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Multiple Ports for Sensors in Simulink

This memo describes how a VS Math Model with multiple ranging and detection sensors can run within a Simulink model using multiple ports (one port per sensor) that are created automatically.

Running the VS Math Models for this example requires a license for the Sensor option.

The multiple-port method is used in an example installed in the CarSim database for an Advanced Driver Assistance Systems (ADAS) system with two radar sensors that can apply emergency brake control. Similar examples are available for BikeSim and TruckSim.

> **Note** This memo is intended describe a method for connecting a VS Math Model with sensors to Simulink. It is not intended for ADAS specialists, and does not go into detail about the control logic of the Simulink model.

Details about target objects and sensors are covered in the document associated with the sensor and target screens, accessed with the **Help** menu for **Traffic, Target Objects, and Sensors**.

The Simulink ADAS Example

The example that will be discussed is a Simulink ADAS model that is used for a scenario with two sensors and two target vehicles. Locate it from the **Run Control** screen with the **Dataset** menu with the category *** More Examples (Extra License Options)** and named **Object Sensors: 2 Sensors, Crossing Vehicles w/ Simulink**.

After locating the example, click the **Video** button to see the scenario (Figure 1). The vehicle has two sensor fields, and the vehicle brakes to avoid hitting one of the moving targets. Close VS Visualizer when you are through viewing the example.

Click the button **Send to Simulink** to view the Simulink model (Figure 2). There are a two things to note about the Vehicle S-Function (4):

1. The S-Function has three output ports.
2. The first port (2) has a single signal. The other two ports (3) each have 21 signals.

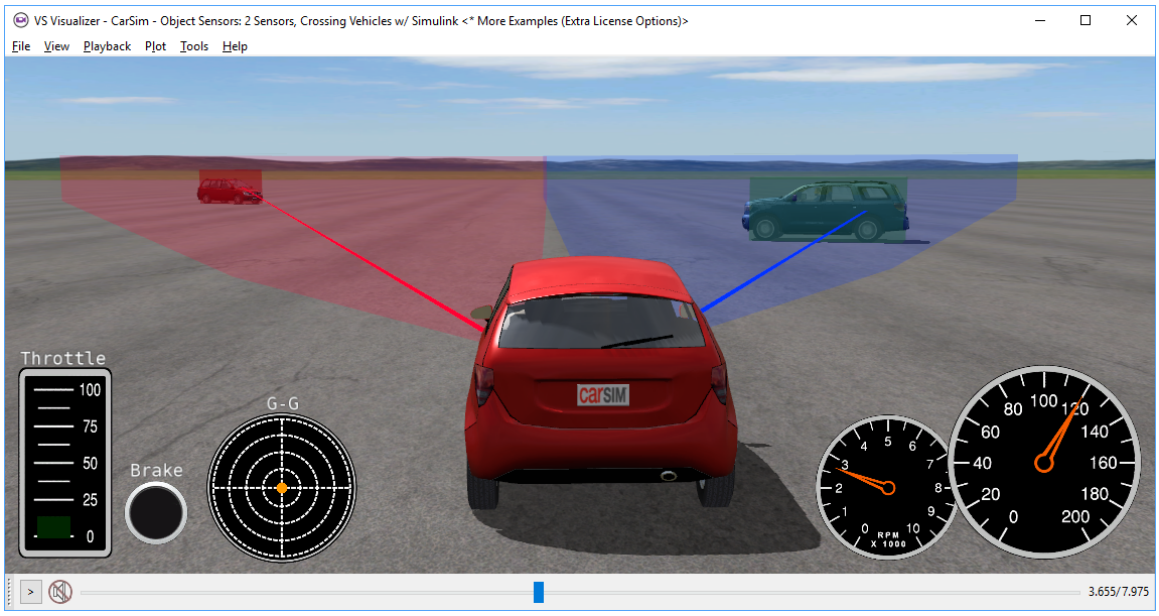

Figure 1. Example ADAS scenario in CarSim involving two sensors and two targets.

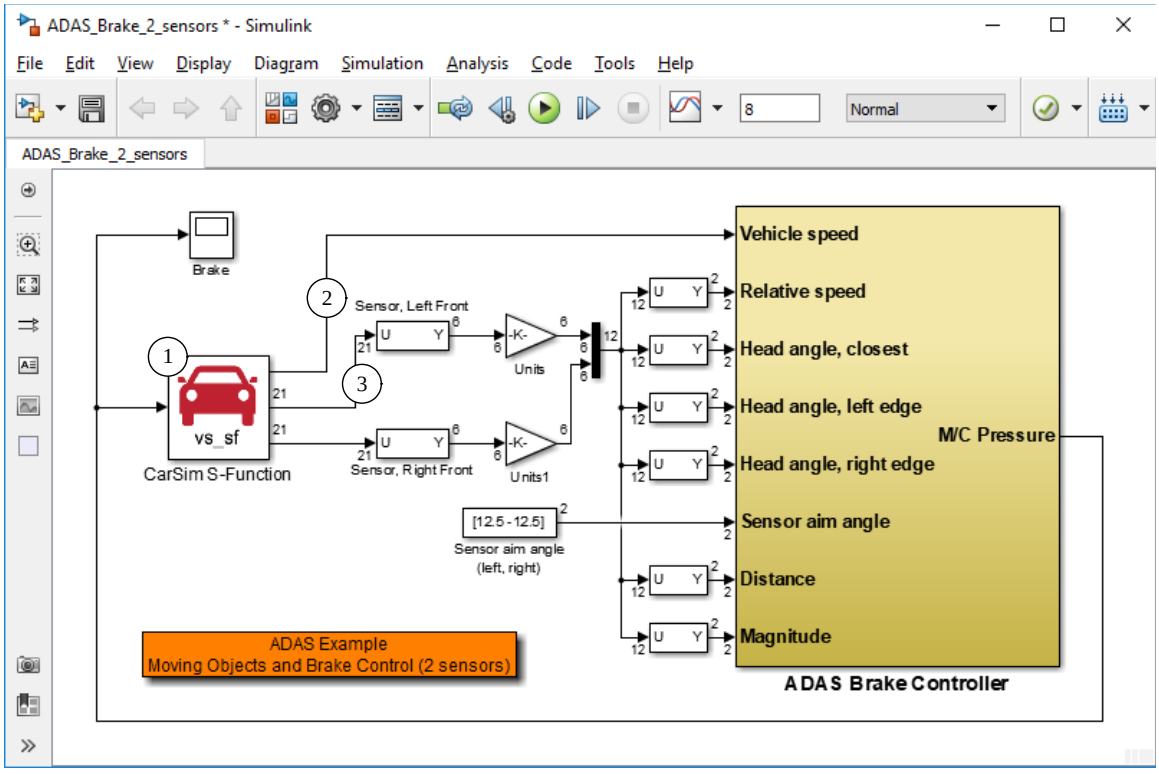

Figure 2. Simulink Model with ADAS Controller for CarSim.

Adding Objects and Sensors

From the **Run Control** screen, go to the **Procedures** screen to see the details of the dataset named **Two Sensors, Two Target Vehicles** (Figure 3).

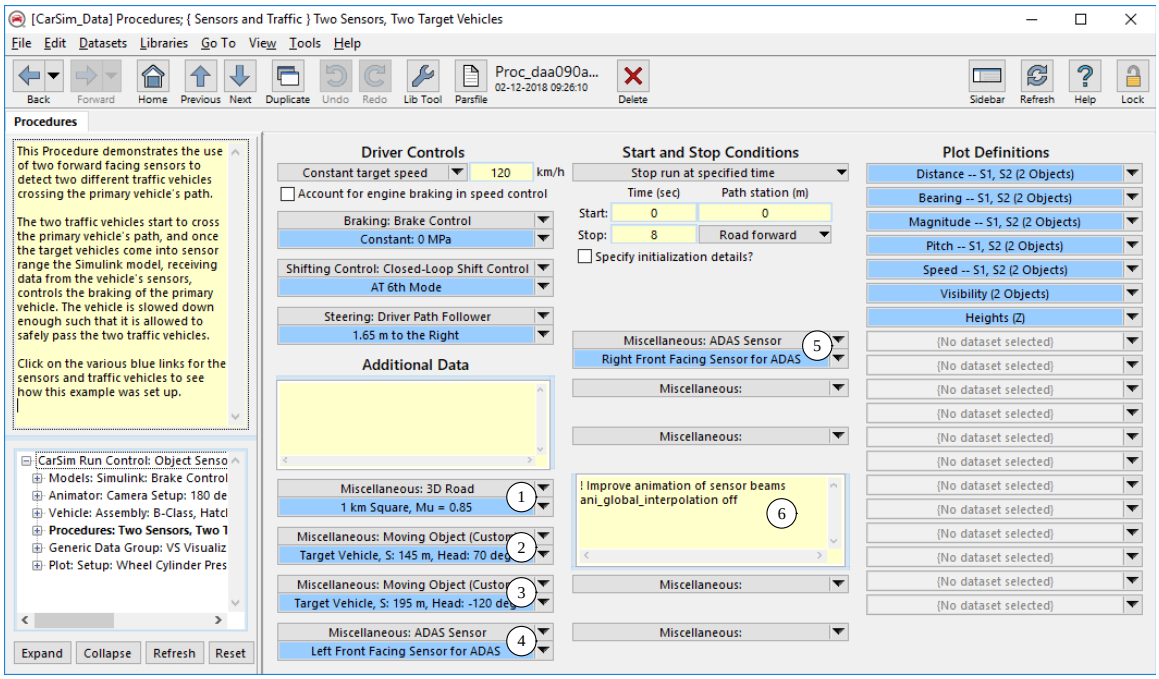

Figure 3. Procedures dataset for ADAS example.

The **Procedures** screen assembles a set of driver controls and other information. In this case, it also includes a road environment (1), motions for two target vehicles (2) and (3), and two sensors (4) and (5). It also includes a setting for VS Visualizer (6) to disable interpolation, to avoid artifacts with animations of detection vectors (the red and blue lines connecting to the closest points of the targets that are visible in Figure 1).

The software supports up to 200 targets and up to 99 sensors. The objects are numbered in the order in which they are defined and so are the sensors. For this example, the first target vehicle (2) is object #1 and the second (3) is object #2. The sensors are also numbered in the order in which they are added, so for this example, the sensor facing to the left (4) is sensor #1 and the sensor facing to the right (5) is sensor #2.

A number of output variables are introduced with each target and sensor. These variables are available for plotting, supporting animation, export to Simulink, and any other functions associated with output variables from a VS solver. In addition, a set of output variables is introduced for each combination of a sensor and target, used to describe the potential detection information. These include range, range speed, bearing angles, etc. In this example, with two sensors and two objects, 88 variables are available that define four possible detections with 22/detection. (These numbers apply for version 2018.0; in general the number of detection variables increases with new releases.)

Sensor Options for Simulink

Click the blue link (4) (Figure 3) to see the dataset for the left-front sensor (Figure 4).

Two of the checkboxes on this screen partly define how information from the sensor is sent to Simulink.

(1) Checkbox to sort objects by proximity.

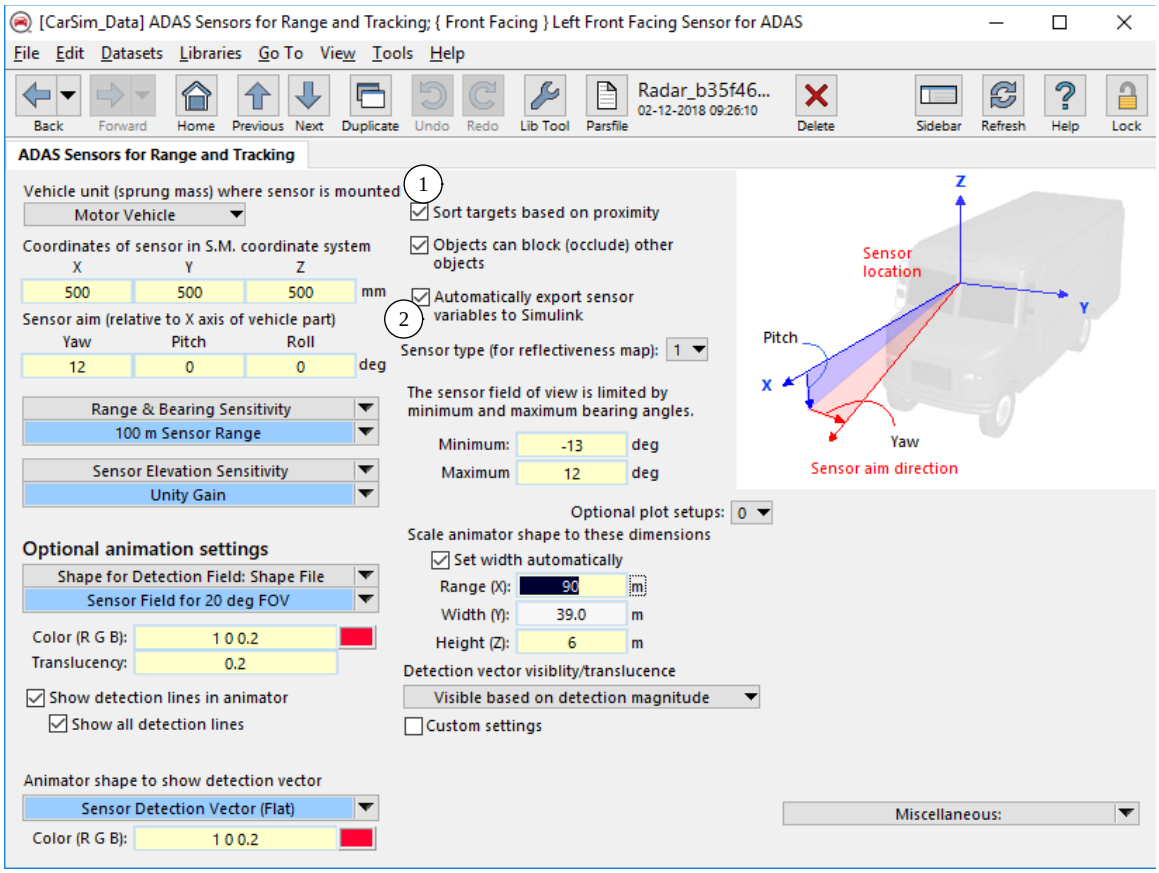

Figure 4. Sensor dataset.

If the box is checked, as in the figure, then the number in each variable name corresponds to the proximity to the sensor; detection #1 is the closest object, detection #2 is the second closest, etc. In this case, the relationships between the objects and the corresponding variable names are dynamically changed depending on the proximity of the objects to each sensor.

If the box is not checked, then the ID number of each detection corresponds to the ID number of an object. In this example, the first specified object is **Target Vehicle, S: 145 m, Head: 70 deg** (2 in Figure 3). Therefore, detection #1 always would correspond to this object, even if it were not the closest.

2 Checkbox to specify whether output variables from this sensor are automatically exported to Simulink.

If you check this option, the S-Function will automatically create an output port for this sensor with a maximum of 101 elements:

$$\text{Number of elements} = 1 + 10 * \min(10, \text{number of objects})$$

where the first element is the sensor ID, and ten variables are included for up to ten target objects. The sensor ID is generated by the order in which sensors are linked. In this example, the first specified sensor (**Left Front Facing Sensor for ADAS**, 4 in Figure 3) is sensor 1 and the next sensor (**Right Front Facing Sensor for ADAS)** is sensor 2.

If the box to automatically export is not checked, then the information from the sensor is not automatically sent to Simulink. Variables related to the sensor are activated for export the **I/O Channels: Export** screen, as is done with other potential export variables.

Each detection has 22 variables; 10 of them are automatically sent to the port.

> **Note** As noted earlier, the number of detection variables has increased with some releases; the number can be expected to grow further in future releases. New variables are not added automatically. The ten variables per detection are the same as when this feature was introduced in version 8.0 (2009).

Although you can specify up to 200 objects (moving or non-moving), the information exportable from each sensor by this checkbox is restricted to the first 10 detections, based on proximity.

Table 1 lists the variables that are automatically put into the port for a sensor when the box is checked. As noted earlier, the first variable is the sensor ID number, variables 2 - 11 are associated with the first detection, variables 12 – 21 are associated with the second, and so on. In the table, the character *i* in the variable name corresponds to the sensor number.

> **Note** Units in the table are cannot be changed.

The Vehicle Solver S-Function Block

The vehicle block (Figure 5) is a Simulink S-Function with several properties that are set dynamically to both represent the vehicle as specified in the VS Solver (e.g., CarSim), and to fit with the signal requirements of the Simulink model. The input port and first output port are the same as the ports that have always been used with VS S-Functions. The settings for these two ports are typically made from the Import/Export data screens.

Output ports 2 to n+1 are dynamically created for sensors with the checkbox (2) (Figure 4) set as described in the previous section. Each sensor has an output that can include up to 101 variables. The VS Solvers support up to 20 sensors, and the S-Function can automatically generate separate ports for each.

Custom Ports

Version 9 (2014) introduced a new S-Function that supported multiple user-defined ports. Called “Generation-2”, the version did not support the automatic port creation for sensor detections. Version 2018.1 replaces the original and generation-2 S-Functions with a single S-Function called vs_sf, which includes the capabilities of both prior versions. If the detection signals listed in Table 1 are adequate, then the automatic generation of one per per detection can be used. For more control, ports can be created interactively (use the **I/O Channels: Ports** library to specify signals for each port).

Table 1. Sensor variables (from checked sensor i) that can be automatically exported.

No.	Name	Units	Description
1	Sensor ID	-	Sensor ID number
2	DisS*i*_1	m	Distance to first detected object (detection #1).
3	SpdS*i*_1	m/s	Speed (rate of change of distance) to first object.
4	MagS*i*_1	-	Magnitude of first detection signal from sensor i.
5	WidS*i*_1	m	Width of detected object by sensor i.
6	BrCS*i*_1	rad	Bearing angle of line to the closest point of object, relative to the direction in which the sensor is aimed.
7	BrLS*i*_1	rad	Bearing angle of line to the left edge of object relative to the direction in which the sensor is aimed.
8	BrRS*i*_1	rad	Bearing angle of line to the right edge of object relative to the direction in which the sensor is aimed.
9	ElS*i*_1	rad	Elevation angle of line to object relative to the direction in which the sensor is aimed.
10	YawS*i*_1	rad	Global yaw angle of line to object.
11	PchS*i*_1	rad	Global pitch angle of line to object.
12	DisS*i*_2	m	Distance to second object detected by sensor i.
…			
last	PchS*i*_n	rad	Global pitch angle of line connecting sensor i to the last object.

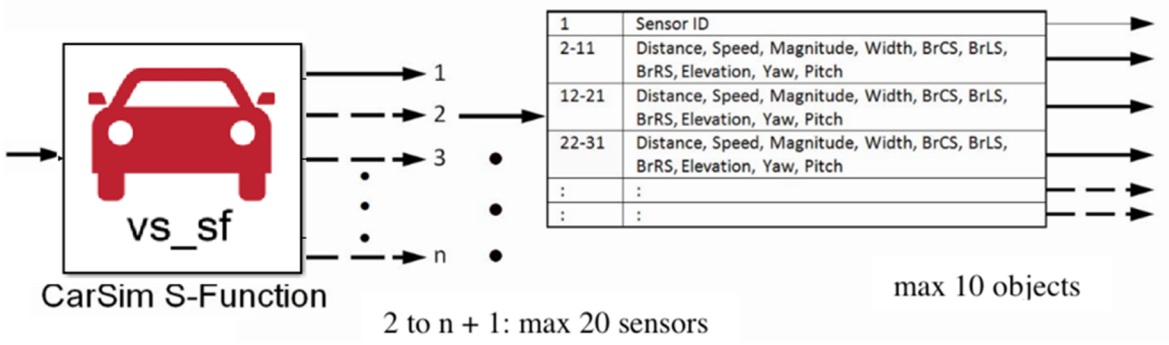

Figure 5. VS Solver S-Function with sensor ports.