MotionDesk and Sensor Simulation

Glossary

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dSPACE

How to Contact dSPACE

Mail:	dSPACE GmbH Rathenaustraße 26 33102 Paderborn Germany
Tel.:	+49 5251 1638-0
Fax:	+49 5251 16198-0
E-mail:	info@dspace.de
Web:	http://www.dspace.com

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Important Notice

MotionDesk and Sensor Simulation Glossary

Introduction

The glossary briefly explains the most important expressions and naming conventions used in the MotionDesk and Sensor Simulation documentation.

Where to go from here

Information in this section

Numerics

3-D Point cloud A laser sensor projects a laser beam and by measuring the reflections can calculate the distance to a large number of points on the external surfaces of objects in the environment. These points form a 3-D point cloud image of the objects, which can then be converted and rendered. The point cloud data can be inserted into the sensor processing module behind the sensor front end in a raw data simulation. This eliminates the need to test using the front end of the laser sensor.

3-D View A pane in MotionDesk that displays a 3-D view of the scene.

A

Advanced lighting The advanced lighting mode is a function for you to add additional lighting to static and dynamic objects in the scene to create a more realistic scene. It simulates global lighting via atmospheric light dispersion. You can select the light shape type and the position in relation to the object. The lights in the scene can be controlled by the simulation.

Animated characters Animated characters are moving characters that can be added to a MotionDesk scene, for example, a person walking, a person on a bicycle, or an animal. You can also assign motion data to the animated characters and incorporate them into a ModelDesk scenario. The speed of the movements of the animated characters changes with the changes in the simulation.

The animated characters license is required to use these characters in MotionDesk and in sensor simulation.

Automation interface A programming interface that allows you to automate MotionDesk, for example, by using Python scripts. The automation interface is an API which is implemented as a COM object model. The Microsoft Component Object Model (COM) supports communication between objects from different applications. It can be used by any COM-compatible application, regardless of the programming language in which it was developed.

Automotive Simulation Model (ASM) A Simulink model that is intended for simulation of an automotive engine (gasoline and Diesel) and vehicle dynamics. All the Simulink blocks in the model are visible, so it is possible to add or replace components with custom models to adapt the properties of modeled components to individual requirements.

B

Bird's-eye view The bird's-eye view is a two-dimensional view from above the MotionDesk scene in the 3-D View.

If an observer is fixed to a movable object in the selected view, the bird's-eye view follows the object through the scene in the 3-D View.

C

Camera Observer

Camera sensor A camera sensor provides a standard angle of view of the environment for sensor simulation using a rectilinear lens. The maximum angle of view to produce a valid image is 180 degrees. Radial lens distortion can occur at wide angles of view, for example, beyond 100 degrees.

In sensor simulation, a horizontal and vertical field of view angle above 140 degrees for a camera sensor is not advised.

Cardan angles The Cardan angle system describes the rotation of a 3-D object along the three rotational axes: x, y, and z. The three degrees of movement along these axis are called roll, pitch, and yaw. They can be measured with the Phi θ, Theta Φ, and Psi ψ angles, respectively.

Cartesian coordinate system A coordinate system that specifies each point uniquely by numerical coordinates, which are the signed distances from the point to fixed orthogonal directed lines. Each reference line is called an axis of the system, and the point where they meet is its origin. The coordinates can also be defined as the positions of the orthogonal projections of the point onto the axes, expressed as signed distances from the origin.

Child instrument An instrument that is part of an instrument Panel.

Chromatic aberration Chromatic aberration is an image distortion effect where there is a dispersion of light colors due to different indices of refraction of light of different wavelengths. The image is blurred with a rainbow effect between dark and bright areas of the image. This is due to a failure of the lens to focus all the colors to the same convergence point in the camera image sensor chip.

Clipping plane (near and far points) The clipping planes are defined by the near and far points of the lens. Any objects closer than the near clipping plane or further than the far clipping plane of the Frustum are not displayed.

The far point for a camera sensor is 10 km. For laser sensor, the near and far point can be set in the MotionDesk laser sensor properties.

Clothoid segment A segment of a road that has a transition curve with a variable curvature. The curvature monotonically changes from a start radius to a specified radius at the segment's end point. The start radius is identical to the end radius of the preceding segment.

COLLADA A file format that is established as an interchange file format for interactive 3-D applications. COLLADA is the short form of a Collaborative Design Activity. It defines an open standard XML schema for exchanging digital assets among various graphics software applications. COLLADA documents that describe digital assets are XML files, usually identified with a .dae (digital asset exchange) file name extension. MotionDesk uses this file format for describing the 3-D objects since MotionDesk 3.0.

Crop factor The crop factor is a ratio of the size of the sensor image compared to the reference format of a standard 35 mm film. The sensor image is the same size if the crop factor is 1. Lenses can have different crop factors. The standard crop factors used by different lenses are 1.3, 1.5, and 2.0.

You divide the diagonal length of a 35 mm film (43.3 mm) by the diagonal length of the camera image sensor chip to calculate the lens sensor crop factor. For example, if a camera sensor has a crop factor of 2, the standard 35 mm film image is twice as large as the camera sensor (21.65 mm). The field of view of the camera sensor is half as small.

The crop factor is related to the focal length. Refer to Focal length.

Crop factor is also known as *Sensor Format Factor* or *Focal Length Multiplier*.

Custom objects library A library that contains your 3-D objects. You can import your 3-D objects in the VRML2 or COLLADA format into the library. Then you can use them in the scene in MotionDesk.

D

DEM file A file that contains a digital elevation model. This model represents height information without any further definition about the surface. This file can be used for terrain generation as it provides the position and the height information of a terrain.

dSPACE objects library A library that contains 3-D objects provided by dSPACE. The library contains objects for creating a virtual world especially for automotive or robotics applications. The library is read-only. You can use the objects in the scene but you cannot modify the objects nor their properties in the library.

The library includes a range of road, scenery, and vehicle objects that can be added to a MotionDesk scene. The vehicles include specific models of Mercedes, BMW, Volkswagen, and NCAP global vehicle targets (GVT). Lorries, trailers, and roadside assistance and emergency service vehicles are also included.

E

Environment Sensor Interface Unit (ESI) An interface unit that gets the sensor data from the SensorSim application and inserts it into the sensor ECU processors. For example, in a raw data simulation ,the data can be inserted into a camera image processor or a laser sensor point cloud generator.

The Environment Sensor Interface Unit is an FPGA unit that splits the raw data or object and target list data that is required for each of the sensors in the sensor simulation architecture. It can also convert the data into a format for the sensor that is not supported by MotionDesk, for example, a 16 bit Bayer pattern.

The Environment Sensor Interface Unit then forwards synchronized raw data to the relevant sensor though a variety of interfaces via the Environment Sensor Interface Unit plug-on device (POD).

ESI Plug-on device (POD) The Environment Sensor Interface Unit Plug-on devices are interfaces between the Environment Sensor Interface Unit (ESI) and the specific sensor processors. They are required to convert different data formats, for example, HiSPI, CSI2, LVDS formats and deliver the data to the sensor processors.

For example, a plug-on device can connect to the Environment Sensor Interface Unit using a fiber-optic cable and to a camera sensor using an HDMI connection.

Euler angles The description of an object's orientation and rotation along its x, y, and z axes. Euler angles can be defined by three of these rotations, using 3 angles. These angles control a sequence of rotation operations around its axes in a defined order.

Euler angles use the same axis for both the first and third rotations. For the Euler angle interpretation the rotation order is always Z - Y' - Z'':

1. Rotation around the z-axis with the Psi ψ angle
2. Rotation around the y-axis with the Theta Φ angle
3. Rotation around the actual z-axis with the Phi θ angle

Exposure Exposure is a camera setting that controls the amount of light that is allowed through the lens. You can control the level of exposure for camera and fish-eye sensor data rendered by the SensorSim application in sensor simulation. Increased exposure increase the luminance or brightness of the scene sensor data.

In MotionDesk, you can also increase or decrease the exposure to brighten or darken the 3-D scene

F

Fellow An object that moves in relation to the ASM vehicle. It is used in scenarios to simulate traffic situations. The movement of a fellow is defined with the Scenario Editor. To visualize a fellow in MotionDesk, a geometry of a 3-D object is assigned to it. A fellow is based on a traffic object.

Field of view The camera, fish-eye, and laser field of view controls the horizontal and vertical angle from which the sensors can read image object data. This is the angle away from the sensor front end or nodal point. It is calculated based on an equation that includes the sensor resolution, focal length, and the crop factor compared to a 35 mm film.

The distortion parameters are also considered in the calculation of the field of view.

Fish-eye sensor A fish-eye sensor lens provides a wide-angle of view that can exceed 180 degrees in all directions. Fish-eye sensors are typically used in sensor simulation to provide a view of between 100 and 220 degrees of the sensor environment. A horizontal or vertical field of view angle below 90 degrees for a fish-eye sensor is not advised. The maximum in MotionDesk is 360 degrees.

It creates a panoramic or spherical image with a radial lens distortion effect. The distorted edges of the fish-eye image can be shown in black as the distortion increases towards the edge and cannot display the image.

Flat shading The same color is applied to the whole of a polygon to represent the effects of light. All pixels inside a polygon are given the same shade.

Focal length The focal length of a camera lens is the measurement in millimeters between the center of the lens to the sensor chip or image plane. It is also known as the principal distance.

The focal length is used to calculate the field of view of a camera or fish-eye sensor. A shorter focal length creates a wider field of view at a lower magnification. A longer focal length creates a narrower field of view at a higher magnification.

You can also multiply the focal length of the lens with the camera sensor crop factor to calculate the equivalent focal length. This is the focal length required to produce the same field of view angle as that of a 35 mm film. For example, a lens with a focal length of 10 mm and crop factor of 1.3 produces the same field of view angle as 35 mm film with a focal length of 13 mm.

The focal length influences the field of view. It is recommended to define focal length to set the field of view.

Focus distance The focus distance is the distance from a camera image sensor chip to the object in the picture.

Fog A technique that can be used to simulate atmospheric effects such as haze, fog, and smog by fading object colors to a background color based on distance from the viewer. Fog also aids in the perception of distance from the viewer, giving a depth cue.

Frame A frame is the graphical position and orientation data of all movable objects at one time.

Frame buffer (general) A frame buffer is a part of the memory of the graphics card that is used to store the currently calculated frame pixel base. It is used to build up a graphic in an invisible frame buffer while an other is being shown. As soon as the frame is complete, the frame buffers are switched to ensure a smooth visualization.

Frame buffer (MotionDesk) In MotionDesk a frame buffer is the memory which stores the motion data (position, orientation) for the replay function.

Frame rate The number of frames shown in one second is called the frame rate and is stated in fps (frames per second). The frame rate should be as high as possible to get a smooth animation. The higher the frame rate, the smoother the animation and the lower the latency times.

Frames per seconds Frames per seconds (fps) are the number of frames displayed in one second on the screen.

Frustum A frustum is the viewing area of a lens. It is defined by the lens field of view angle, the near point, and the far point. The near and far points are the closest and farthest points at which the camera can focus and render the image.

The frustum can be considered as a pyramid with the point of the pyramid at the lens. This is known as the nodal point. The near point of a lens is greater than zero. Therefore, the top of the pyramid is truncated at the near point clipping plane (near and far points). The base of the pyramid is the far point clipping plane.

G

Gamma correction Gamma correction increases the tone and luminance of an image to be shown on a screen.

In MotionDesk, you can enable gamma correction in the properties for the camera and fish-eye sensors to improve the image data rendered by the SensorSim application for an over-the-air simulation (OTA).

Geometric distortion An optical effect that bends the rays of light through the lens to create a distorted image, for example, Radial lens distortion.

Geotiff file A file that contains data of an image as well as geographic information. This file can be used for terrain generation as it provides the position and the height information of a terrain.

Gouraud shading Gouraud shading is a method in which the polygon color is obtained by interpolating the vertex colors that are located at each vertex of the polygon. By utilizing this technique, 3-D objects appear increasingly realistic due to the smooth, curved appearance of the surfaces, even though they consist of many separate polygons.

H

Hardware-in-the-loop (HIL) test environment A hardware-in-the-loop (HIL) test environment lets you test the ECU algorithms and sensors using the physical hardware in connection with an real-time simulation run on a real-time simulation platform, for example, on SCALEXIO systems.

You can perform open-loop testing to test the system under test, for example, the ECU or sensor control unit. For closed-loop test, you can extend the validation to return the resulting data from the system under test to the vehicle and environment simulation that runs on VEOS or a simulation platform.

Headless mode In headless mode, the sensor image data rendered by the SensorSim application is not displayed on screen. The application renders the sensor data in the screen buffer for postprocessing or writing to the shared memory.

Host PC A standard PC that the dSPACE test and experiment software is installed on. ia the host PC, you can configure the dSPACE hardware, download a simulation application to the platform and control the simulation.

I

Image processing unit An image processing unit is a digital signal processor behind the camera image sensor chip and lens. It is used for image processing of the image raw data and the delivery of the data to the ECU and vehicle simulation.

The Environment Sensor Interface Unit (ESI) can insert the image raw data directly to this module. You do not need the camera image sensor chip and lens front ends for sensor simulation tests that insert data directly to the image processing unit.

Image sensor chip An image sensor chip is a sensor that detects and transmits image data. It filters and converts the light traveling through the camera lens into signals, which are transmitted to the image processing unit.

Instrument An on-screen representation that is designed to monitor simulator variables interactively and to display data captures.

Instrument Panel A group of several instruments on the screen. All the instruments included in the panel are positioned relative to the panel. A panel can be minimized to hide the instruments. You can specify the background for the complete panel.

L

Laser sensor A laser (*Light Amplification by Stimulated Emission of Radiation*) emits and receives infrared light that reflects off objects in the environment and return to the sensor. The sensors calculate the distance to the objects by measuring the time of flight of the reflections. It produces a high-precision 3-D Point cloud model of the environment. It is also known as a shader based sensor.

Laser sensors are constructed with a telescopic lens, a light transmitter, and receiver, and a processor to calculate the data. They emit light over a broad area and the reflections return to the sensor which measures the reflection point on the projection plane. Laser sensors can be affected by atmospheric conditions such as rain, snow, and dust.

Latency time The time between the scene being computed in the simulation and displayed on the monitor is called the latency time. It should be as short as possible, specially in a "man-in-the-loop" scenario. Refer to Application Scenarios.

Lens correction profile A file in LCP format is an Adobe lens correction profile. They contain lens settings for specific camera and lens size combinations to correct distortions caused by the lens.

The settings can contain values such as the focal length and focus distance and also distortion correction effects to resolve image distortions, for example vignetting.

The file uses only the Adobe distortion model.

Lidar sensor A lidar (*LIght Detection and Ranging*) transmits and receives short light pulses that reflect off objects in the environment and return to the sensor. The sensors calculate the distance to the objects by measuring the time of flight of the reflections.

Most lidar sensors use infrared light with a wavelength at 905 or 1550 nm so they can reflect off spots on the objects to generate a high-precision 3-D point cloud model of the environment.

Frequency modulated continuous wave (FMCW) lidar sensors are also used in the ADAS/AD development that can calculate the velocity, distance, and reflection intensity of an object.

The continuous wave of light frequency can be varied and the returning wave information can be calculated with the Doppler effect to determine the distance and speed of an object. Radars can also return the velocity, but with a lower resolution and with interference noise due to multiple bounced waves.

Types of lidar sensors

- Flash lidar: Transmits light flash pulses in a diffuse beam to simultaneously illuminate the entire field of view. Flash lidar sensors have no moving parts as they use solid state technology. However, most sensors have a shorter range and a more limited field of view than scanning lidar sensors.
- Scanning lidar: Transmits light in collimated beams. The sensors rotate to cover the field of view.

Scanning lidar sensors contain mechanical moving parts, for example, rotating mirrors and can be negatively impacted by weather conditions, for example, snow, rain, and dust. They can also contain blind spots because of the spaces between the parallel rays.

Typical lidar sensors can rotate 360 degrees at around 1,000 rpm and use a tilting mirror to control the vertical field of view.

Lidar sensor features

- Considers the light sources in the environment.
- Cover a field of view up to 360 degrees on a horizontal (azimuth) plane and elevation angles up to 40 degrees on the vertical plane.
- Range is typically a maximum of 120 meters.
- Detect object materials.
- Emit light in the near infrared range below the visible range of the electromagnetic spectrum.
- More accurate than a laser sensor that illuminate a broader area.
- GPS positioning systems and inertial devices to measure orientation and rotation can be built into a lidar sensor.

Lidar sensor construction

- A telescopic eye lens front end.
- Light transmitter and receiving detector behind the lens.
- Processing unit that calculates the reflected data.

Luminance Luminance is the amount of light intensity from a source that is reflected off objects in the environment, for example, from the sun, moon, or street lighting. The light input from a source is known as illuminance. Luminous intensity can be measured in `candelas per square meter cd/m2`.

Glare is the condition caused by excessive luminance from a light source reflecting off an object, for example, sunlight that reflects off a metal surface. This reduces the visibility of the scene.

In MotionDesk you can adjust the amount of light exposure for each sensor when rendering sensor data for sensor simulation.

M

Material database Materials can be specified with a unique ID and preview color in the material mapping database. This materialmapping.xml database file contains the definitions of the materials mapped to the pixels of the 3-D MotionDesk scene objects and scenery. Using graphics applications, materials are assigned to the pixels of a 3-D object image.

In MotionDesk, you can display the material preview in the scene. The data can also be downloaded to the SensorSim application for sensor simulation.

Material database editor You can add and edit custom materials and the material extended properties in the material database using the MotionDesk material database editor. You can access this dialog from the MotionDesk Home ribbon.

Model and Sensor Interface Blockset The Model and Sensor Interface Blockset provides the Simulink blocks to communicate the simulation data between the simulation, the MotionDesk visualization software, and SensorSim applications for sensor simulation.

In sensor simulation, the blockset transmits the simulation data to the SensorSim application to render the data and to the Environment Sensor Interface Unit (ESI) that splits the data to insert into the specific sensor hardware processors. This is used in raw data simulation. The blockset can also transmits sensor failures to the ESI, for example, pixel failures, and receive sensor feedback and status information.

This blockset must be used for sensor simulations in hardware-in-the-loop (HIL) and software-in-the-loop (SIL) environments.

Monitoring service application The monitoring service application runs on the SensorSim PC to monitor and control the instances of the SensorSim application that run on the SensorSim PC. This is used for sensor simulation.

You use MotionDesk to start, stop, and view the status of the SensorSim applications via the monitoring service that runs on the SensorSim PC.

Motion data Data that describes the movement of movable objects in the scene. The motion data is calculated in the real-time application or PC-based Simulink simulation and transferred to MotionDesk by the MotionDesk services.

MotionDesk Blockset A blockset that provides Simulink blocks to build an interface for a simulation application to MotionDesk. With these blocks you can calculate the motion data and send it to MotionDesk. The MotionDesk Blockset is based on the MotionDesk services.

MotionDesk PC A PC that is used to run MotionDesk. When motion data is transfered from the simulation system using Ethernet, you can use several MotionDesk PC's for visualization if they are connected to the same network. This makes it possible to view the animated scene from different view angles.

MotionDesk service library The MotionDesk service library is used to set up an interface from the simulation application to MotionDesk. The service library contains all the C functions needed for data calculation and communication between the real-time application and MotionDesk when you build handcoded models. If you program in Simulink, you can use the MotionDesk Blockset for connection to MotionDesk or the Model and Sensor Interface Blockset for connection to Sensor Simulation systems and applications.

MotionDesk simulations MotionDesk is used to visualize simulations.

MotionDesk simulation objects

- 3-D objects, for example, a car chassis and wheels.
- Scenario visualization, for example, how the 3-D object follows the road, accelerates and changes gear. These can also be controlled using ControlDesk.
- Instrument signals, for example, scalar values, such as speed, gear changes, yaw and simulation states, such as sensor points.
- Sensor data, for example, sensor points that create a 3-D point cloud image of the scene.

Movable object The movable objects are 3-D geometries which are moved within MotionDesk. Their positions and orientations are calculated from the real-time application.

O

Observer An observer displays the 3-D scene from a specific position in the scene. It displays the 3-D scene from a different perspective.

You can load default observer views, create custom observers and attach each to movable or static objects in the scene. The observers can then move with the scene when the simulation plays.

You can switch between the observers and assign them to the four available views.

Observer and zone navigation There are two available observer navigation modes when working with a 3-D scene.

The observer navigation allows you to move walk and look around the scene with the mouse similar to being inside the scene. You can move around the scene entirely with the mouse and the three mouse buttons. A turbo function allows you to move quickly around larger scenes. You can also easily rotate around an object in the scene in front of the observer.

The zone navigation allows you to move around the scene with the mouse and keyboard. You use the keyboard keys to move the mouse in different directions.

Offline simulation A simulation that runs on the dSPACE PC-based VEOS simulation platform using an offline simulation application (OSA) file. The offline simulation runs on a software-in-the-loop (SIL) test environment. It does not run in real-time. The offline simulation application is built from, for example, vehicle dynamics and traffic models, that calculate the position of objects in the vehicle's environment and to test the ECU algorithms on a virtual ECU on the VEOS platform.

Offline simulation application file (OSA) An offline simulation application (OSA) file is an executable file for VEOS. After the build process with a tool such as VEOS Player, the OSA file can be downloaded to VEOS. An OSA can contain multiple VPUs, each of which contains either a V-ECU or environment VPU. Each VPU runs in a separate process of the host PCs operating system. To perform real-time testing, a service is integrated into the offline simulation application during the build process, refer to Enabling Real-Time Testing for dSPACE Platforms (Real-Time Testing Guide 📖).

OpenDRIVE An open file format that describes road networks including geometry, lanes, or signs. The file name extension is XODR.

Over-the-air simulation (OTA) In over-the-air simulation (OTA), ADAS/AD camera sensors point at an ASM simulation that is displayed on screen in a MotionDesk sensor composition window.

The camera sensors are integrated into a hardware-in-the-loop or software-in-the-loop simulation architecture. They are connected to the ECU and the platform running the Automotive Simulation Models (ASM) that provide the information for controlling the actuators in the simulation.

The sensors for an over-the-air simulation are added to the MotionDesk scene which is downloaded to the SensorSim application to generate the image data to display in the sensor composition window.

P

Pane A separate area of a window, or a separate area of a complex dialog of a software program. A pane can be moved on the entire screen or be docked to a window.

Pitch Pitch is the rotational movement of an object along its lateral (y) axis. Pitch is one of the three movements commonly used to describe the rotation of an object in the Cardan angle system. It is measured with the **Theta Φ** angle.

The axis is drawn from side to side through an object. The object moves by tilting forward and backward along this axis. For example, when you nod your head forward and backward.

The term comes from aviation. A plane controls its pitch movement using the elevators to provide altitude.

Polygon Polygons are defined as shapes, usually triangles with a finite number of straight lines. The straight lines join at the vertices. Polygons are used in computer graphics to form wireframe models of an object surface for 3-D images.

Postprocessing Postprocessing is the manipulation of the images processed by camera and fish-eye sensors in sensor simulation, for example, to change the luminance of the image or add pixel errors and other distortions. The postprocessing of the image is programmed in a dynamic link library, for example, by using the NVIDIA CUDA API. Postprocessing is enabled in MotionDesk for a camera and fish-eye sensor. When enabled, the MotionDesk distortion properties will also be applied before the postprocessing routines.

For laser and lidar sensors, postprocessing is carried out in the background to produce the sensor output modes using the delivered dynamic link libraries.

After postprocessing, the output settings set in the properties for the sensor are applied. The image data can be displayed in the sensor composition window or written to the shared memory.

Project controlbar A controlbar that provides access to projects and experiments and all the files they contain.

R

Radar sensor A radar (*RAdio Detection And Ranging*) transmits short electromagnetic radio waves that reflect off objects in the environment and return to the sensor receiver.

The sensor measures the frequency modulation of the reflected radio waves or rays to determine the distance, angle, and speed of the objects within the range of the sensor.

The wavelength of the electromagnetic radiation is much smaller than typical distances and dimensions of the objects in the scene. The light's interaction with materials must be described in detail and separately for each wavelength.

In ADAS/AD development, radar sensors are typically used for systems such as adaptive cruise control (ACC), blind spot monitoring, lane departure assistant, collision avoidance, and advanced emergency braking (AEB).

Radar sensor features

- Radio waves are used over a longer distance because they are absorbed less by the detected objects than light.
- Radar sensors use millimeter waves, which operate between 24 GHz and 300 GHz.

  Typical frequencies for radar sensors are: 24 GHz and 76 to 81 GHz.
- Radio waves can penetrate some materials but can be affected by atmospheric conditions, for example, fog, rain, snow and dust.

Radar sensor construction

- Radio wave transmitter to transmit rays.

  Rays can be isotropic, where the radiation uses the same amplitude in all directions or directional where the amplitude is varied in specific directions.
- Radio wave antennas to receive reflected radio wave signals.
- Processing unit that calculates the reflected signals.

Radial lens distortion Radial lens distortion is an image distortion where the straight lines of an object appear to be curved. It can be classified into the following types:

- Barrel: An image distortion effect where the image magnification decreases the farther you move away from the center of the image. In barrel distortion, lines that are actually straight curve outward. The image appears to bulge outward.

A **fish-eye lens** has a very wide angle of view that can exceed 180 degrees in all directions. A fish-eye lens is recommended for field of views above 100 degrees. It creates a panoramic or spherical image with a barrel distortion effect. The edges of the fish-eye image are distorted. For more information, refer to fish-eye sensor.

A **rectilinear Lens** has a regular angle of view of up to 100 degrees. It produces an image that matches the image viewed by the human eye. It is also know as perspective lens. It is therefore recommended for smaller field of views.

- **Pincushion**: The opposite of barrel lens distortion. Pincushion distortion is an imaging effect where the image magnification increases the farther you move away from the center of the image. In pincushion distortion, lines that are actually straight curve inward. Telephoto lenses are used to create this effect.

Raw data simulation In raw data simulation, sensor data is inserted into the sensor ECU processors behind the sensor front end.

ADAS/AD sensors are integrated into a hardware-in-the-loop or software-in-the-loop simulation architecture. They are connected to the ECU and the platform running the Automotive Simulation Models (ASM) that provide the information for controlling the actuators in the simulation.

The sensors are added and controlled in MotionDesk for the simulation. The scene is downloaded to the SensorSim application to generate the raw data.

The image raw data or object and target list data from the simulation environment is rendered by the SensorSim application and inserted into the sensor ECU processors behind the sensor front end at various points of the sensor hardware.

The sensor front end and a screen for MotionDesk that displays the simulation in the 3-D scene or in a sensor composition window are not required.

Real-time application An application running in real time on a dSPACE platform. A real-time application can be built, for example, from a Simulink model containing RTI blocks. A real-time application for a SCALEXIO system is built from a real-time model in ConfigurationDesk. To get motion data for animating the movable object, the real-time application must be extended, refer to MotionDesk Calculating and Streaming Motion Data and Model and Sensor Interface Blockset Manual for sensor simulation.

Real-time simulation A simulation that is performed in real-time. It uses a real-time application running on a dSPACE real-time platform. The real-time applications that are built from, for example, vehicle dynamics and traffic models, calculate the position of objects in the vehicle's environment to test the ECU hardware and algorithm.

Reflection Reflection is the return of a transmitted signal or light after it meets an object in the environment. Light ray reflection is an important factor when working with radar and lidar sensors in sensor simulation. The reflection of light of an object can be specular and diffuse.

- **Specular**: The light is a mirror like reflection of a smooth surface in a single angle relative to the incoming angle of the light. The quality of the light and image reflected is higher.

- **Diffuse**: The light reflected or scattered in multiple directions off a surface with a loss of quality in the light or image. Materials can have a high level **Lambertian reflection**. This refers to the level of light scattering off objects, for example, snow or polymer coated surfaces are materials with higher Lambertian reflectance properties . There is equal luminance reflected in all directions.

  Therefore, diffuse reflection does not only occur off uneven surfaces, for example, wood or stone. It occurs of flat surfaces but is defendant on the material properties.

Rendering Rendering is the transformation of 3-D data into a 2-D projection for display on the computer screen to produce a photo realistic effect of a scene. The polygons of a wireframe can be quickly rendered depending the light sources. Ray casting and ray tracing are used for some sensor types.

Ray tracing requires high graphics resources to render and object due to the complexity of calculation the multiple light reflections, refractions and light scattering that occur in a scene. Ray tracing can therefore produce a highly realistic scene.

Roll Roll is the rotation of an object along its longitudinal (x) axis. Roll is one of the three movements commonly used to describe the rotation of an object in the Cardan angle system. It is measured with the **Phi θ** angle.

The axis is drawn from back to front through an object. The object moves by tilting left and right along this axis. For example, when you roll or tilt your head to the left and right.

The term comes from aviation. A plane controls its roll movement with the ailerons to alter the bank angle.

Route A route is defined for a road network in ModelDesk. This is needed for the simulation of the vehicle movement in the road network in the MotionDesk scene.

S

Scene A scene is the term for a virtual 3-D world that includes the environment, atmospherics, objects, observer positions, sensors and lights etc. This is displayed in the 3-D View in MotionDesk.

You can display the 3-D scene from the position of different observers in the scene. There are four views that you can display on the screen at any one time. You can assign different observer views to these views.

For each MotionDesk view, you can also enable pseudo colors, tone mapping, and control the exposure to view objects in the scene that may be hidden. You can also preview the materials from the material database that are used in the objects in the scene.

Scene Navigator The Scene Navigator is one of the MotionDesk panes. In the Scene Navigator you can view or specify the settings of a scene, such as the objects, observers, views, environment, atmospherics, instruments, and sensors.

Sensor composition window An image that contains the simulated sensor data for all sensors. It can be output via HDMI and DisplayPort connections and to SharedMemory. You can view the animation of the sensor simulation or use the animation on a display for over-the-air sensor simulation.

The first row of the data contains the metadata related to the sensors. You can select to display this information in the animation.

Sensor Simulation Sensor Simulation provides a toolkit containing software applications and dSPACE product features for integrating sensors that are connected to the automotive Simulation Model (ASM) into a hardware-in-the-loop real-time environment or into a software-in-the-loop environment using VEOS and a virtual ECU.

Camera sensors can also be used in sensor simulation with the ECU model in an over-the-air simulation by pointing the sensor hardware at a screen that displays a MotionDesk animation of the simulation.

In addition, raw data can be created and postprocessed for insertion directly into the sensor hardware processors. This eliminates the need for the front end of the sensor hardware and an over-the-air screen. Real-world test scenarios, including those hard to recreate, can therefore be easily verified with sensor simulation

MotionDesk is used to configure and download the scene to the SensorSim application to produce the raw data for sensor simulation. MotionDesk can also display the sensor simulation animation on a MotionDesk PC.

Sensor simulation incorporates the following hardware and software:

- Offline simulation or real-time simulation platform
- MotionDesk simulations
- Model and Sensor Interface Blockset
- SensorSim application
- Environment Sensor Interface Unit (ESI) and the ESI Plug-on device (POD)

SensorSim application The SensorSim application generates the data for ADAS/AD sensors that are integrated into a sensor simulation architecture.

The SensorSim application uses the graphics processing unit of the SensorSim PC to generate the raw graphic image data, point cloud image, target list, or object list data for insertion into a the sensor ECU processors or to be displayed on a screen.

The application and download of the scene to the SensorSim application is controlled by MotionDesk.

In raw data simulation, the Environment Sensor Interface Unit (ESI) inserts the data into the sensor hardware processors in a hardware-in-the-loop architecture or into the sensor algorithms in a software-in-the-loop environment.

The rendered image data can also be displayed in a MotionDesk sensor composition window on a dedicated screen for over-the-air simulation (OTA).

SensorSim PC A dedicated computer with a high-quality graphics card that runs the SensorSim application. The SensorSim application uses the graphics processing unit of the computer to generate and render the sensor data for sensor simulation.

The computer is controlled by MotionDesk and therefore does not require a monitor or any input devices.

The computer connects to the simulation platform, for example, SCALEXIO, using an Ethernet connection for hardware-in-the-loop simulations.

The PC connects to the Environment Sensor Interface Unit (ESI) through an Ethernet connection for the transfer of the data to the sensor ECU processors and by HDMI or a Display port to display image data on a screen.

The VEOS simulation platform can can be used for software-in-the-loop testing of the ECU software early in the development phase.

Shading Shading is a way to define the colors on polygons. The simple and advance lighting 3-D shading methods differ in the algorithms used to apply colors to the polygons.

Shared memory MotionDesk images that are calculated for the sensors can be stored in shared memory. This shared memory can then be read and the image data analyzed or further processed for use with sensor simulation. The data can be accessed by other applications, for example, the Environment Sensor Interface Unit. The MotionDesk installation provides a library with the appropriate functions.

Simulation application The generic term for real-time application and offline simulation application. The application runs on a simulation platform.

Simulation model A model that is designed in MATLAB/Simulink for simulating control algorithms or a controlled system. It is a generic term for real-time models or models that are used for offline simulations.

Simulation platform The generic term for real-time systems that calculates the real-time application in real time and simulators that are not connected to a physical system and therefore independent of the real time.

Software-in-the-loop (SIL) test environment A software-in-the-loop (SIL) test environment is a PC-based environment that lets you test algorithms of ECUs or sensors in connection with an offline simulation run on VEOS.

You can perform open-loop testing to test the system under test, for example, the ECU or sensor control unit. For closed-loop test, you can extend the validation to return the resulting data from the system under test to the vehicle and environment simulation that runs on a VEOS simulation platform.

State object 3-D object that has subobjects which can change their look according to a value of a simulation variable.

Static object A static object is a non-movable 3-D geometry (body) in the scene, for example, roads, trees, houses.

T

Terrain generation A feature of MotionDesk to provide an environment for a large 3-D world. It generates a 3-D object for the ground that can base on real world or artificial data. It is possible to embed a road model created by ModelDesk's Road Generator.

Texture mapping In 3-D graphics, texture mapping is the process of adding a graphic pattern to the polygons of a 3-D scene. Unlike simple shading, which applies colors to the underlying polygons of the scene, texture mapping applies simple textured graphics, also known as patterns or more commonly "tiles", to simulate the surfaces of houses, trees, the sky, and so on.

Traffic object An object that can be used as static object on a road network or as a fellow in a traffic scenario. An traffic object is used in simulations for object detection sensors. To visualize a traffic object in MotionDesk, a geometry of a 3-D object is assigned to them.

Trajectory A trajectory is used in the simulation as path along a road when the ASM vehicle must divert from the preferred lanes. The trajectory is created as a shape in a ModelDesk road project. It must start and end at connection points of the road elements or junctions.

Transmission Control Protocol (TCP/IP) The Transmission Control Protocol (TCP/IP) is an Internet communication protocol to connect applications across a network. TCP/IP transmits and receives strings of single bytes with an endless data length that are grouped into packets. The order of the data is retained.

TCP establishes a connection before it sends the packets of data. It also sends and receives acknowledgments for transmitted packets and retransmits packets after a specific timeout period. The connection is closed after a packet is successfully delivered or if an unrecoverable error occurs.

This protocol is used where it is important not to loose any transmitted data.

U

User Datagram Protocol (UDP/IP) The User Datagram Protocol (UDP/IP) is an Internet communication protocol to connect applications across a network. UDP transmits data in a single packet or datagram. It has a limited byte size.

UDP does not establish a connection before sending a packet of data and does not wait for an acknowledgment to confirm that the data was successfully transmitted. The packets can arrive out of order, be duplicated or fail to arrive.

This protocol is used where the loss of some data is not critical to the operation. For example, while transmitting motion data to MotionDesk for an animation.

UTM coordinate system The Universal Transverse Mercator (UTM) is a conformal projection that uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the earth. It not a single map projection. The system divides the earth into 60 zones, each being a 6° band of longitude, and uses a secant transverse Mercator projection in each zone.

V

VEOS A simulator that runs on a PC. It runs an offline simulation application (OSA) without relation to real time.

VEOS Player is the graphical user interface for VEOS.

Vignetting Vignetting is an image distortion effect where the brightness or saturation of an image is reduced around the edges, in comparison to the image center. It can be caused by lens or camera limitations, or by lens interference. The image borders are darker.

Virtual Environment Sensor Interface (V-ESI) The Virtual Environment Sensor Interface (V-ESI) is used in a software-in-the-loop (SIL) test environment for sensor simulation. The V-ESI processes the sensor data generated by the SensorSim application and passes the correct output to the required output, for example, to the virtual ECU customer software.

The VEOS ASM simulation also connects to the customer software using a client-server connection.

Virtual Reality Modeling Language (VRML2) VRML2 (or VRML97) as a text-based language is a powerful yet simple language to build virtual worlds, which include 3-D objects, light sources and animations. The description of these virtual environments is a text file, usually identifiable by its '.wrl'-extension.

W

Wireframe A wireframe is a model of a 3-D object created by joining multiple polygons. Straight lines that form the edges of the object join at points or vertices of the object to form a polygon mesh wireframe. The polygons can be quickly rendered. Wireframes in MotionDesk are mainly used to highlight objects or check the tilling.

Wireframes are used in MotionDesk to display static and movable (dynamic) 3-D objects. You can select the wireframe render mode in the Scene ribbon.

Y

Yaw Yaw is the rotational movement of an object along its vertical (z) axis. Yaw is one of the three movements commonly used to describe the rotation of an object in the Cardan angle system. It is measured with the **Psi ψ** angle.

The axis is drawn from top to bottom through an object. The object moves by turning left and right along this axis, For example, when you turn or rotate your head to the left and right.

The term comes from aviation. A plane controls its yaw movement with the rudder.