes a decrease in field of view along with image distortion at the edges which should not take place during recognition.

Table 7 contains camera installation parameters for surveillance on access points to secured areas designed for cameras with 1/3" sensor. These parameters provide minimal distance from camera installation place to surveillance area of specified width (3 and 6 meters). The distance between camera installation point (e.g. streetlight post, fence) and surveillance area as well as required focal length vary depending on vertical camera angle and height of installation. Quality of a license plate image in the frame must be considered during the installation.

Table 7 – Example of camera installation parameters calculation for access-point surveillance (1/3" sensor)

Installation height, m	1	1,2	1,5	1,7	2	2,2	2,5	3	4
Surveillance area width, m	3								
Vertical angle, degrees	18	20	25	27	30	30	30	30	30
Focal length, mm	5	5	5	5	6	6	7	8	11
Near area, m	1,3	1,4	1,6	1,6	1,9	2,1	2,6	3,3	5
Focal point, m	3,1	3,3	3,4	3,3	3,5	3,8	4,3	5,2	7
Far area, m	∞	343	20	13,5	8,5	9,3	9	9,6	10
Surveillance area width, m	6								
Vertical angle, degrees	9	10	14	16	19	21	23	28	30
Focal length, mm	5	5	5	5	5	5	5	5	6
Near area, m	1,7	1,9	2,2	2,4	2,5	2,5	2,7	2,7	4
Focal point, m	5,7	5,6	6	5,0	5,8	5,7	5,9	5,6	7
Far area, m	∞	∞	∞	∞	∞	105	44	21	17

When operating at an access point, aside from license plate recognition, an additional way to identify vehicles and confirm their entering the control zone is required.

IR or capacitive sensors, induction loops, weight gauges, laser sensors, radars, etc. may be used to register arrival of the vehicle to the control zone. Using induction loops is the most reliable way – this section contains examples of using them on access points of various types.

When external gauges are used, license plate recognition software is running in standby mode. This means that license plate detection process is initiated only after the vehicle is detected by the gauge. If recognition is a success, an image of the vehicle is saved to the database along with the license plate number.

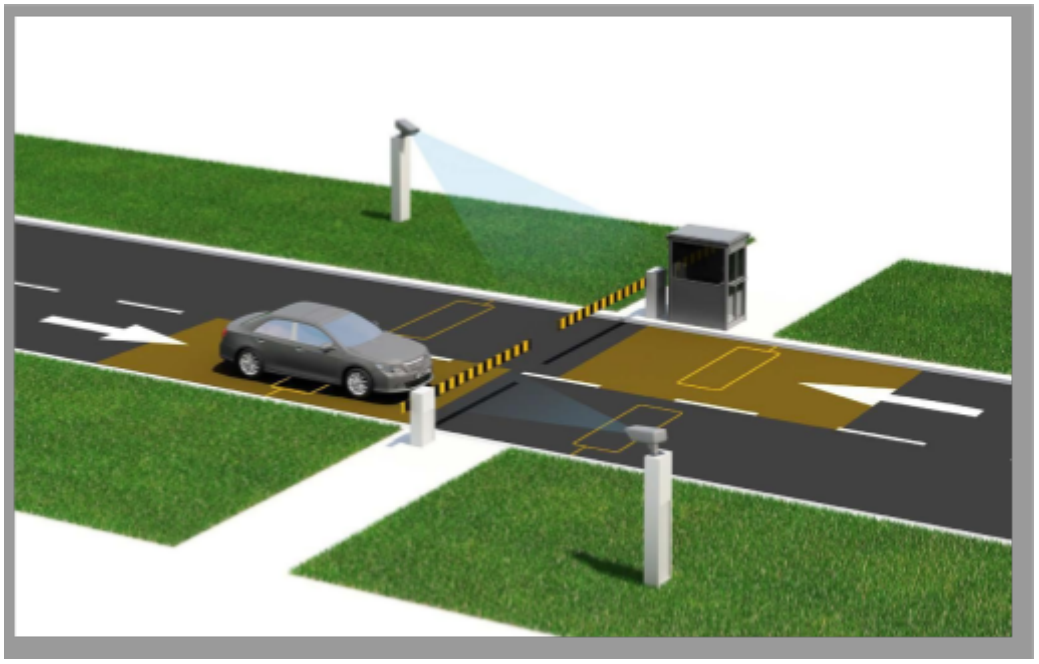
If due to any reasons the license plate was not recognized at the moment of vehicle's entry (e.g. due to its absence on the vehicle), an image of the vehicle would still be saved to the archive.

Thus, entering vehicles are accounted regardless of recognition process. When operating on a controlled access point equipped with a barrier (Fig. 10), two loops should be installed: one before the barrier and one after.

The loop must cover one access area (regardless of the amount of areas covered by the barrier). Alternative way is to install inductive loops on each area (along with providing an obstacle between access areas) which allows registering vehicles on all areas.

Front loop is installed at the beginning of the camera field of view, initiating the recognition process. The second loop is installed immediately behind the barrier and registers the fact of a vehicle passing the access point. Additionally, it may close the barrier to avoid entrance of two vehicles at a time.

Figure 10 – Camera placement on the access point (barrier used)



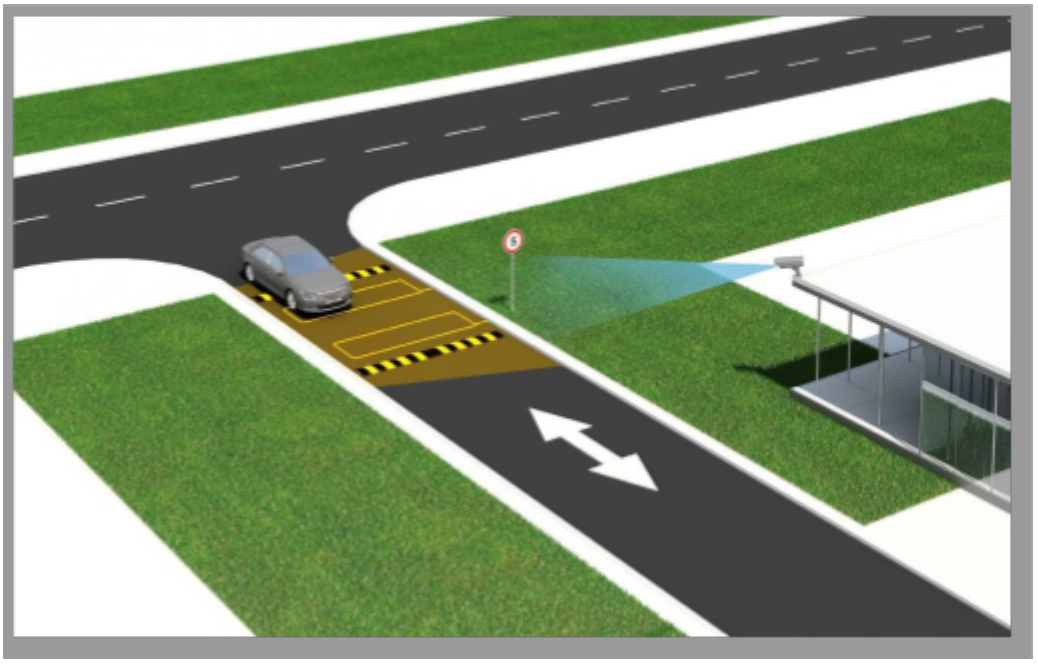
When operating at an access point equipped with a gate, roll-down gate or any other solid obstacle (Fig. 11), control zone of the camera must not begin at access point border line. A stop line, a stop sign

or a traffic light is used to hold the vehicle in control zone. The loop that initiates recognition should be located before the first border line of control zone. The loop that registers crossing the border line is to be located immediately behind the line.

Figure 11 – Camera placement on the access point (a solid obstacle is used)

When operating at an unsupervised two-way access point (Fig. 12), it is necessary to install two induction loops that, by being triggered in succession, would allow determining the direction of the vehicle. The loops should be placed at the edges of control zone (on closer and farther edges of control zone). Speed-bumps may be added to limit the speed of a vehicle within the control zone.

Figure 12 - Camera placement on an unsupervised two-way access point



3.3. Camera installation for highway surveillance

Cameras for highway surveillance are usually installed on L-shaped posts (near the edge of the lane, see Fig. 13 and 15) or on arches (above the middle of the lane, see Fig. 14).

- Standard height is 4-6 meters (maximum height – 20 meters).
- Vertical angle of the camera is determined by requirements specified in Table 13, based on which the distance to control zone as well as focal length are determined (Table 8).

Table 8 contains camera installation parameters for highway surveillance designed for cameras with 1/3" sensor. These parameters provide minimal distance from camera installation place to surveillance area of specified width (3 and 6 meters). The distance between camera installation point (e.g. streetlight post, arch) and surveillance area as well as required focal length vary depending on vertical camera angle and height of installation. Quality of a license plate image in the frame must be considered during the installation.

The cells with focal length values exceeding the range provided by a 5-50 mm varifocal lens are highlighted in Table 8.

Table 8 – Example of camera installation parameters calculation for highway surveillance 1/3" sensor)

Installation height, m	4	6	10	15	20
Surveillance area width, m	3				
Vertical angle, degrees	30	30	30	30	30
Focal length, mm	11	17	28	42	56
Near area, m	5	8,2	15	23,6	32
Focal point, m	7	10,4	17	26	34,6
Far area, m	10	13,5	20	29	37,4
Surveillance area width, m	6				
Vertical angle, degrees	30	30	30	30	30
Focal length, mm	6	8	14	21	28
Near area, m	4	6,5	13	21,5	30
Focal point, m	7	10,4	17	26	34,6
Far area, m	17	19,2	24	32	40,4

Table 9 shows main FOV measurements (front and rear FOV distance) depending on lens focusiong distance used for Vivotek LPR cameras.

Table 9. Vivotek cameras calculations

Camera model	Frame resolution	Sensor size	Lens, mm	Installation height, m	Distance to:	
					front FOV distance for 1 lane road (for 2 lanes road), m.	Rear FOV distance, м.
IB9165-LPC	1920x1080	1/2"	4	4	3 (4)	7
			9	4	6 (7)	18
			12	4	8 (12)	24
			40	4	30 (40)	85
IB9365-HT	1920x1080	1/2"	4	4	3 (4)	7
			9	4	6 (7)	18
			12	4	8 (12)	24
			40	4	30 (35)	85
IB9172-LPC	2056x1542	1/1.8"	4	4	2 (3)	9
			9	4	5 (7)	21
			12	4	6 (10)	27
			40	4	23 (30)	90

The higher the camera is installed, the higher is the possibility to capture (and therefore detect and recognize) license plates of vehicles moving at small distance from one another (e.g. during traffic jams). However, it's important to keep in mind that an increase in installation height causes license plate image distortion, meanwhile, the symbol size is almost at minimum allowed level (or does not meet the requirements specified in "1. Requirements for license plate image in the frame" section). In such cases it is possible, by decreasing vertical angle and changing focal length (zooming), to shift area of interest to farther distance so that license plates may be recognized under specified installation height.

Conclusion

As a conclusion, main camera installation and setup conditions for license plate recognition using AutoSDK-based software are provided. These conditions are to be adhered to by specialists in charge of designing an independent vehicle surveillance system or integrating this feature into existing hardware-software environment. In order to successfully perform this task, a specialist should be able to apply these requirements accordingly to specific surveillance conditions.

The image of a license plate in the frame

Specifications and installation conditions of the camera as well as video recording and processing settings must provide for meeting the following requirements:

- License plates in the frame must be contrasted, equally lit, properly exposed, with no blurred and/or distorted symbols.
- License plates in the frame must have 20-30 pixels symbol height.
- Stream must exclude compression and network bandwidth artifacts.

Camera specifications

Characteristic	Requirement
Supported models	• Vivotek IB9165-LPC • Vivotek IB9365-HT • Vivotek IB9172-LPC
Framerate	• “parking” mode – about 6 fps, • “freeflow” mode – 15 fps or higher.
IR illumination	• Required for 24-hour recognition. • Either embedded or stand-alone IR- projectors (preferably, supporting impulse operation mode) are allowed. • IR illumination range: 850-880 nm.
Lens	• Type: varifocal lens is recommended. • Focal range: 5-50 mm, 7-70 mm. • Aperture: 1.0, 1.2, 1.3, 1.4, 1.8. • Automatic iris control: P-iris is recommended, DC-iris is allowed. • IR correction: required (for 24-hour surveillance).

Camera settings

Setting	Action
Shutter speed	Value is set based on maximum speed of a vehicle in the frame (Table 2, 3). Parking mode: ~1/250sec for up to 20km/h Traffic mode: ~1/2000sec for up to 180km/h
Day/night mode	Remember to configure according to illumination options you have
White balance	Auto, except cases when you need to save true colors and have specific color illumination.
Image adjustment	Use 50% values, except specific cases with lack of illumination or image quality then you can try image adjustment fine tuning.
3D noise reduction	Disabled
Digital image stabilizer	Disabled
Exposure mode	Manual
Iris adjustment	Central position or close to “open”
Gain control	Up to 20%
WDR	Disabled

Camera installation

Correct installation of the camera should be based on next principles:

- License plate image meets all requirements mentioned above.
- License plates being in the frame for a maximum possible period of time.

To achieve this result, it’s necessary:

- To avoid high-contrasted objects such as billboards, trees or wire fences being visible in the frame.
- To avoid capturing the sky in surveillance area.
- To avoid pointing camera directly at light sources (sun, streetlights) or reflecting surfaces.
- To set up an optimal camera angles:
    - vertical – 18-20 (maximum - 30) degrees.
    - horizontal – 5-10 (maximum - 20) degrees.
- To consider for possible road incline.
- To provide for the angle of a license plate on the image that should not be more than 5 degrees to the surface of the road (for both single- and double-line license plates).
- To provide the angle of IR illumination (when using an external IR-projector) that is equal to camera angle of view.
- To set an optimal height for camera installation:
    - at access points – above the headlight level (1.5-2 meters).
    - at highways – 4-6 (maximum - 20) meters.
- To set an optimal distance between installation point and focal point:
    - at access points – 3 meters or longer.
    - at highways – determined based on available angle and focal length of the camera.
- To avoid overexposure of the frame (e.g. by using ND-filters) during surveillance under changing lighting conditions.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