

The principles of CCTV design in VideoCAD

Part V Video surveillance of moving objects

Edition for VideoCAD 7 Professional

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In [previous articles of this learning cycle](#), we have considered video surveillance of static objects only. But in reality, many of targets which interest us are moving objects that causes additional distortion of their images. Distortion of moving objects can make impossible, for example, recognition of a running person and reading license plate of a moving car, although standing person can be identified and license plate of standing car can be read. Because of the persistence of human vision, such distortion is less noticeable when watching video with high frame rate, but become apparent when viewing individual stop-frames.

Distortions of moving objects are difficult to predict without using special modeling tools. Most of camera parameters are measured without taking into account motion. As a result, in most cases, the distortions of moving objects are ignored by CCTV designers.

Neglect of motion of surveillance targets is one of the reasons of mismatch in image quality installed CCTV systems to specified requirements.

In proper CCTV project object's motion and possible distortion of their images should be taken into account. VideoCAD version 7 provides special tools for this purpose.

In this article we consider the main reasons of the distortion of images of moving objects, and tools for modeling these distortions. The article may be useful not only for VideoCAD users, but also for a wide circle of specialists. The information in the article is applicable for both analog and IP video surveillance.

Table of contents

The reasons of distortion of moving object images	2
Interframe compression.....	2
Finite exposure time	3
Rolling shutter	4
Interlacing.....	5
Finite frame rate	6
Work with VideoCAD	7
Placing cameras, constructions and 3D models	7
Specifying velocity vectors for moving objects.....	7
Simulation of distortion of moving objects from exposure time, interlacing and rolling shutter	8
Modeling image from three-megapixel (3MP) IP camera	9
Modeling image from 1.3MP IP camera	12
Modeling image from 0.4MP analog camera	14
Choosing optimal frame rate	16
Simulation of animated monitor.....	18
Adjusting animation of the cameras which should have animated images	18
Connection of the cameras to the Monitor.....	20
Switching the Monitor window to the animation mode.....	20
Saving the animated Monitor to HTML file.....	20

The reasons of distortion of moving object images

Images of moving objects in video surveillance are subject to both the same distortions as images of static objects (due to limited resolution, limited range of brightness, sharpening, compression, etc.) and additional specific distortions.

These distortions depend on velocity of the objects, parameters and configuration of equipment, scene illumination, camera position and features.

In case of the camera itself is being moved or vibrated, then these additional distortions have effect to the whole scene.



The main reasons of additional distortion of moving objects images are:

- Interframe compression;
- Finite exposure time;
- Rolling shutter;
- Interlacing;
- Finite frame rate.

On real frames distortion caused by different factors are summarized, resulting in a significant loss of resolution of the object's image.

Let's consider the reasons of distortion in more detail.

Interframe compression

Compression algorithms, which uses one or more earlier or later frames in a sequence to compress the current frame (MPEG, H264, etc.) can significantly increase compression ratio, saving disk space and reducing the cost of data transmission channels. However, when using such algorithms moving objects can be recorded with distortions. Type and degree of these distortions depend on many factors, including features of compression algorithm and its settings, computing power of processor, the rate of recording frames, amount of changes of the whole image between frames.

This kind of distortion becomes the most pronounced in the cases of high compression ratio of video, for example, when transmitting video via channels with insufficient bandwidth, at times of significant changes between frames and when using equipment with low computing power.

It is impossible to accurately predict or simulate these distortions without going into detail of each compression algorithm, but in practice you can sometimes change their intensity by changing compression settings.

When using **intraframe compression** which process each frame separately (MJPEG) this kind of distortion does not occur. Thus, if it is possible to use intraframe compression, we can eliminate this type of distortion. However, in this case, you must have reserve of bandwidth and storage capacity because of intraframe compression algorithms compress video stream much weaker for the same image quality of static objects.

Finite exposure time

The **motion blur** is the main source of distortion of moving objects, which is shown up with varying intensity in many cases. Video sensor collects light in a finite period of time - **exposure time** (shutter speed). If an object has been moved on the screen during this time over a distance of more than half of pixel - object's blur becomes noticeable. The greater the exposure time is and the more velocity of the object on the screen, the more it becomes blurred.



Fig 1. Motion blur because of finite exposure time.

The most of CCTV cameras have Automatic Electronic Shutter Control (**AESC**) which selects the exposure time automatically depending on lighting conditions. The worse the light is, the greater the exposure time is set. Thus, the worse the lighting, the greater is the blur of moving objects.

On the other hand, the more sensitive a camera is and the more light passes camera's lens (smaller **F number** of the lens), the less exposure time is required to obtain images with the same signal/noise ratio at the same light condition, the less is blur of moving objects.

When using a lens with **Auto iris**, only the lens iris is adjusted according to the illumination, but the exposure time, as a rule, remains long regardless of the illumination. Long exposure time even in good light, leads to more blur of moving objects than when using lenses with **fixed iris**.

To minimize the blurring you should use good lighting, fast lenses (with maximum aperture, minimum **F-number**) and high sensitive cameras with the possibility of limiting exposure time.

When reducing light, starting from a certain **threshold illumination**, the **AESC** of camera sets the **maximum exposure time**. When further reducing of light the exposure time is not increased anymore. Knowledge of the **maximum exposure time** and the **threshold illumination** of cameras are very useful when designing video surveillance systems.

The **maximum exposure time** of standard analog cameras without light accumulation is 20 microseconds (ms) for PAL system and 16.5 ms for NTSC. IP cameras and analog cameras with accumulation of light can use the exposure time up to 200ms and more. With latent increasing the maximum exposure time, many manufacturers increase the certified sensitivity of their cameras. Because of the long maximum exposure time, the blur of moving objects is especially topical for IP cameras in low light conditions.

Many modern cameras allow to change the **maximum exposure time**, switching between "night", "high sensitive" modes (long maximum exposure time - high sensitivity, but strong motion blur at low illumination) and "fast" "high speed" modes for surveillance of motion (maximum exposure time is short - noised image, but small motion blur at low illumination).

If a camera has several modes of exposure time, for their proper use it is helpful to know the maximum exposure time for each of them.

When the exposure time and the object's velocity are known, the object's blur on the image can be accurately modeled. VideoCAD offers special tools for this.

In case the maximum exposure time is not given in the camera specification, VideoCAD offers a technique for measuring the exposure time. See the [Help system: Examples of work with VideoCAD> Example 27 Measuring exposure time of IP camera](#).

Rolling shutter

Distortion from rolling shutter is not critical in the most practical cases, but sometimes it must be taken into consideration.

Rolling shutter is often used in IP cameras with **CMOS** video sensors and never used in cameras with **CCD** video sensors.

This technology allows manufacturers to increase the sensitivity of CMOS video sensor.

As a result of the rolling shutter effect, the exposure of different rows of pixels on the sensor is performed with a **time-shift**, which causes a **horizontal skew** of moving objects. Distortion of objects with complex movement trajectories may be more complex.

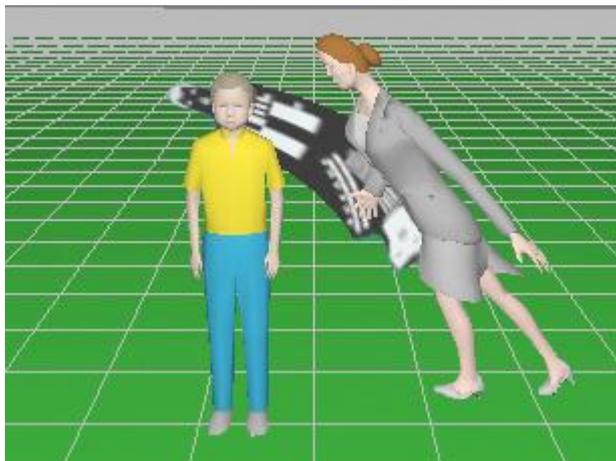


Fig 2. Distortion from rolling shutter.

This kind of distortion becomes the most pronounced on images from megapixel cameras with many rows of pixels.

The opposite of the **rolling shutter** is the **global shutter** with which the entire frame is exposed for the same time window.

The angle of the horizontal skew of a moving object on the image depends on horizontal component of velocity of the object's image on the screen. If the velocity is constant, the skew angle is constant too. It depends on features of sensor used in the camera.

The skew angle usually doesn't depend on lighting and the exposure time. If you change size of the image (number of rows of the image) in camera settings, the skew angle may remain the same or change based on sensor's features.

It should be noted that cameras with rolling shutter have **the same blur of moving objects** because of finite exposure time as cameras with **global shutter**. The skew from rolling shutter is appeared in addition. When illumination is sufficient, camera automatic sets short exposure time, therefore the skew from rolling shutter becomes more prominent. If there is insufficient light, exposure time increases, and the motion blur masks the rolling shutter skew.

An important parameter of rolling shutter is an interval of time between starts of exposure of neighboring rows. Let's call this parameter - the **row time**. This parameter is determined by camera sensor properties. In modern CMOS sensors it is within the limits of 20 - 100 microseconds.

It is easy to calculate, for example, if video sensor has 1536 rows (3MP resolution - 2048x1536) and row time = 50 microseconds, the time difference between the exposure of the top and bottom rows will be $50 * 1536 = 76.8 \text{ ms} = 76800 \text{ microseconds}$.

*Unfortunately, the **row time** is not given in the camera's specification. Therefore VideoCAD offers a technique for measuring the row time. See the [Help system: Examples of work with VideoCAD> Example 28 Example 28 Measuring rolling shutter row time of IP camera](#).*

If the row time and object's velocity in the frame are known, object's skew on the image can be accurately modeled. VideoCAD offers for this special tool.

Interlacing

Distortions of moving objects caused by interlacing (combing) are familiar to specialists in video surveillance from the time when video signal from interlaced cameras was displayed on a computer monitor.

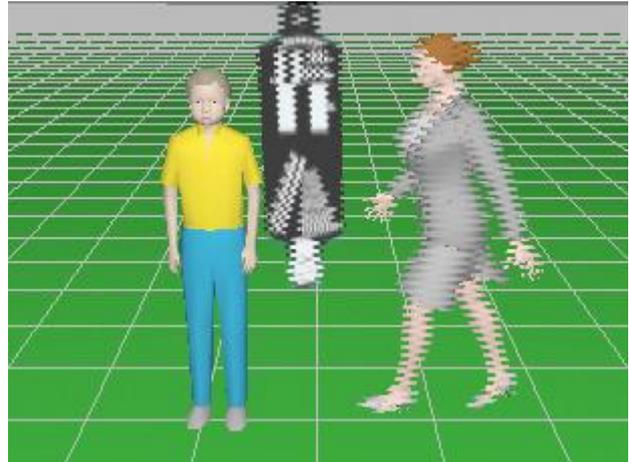


Fig 3. Distortion from interlace scan (combing).

The combing effect appears when an image from a camera with interlaced scan is being shown on a display with progressive scan.

In the cameras with interlaced scan the full frame is composed of two fields, line via line. These fields are exposed sequentially, at different times. And when this composite frame is being shown on a digital display, a time shift of moving objects on different fields becomes visible.

Analog monitors (CRT) have the interlaced scan too, two fields on analog monitors are displayed sequentially as exposed, and therefore on an analog monitor the combing effect is absent.

All analog cameras PAL and NTSC have the interlaced scan. All digital monitors have are progressive scan. Recording images to a file in computer memory is performed with progressive scan too. Therefore, the combing is manifested in almost all cases of use of analog cameras.

The time period between exposures of neighboring fields in the PAL system is 20ms. (50 fields per second, 25 full frames per second). In the NTSC system the period is 16.5ms. (60 fields per second, 30 full frames per second).

If an object moved on the screen during this time over the distance more than half of pixel - the combing effect becomes noticeable.

To combat the combing effect, video recording by individual fields is used, without combining fields into frames, which leads to loss of vertical resolution by 2 times.

Special image processing - **deinterlacing** is also used, which makes the combing less noticeable, but it reduce vertical resolution of moving objects.

If the time period between two fields in one frame and object's velocity on the screen are known, the combing effect can be accurately modeled. VideoCAD offers special tools for this.

Finite frame rate

The finite frame rate restricts possibilities of surveillance of moving objects, although in general, it does not affect the image of the objects on individual frames.

Obviously, the actual monitoring is being carried out only at moments of recording frames. During the time between frame shots surveillance is not made.

If object's speed is sufficient for crossing the camera's view area during the time between frame shots, then this object can be lost.

When choosing the frame rate you must take into account the possible velocities of objects and the possible ways of crossing the view area so that the objects would not be lost. To slow objects additional obstacles (fences, turnstiles etc..) can be used.

If you want detailed image of an object, the number of frames in which the object must get, should be increased, which increases the probability of getting the object at favorable angle.

If trajectory and velocities of an object are known, as well as camera frame rate, it is possible to simulate a video in which we can estimate the number of hits of the object into the frame.

You can also display the object's path during the period of time between frame shots as a vector and visually estimate the number of hits into frame on the 2D layout.

Work with VideoCAD

VideoCAD 7 Professional version has tools for accurately modeling the distortions of moving objects caused by the exposure time, rolling shutter, interlaced scan, and tools for choosing the minimum frame rate based on the velocities of the moving targets. It can also generate animations with moving objects, and animated monitors with images from different cameras with different frame rates.

Simulations of distortion of moving objects and animated images are resource intensive operations that require time and computer resources. In normal use it is not recommended to leave these functions enabled.

Let's consider several examples of working with moving targets.

Placing cameras, constructions and 3D models

First, you must create a project, place cameras, set the basic parameters of cameras and lenses, place constructions, fixed and moving **3D models**.

Order of work is described in detail in the first and third articles of this cycle, [Camera view area](#) and [3D modeling in VideoCAD](#).

Usual **3D models** are used as **moving objects**.

Specifying velocity vectors for moving objects

For the 3D models used to simulate the moving objects, you must specify **velocity vectors**. In VideoCAD 7 you can specify a velocity vector for any 3D model, thus turning it into a **moving 3D model**.

Switch the 3D model into **editing state** by double clicking on its projections in the Graphics window. In the **Speed** box on the appeared **Current construction parameter panel** (at the bottom of the Graphics window), enter any nonzero velocity of the object in meters (feet) per second.



On the projection of the 3D model the velocity vector (**crimson arrow**) will appear.

You can edit the velocity vector of the 3D model in **editing state** by moving its terminus.

Bring the cursor to the terminus of the velocity vector, click the left mouse button and drag the terminus. At the same time the speed value and direction of movement is being edited simultaneously. Click for the second time to specify new velocity and finish editing.

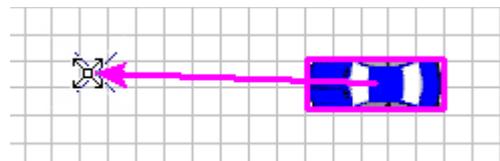


Fig 4. Velocity vector of moving 3D model.

If 3D model **is selected** then length of the **velocity vector** equals to the **distance in meters (feet) which the 3D model passes per second (crimson arrow)**.

If 3D model is in the **normal state (non-selected)**, the length of the **velocity vector** equals to the **distance which the 3D model passes for the period between successive frames of the active camera (black arrow)**.

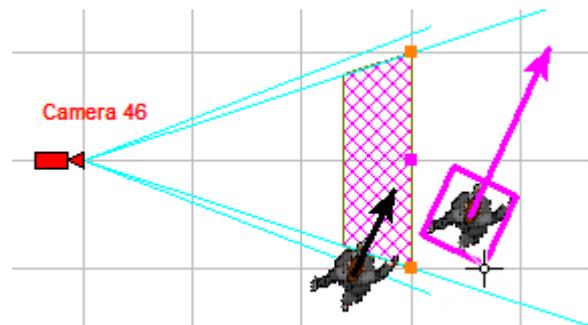


Fig 5. Velocity vectors of selected and non-selected 3D models.

Simulation of distortion of moving objects from exposure time, interlacing and rolling shutter

For cameras which need to simulate distortion of moving objects you should set parameters that affect these distortions:

- Exposure time;
- Row time of rolling shutter for cameras with rolling shutter;
- Time between fields in one frame for interlaced cameras.

It is not necessary to set all parameters. For example, if you want to simulate only motion blur from exposure time, it is sufficient to set only the exposure time.

VideoCAD can simulate all types of distortions on one image, but the simulation of each type of distortion increases the time of creating 3D image in several times.

For proper modeling you must also correctly set the **basic camera parameters: Sensor format, Lens focal length and Number of pixel on the sensor**.

In case the exposure time or the row time of rolling shutter is unknown, VideoCAD offers [techniques](#) for measuring these parameters.

Let's consider an example. There are three cameras:

- Three-megapixel (3MP) (2048x1536) IP camera with CMOS sensor and rolling shutter;
- 1.3 megapixel (1280x960) IP camera with CCD sensor and global shutter;
- 0.4MP (768x576) analog camera with interlace scan.

We know camera **exposure time** at the scene light conditions:

- 3MP IP Camera - 100ms;
- 1.2MP IP camera - 50ms;
- Analog camera - 20ms (PAL).

3MP camera uses the **rolling shutter**, the period between reading successive rows (**row time**) = 50 microseconds.

All cameras have the same **sensor size** 1/3" and a **lens with focal length** = 4mm.

We know the camera position, location and velocity of moving objects on the scene.

On the scene there is a car moving at speed of 20 m/s (72 km/h) and a woman running with speed of 2 m/s (7,2 km/h)/

We need to get models of images of the moving objects from each camera at the same position and compare these images.

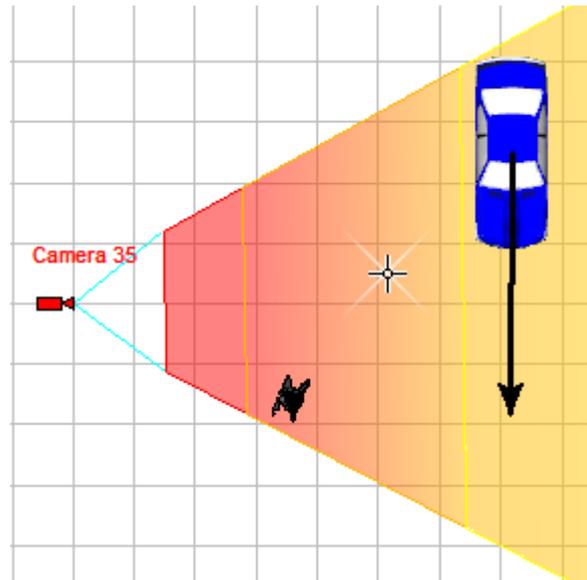


Fig 6. A car and a woman on the horizontal projection of view area in the Graphics window

First, place camera, place 3D models and assign velocity vectors for the 3D models (see above).

Modeling image from three-megapixel (3MP) IP camera

Activate the camera by double clicking on its lens or by choosing its name in the **Active camera** combo box on the Toolbar.

Open the **Camera Geometry**  box and specify:

- Image sensor format - 1/3";
- Lens focal length - 4mm;
- Aspect ratio - 4:3.

Then close the box.

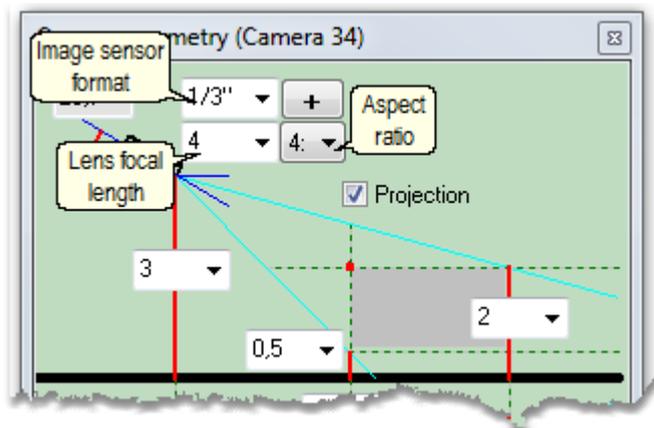


Fig 7 Basic camera parameters in the Camera Geometry box.

Open the **Sensitivity and resolution**  box and specify numbers of pixels horizontal - **2048**, vertical - **1536**.

Close the box and save changes.

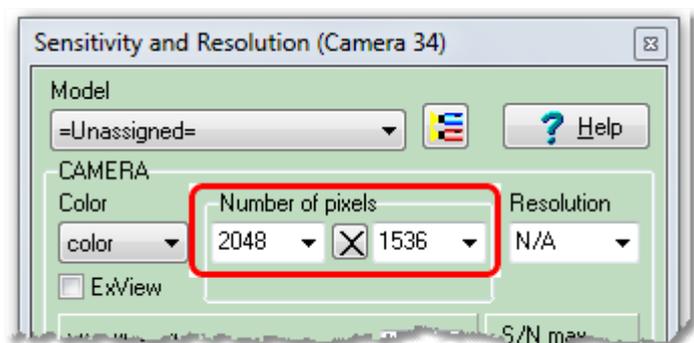


Fig 8. Specifying number of pixel in the Sensitivity and Resolution box.

Open the **3D window** . Stretch the 3D window for better resolution if needed.

If the **PiP mode** is enabled (by default) in the 3D window a **yellow rectangle** will be displayed. And in the corner of the 3D window, inside a **green rectangle**, an image fragment from the yellow rectangle will be displayed (**Fig.9**).

Pay attention that the entire frame is shown with a resolution lower than specified 2048x1536 and only the fragment from the **yellow rectangle** is shown with the actual resolution - 2048x1536.

Place the yellow rectangle on the **moving 3D model**, by clicking the middle mouse button (wheel).

For detail about PiP, see. [Help system>Interface>3D window>Image parameter panel>PiP.](#)

By right clicking on the **3D window**, open the **Image parameter panel**.

Choose the **Camera** tab.

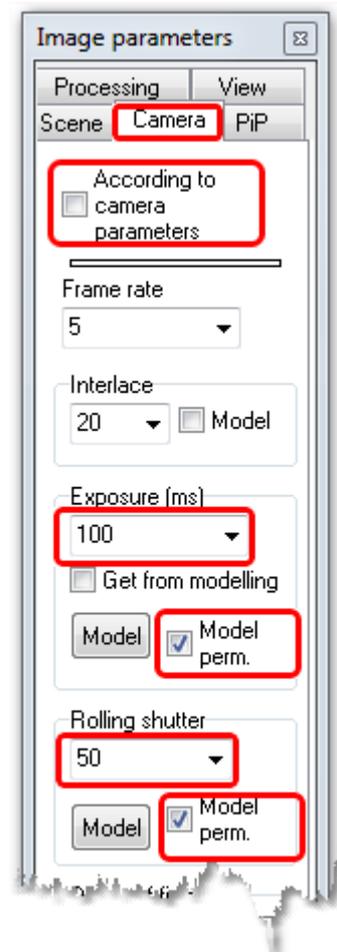
Uncheck the **According to the camera parameters** box if it is checked.

Choose '**100**' in the **Exposure (ms)** combo box.

Check **Model perm.** on the **Exposure (ms)** panel.

Choose '**50**' in the **Rolling shutter** combo box.

Check **Model perm.** on the **Rolling shutter** panel.



During the image generation in the **3D window**, on the 3D window  button red frame flashes .

Simultaneous modeling exposure and rolling shutter can take several minutes.

After a while you will see the image model (**Fig.9**).

Save the image in the **3D window: 3D window>Main menu>Save as *.png**

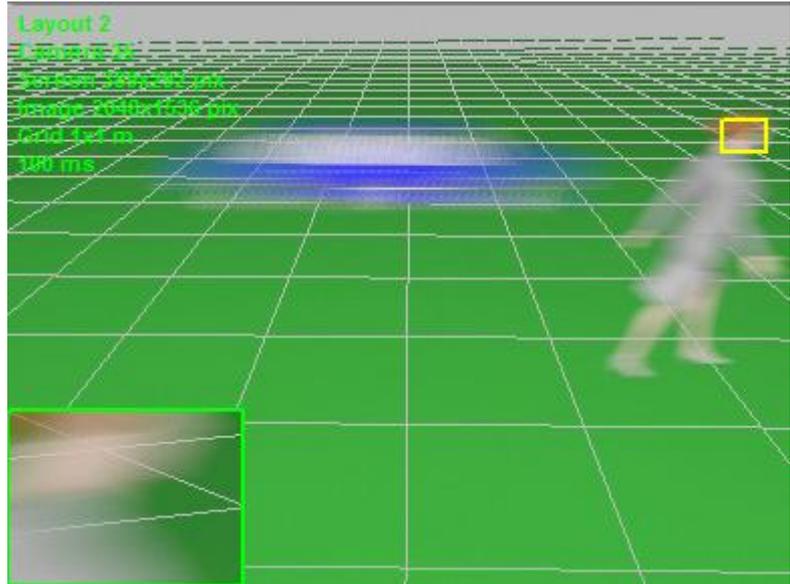


Fig 9. Image model from 3MP IP camera.

*You can adjust realism of modeling **exposure** and **rolling shutter** on the **3D tab** of the **Options box**. The more realistic simulation is, the more time required to generate the images in the 3D window.*

Modeling image from 1.3MP IP camera

Open the **Sensitivity and resolution**  box and specify numbers of pixels horizontal - **1280**, vertical - **960**.

Close the box and save changes.

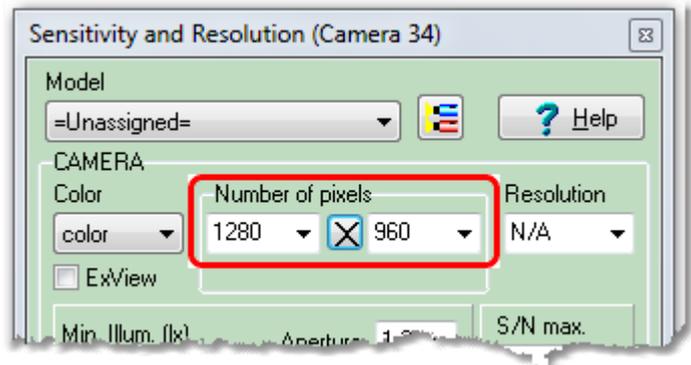
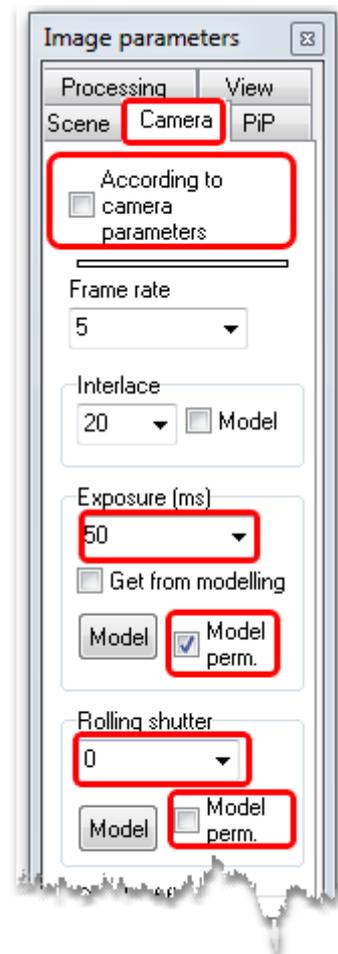


Fig 10. Specifying number of pixel in the Sensitivity and Resolution box.

Open the 3D window . By right clicking on the **3D window**, open the **Image parameter panel**.

Choose the **Camera** tab.

Uncheck the **According to the camera parameters** box if it is checked.



Choose '50' in the **Exposure (ms)** combo box.

Check **Model perm.** on the **Exposure (ms)** panel.

Clear **Model perm.** on the **Rolling shutter** panel.

After a while you will see the image model (Fig.11).

Save the image in the **3D window: 3D window>Main menu>Save as *.png**

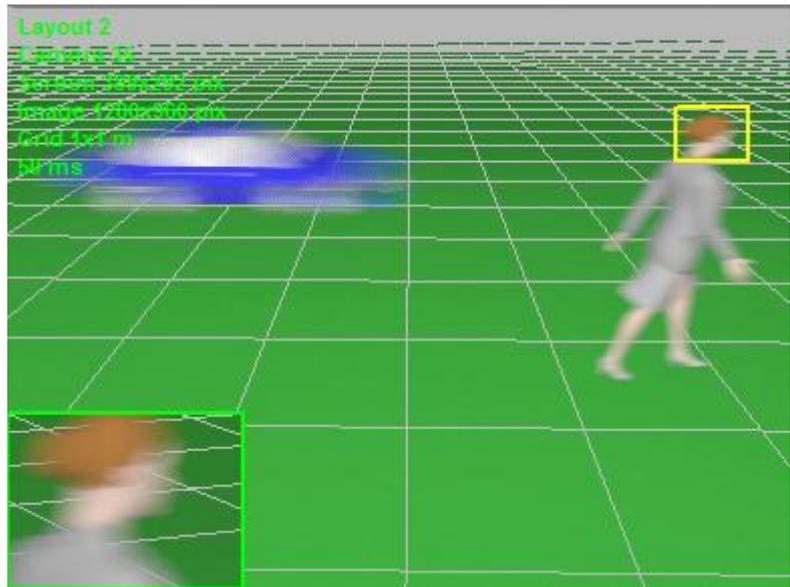


Fig 11. Image model from 1.3MP IP camera.

Modeling image from 0.4MP analog camera

Open the **Sensitivity and resolution**  box and specify numbers of pixels horizontal - **768**, vertical - **576**.

Close the box and save changes.

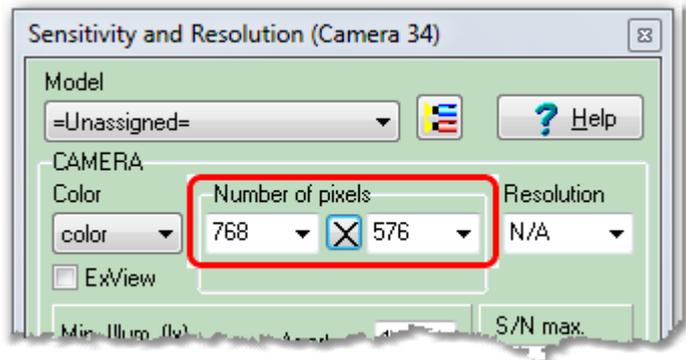


Fig 12. Specifying number of pixel in the Sensitivity and Resolution box.

Open the 3D window . By right clicking on the **3D window**, open the **Image parameter panel**.

Choose the **Camera** tab.

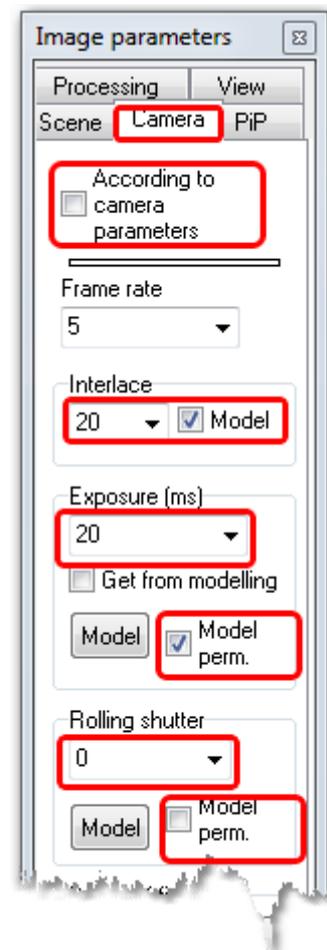
Uncheck the **According to the camera parameters** box if it is checked.

Choose '20' in the **Interlace** combo box.
Check **Model** on the **Interlace** panel.

Choose '20' in the **Exposure (ms)** combo box.

Check **Model perm.** on the **Exposure (ms)** panel.

Clear **Model perm.** on the **Rolling shutter** panel.



After a while you will see the image model (Fig.13).

Save the image in the **3D window: 3D window>Main menu>Save as *.png**



Fig 13. Image model from 0.4MP analog camera..

Compare images from different cameras (**Fig. 9, Fig 11, and Fig.13**). You can see that resolution of moving objects depends of camera's exposure time more than of camera's number of pixels.

Choosing optimal frame rate

The **frame rate** greatly affects the required bandwidth of communication channels, capacity of the video archives, computing power, and hence the total cost of video surveillance systems.

At the same time, choosing optimal frame rate is not an easy task and criteria for selection are not always unambiguous. When the frame rate is too low, the losing important events is possible, too high frame rate leads to unjustified rise in price of the video surveillance systems.

VideoCAD offers a tool for choosing frame rates based on the **desired frequency of getting into the frame objects with known positions and velocities**. Additionally, you can create **animated images with the specified frame rate**.

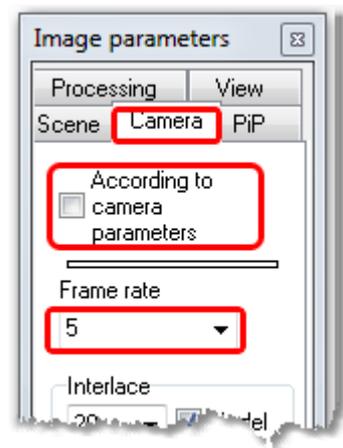
Suppose we set the camera, set the location and speed of moving objects (3D models). We need to choose the minimum frame rate to get any object into the frame at least twice.

Choosing the frame rate for the active camera is carried out visually by comparing the velocity vector of moving 3D model and the width of camera view area at the locations of the moving objects.

The lengths of the velocity vectors of non-selected (in the normal state) 3D models show which distance is passed by the appropriate 3D model during the period of time between frames of the active camera.

Remove selections from the 3D models if there are selected ones.

Open the **3D window** . By right clicking open the **Image parameters** panel. Chose **Camera** tab.



Change **Frame rate** value, watching the **velocity vectors** of 3D models in the **Graphics window**.

Select the **Frame rate** in order that all **velocity vectors** fit in the view area projection **at least twice**.

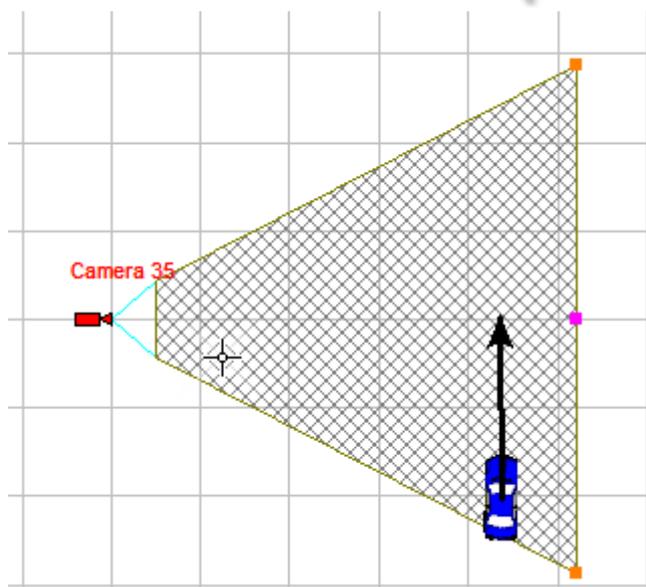


Fig 14. The length of the velocity vector equals to the distance which the 3D model passes for the period between successive frames of the active camera.

Choose the **View** tab on the **Image parameters** panel.

Uncheck the **According to the camera parameters** box if it is checked.

Check **Animation** box. Set the **Number of frames** =3 or more.

In several seconds **animated image** with **specified frame rate** will appear in the **3D window**. In the image there will be **3D models** with specified velocity.

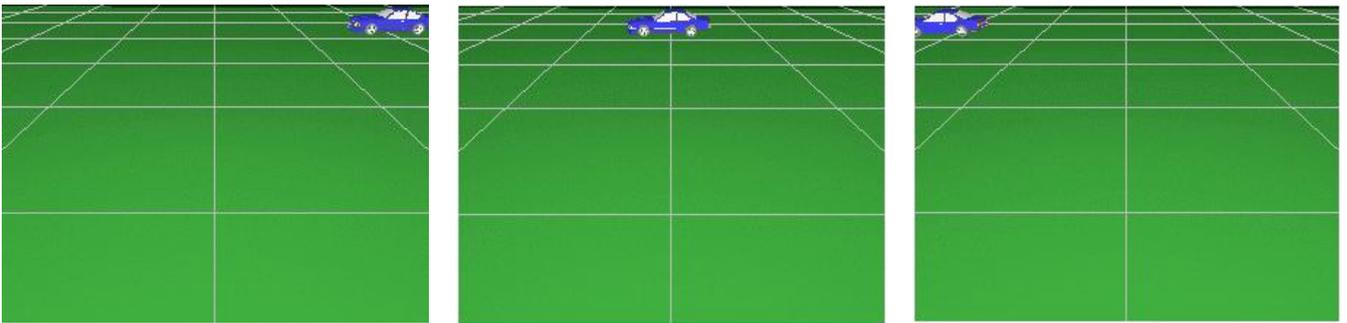
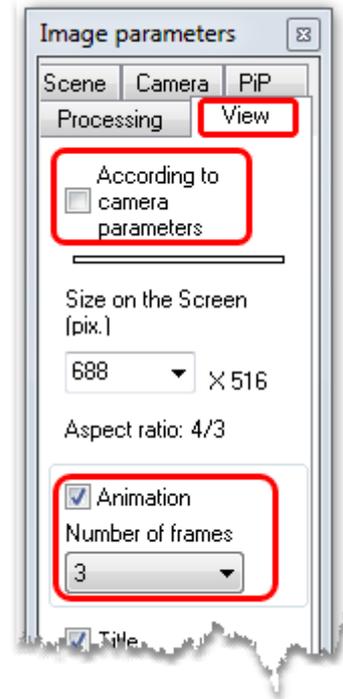


Fig 15. The frames of the animated image with specified frame rate.

Simulation of animated monitor

VideoCAD 7 Professional allows to create animated models of monitor as *.html file. These models may contain up to 100 animated images from different cameras. Each image has its own settings (frame rate, resolution, etc.). Obtained html file can be viewed by any Internet browser, placed in the internet, edited with any text editor, etc.

Clicking on any image on your monitor you can show the selected image with resolution of the appropriate camera.

Adjusting animation of the cameras which should have animated images

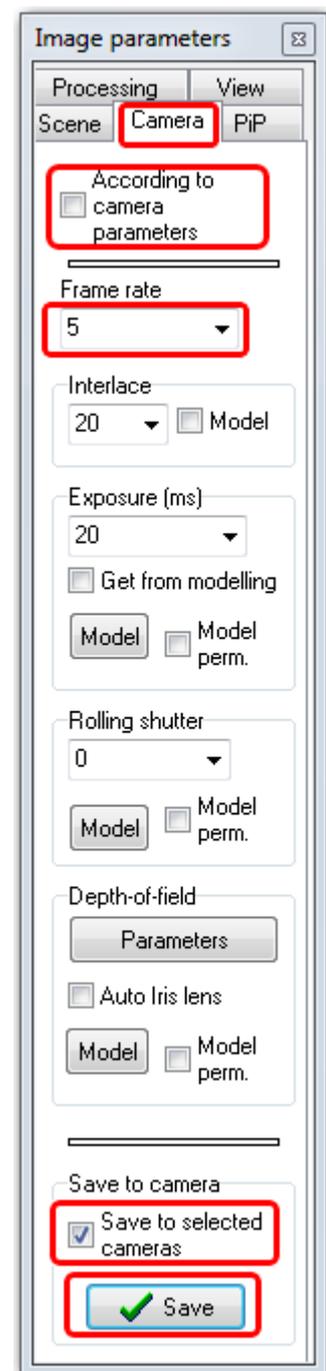
Activate one of those cameras, which should have animated images.

Open the **3D window** by clicking on the **3D window**  button on the **Tool bar** of the **Graphics window**. Right click on the **3D window** to open the **Image parameter panel**.

Choose the **Camera** tab.

Uncheck the **According to the camera parameters** box if it is checked.

Adjust the **Frame rate**.



Select all cameras on the layout, which should have animated images.

Check the **To selected cameras** box.

Click on the **Save** button.

Switch to the **View** tab.

Uncheck the **According to the camera parameters** box if it is checked.

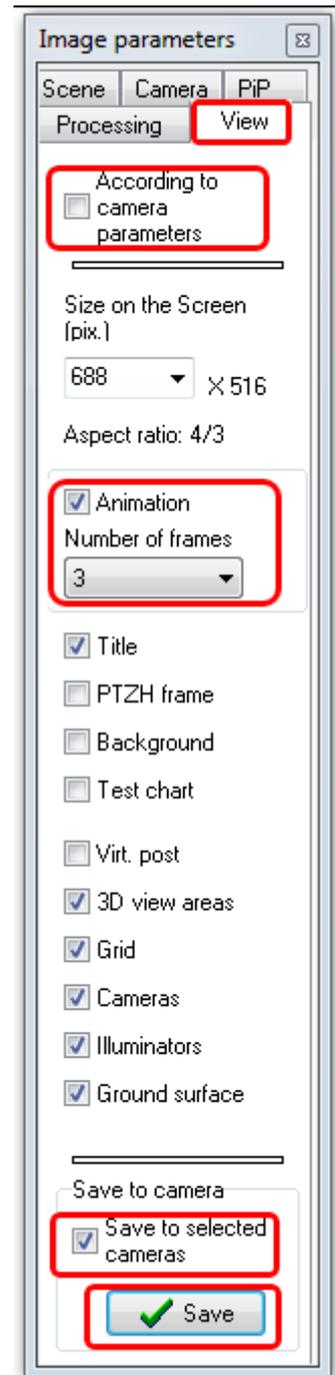
Check the **Animation** box.

Set the **Number of frames** = 2 or more.

Select all cameras on the layout, which should have animated images.

Check the **Save to selected cameras** box.

Click on the **Save** button.



After several seconds in the **3D window** the animated image will be shown. The image with the specified frame rate will contain moving with the specified velocities 3D models.

*We have set the same **number of frames** in the animated images and the **frame rate** for all selected cameras simultaneously. You can set individual values for each camera, not checking the **To selected cameras** box before clicking the **Save** button and repeat adjusting for each camera separately.*

*To save animated image from the active camera on this step, click **Main menu of 3D window>Image>Save as animated *.gif**.*

Connection of the cameras to the Monitor

Open the **Monitor window** by clicking on the **Monitor window**  button on the **Tool bar** of the **Graphics window**.

Click on the **Edit**  button on the **Tool bar** of the opened **Monitor window**.

Select on the layout cameras which should be displayed on the Monitor.

You can select cameras with static and animated images mixed.

Then click on a cell of the **Monitor** starting from which these cameras should be displayed on the **Monitor**.

*After some time the **3D window** will appear, in which **static** images from these cameras will be simulated. Then these images will appear in the cells of the Monitor, starting from the clicked cell.*

See more details of work with Monitor: [Help system>Interface>Monitor window>Work with Monitors.](#)

Switching the Monitor window to the animation mode

Click the **Animation**  button on the **Tool bar** of the **Monitor window**.

*The **3D window** will appear again, but this time it will generate **animated** images for your monitor.*

Generation of animated images takes much longer, it is a complex multi-threaded resource-intensive operation. Be patient, do not touch the mouse and keyboard, do not interfere the program, otherwise errors are possible.

Saving the animated Monitor to HTML file

For this click on the **Monitor window Main menu> Image> Export to *.html**.

*It is recommended to save the *.html file to a separate directory. The resulting "file" includes the actual HTML file with links to images and the image files in animated GIF and PNG formats. The images are stored with the resolution and other parameters of the corresponding cameras.*

See an example of animated monitor (file size about 4 Mb).

http://cctvcad.com/monitor/Monitor_1.html

Back:

[Part I. Camera view area.](#)

[Part II. Person detection area, person identification area, license plate reading area. Spatial resolution.](#)

[Part III. 3D modeling in VideoCAD.](#)

[Part IV. Illumination and camera sensitivity in CCTV.](#)

Continue:

[Part VI. Lens distortion in CCTV design](#)