

User Manual – Safety Planning Supporting Tool

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Getting Started

Installation

To install the plug-in, start the installation file “SSMPluginSetup-free.exe”.

Note – you will need administrator rights to install the plug-in.

Requirement: Visual Components Professional v4.3 or higher (not included in the installation)

Intended use

This is not a guide to using Visual Components.

This plug-in is intended to help designers and planners of industrial collaborative robotics applications featuring the operating mode Speed and Separation Monitoring according to ISO-TS 15066:2016 to calculate the size of the minimum required separation distance. This is only for industrial robots (not mobile platforms or mobile manipulators).

For more details on the calculations, please see Appendix: Background to calculation of the protective separation distance for Speed and Separation Monitoring.

Using the Supporting Tool

The Safety Analysis Supporting Tool is used in conjunction with a robot in a specific robotics application. Therefore, the starting point is a simulated robotics application in Visual Components (Figure 1).

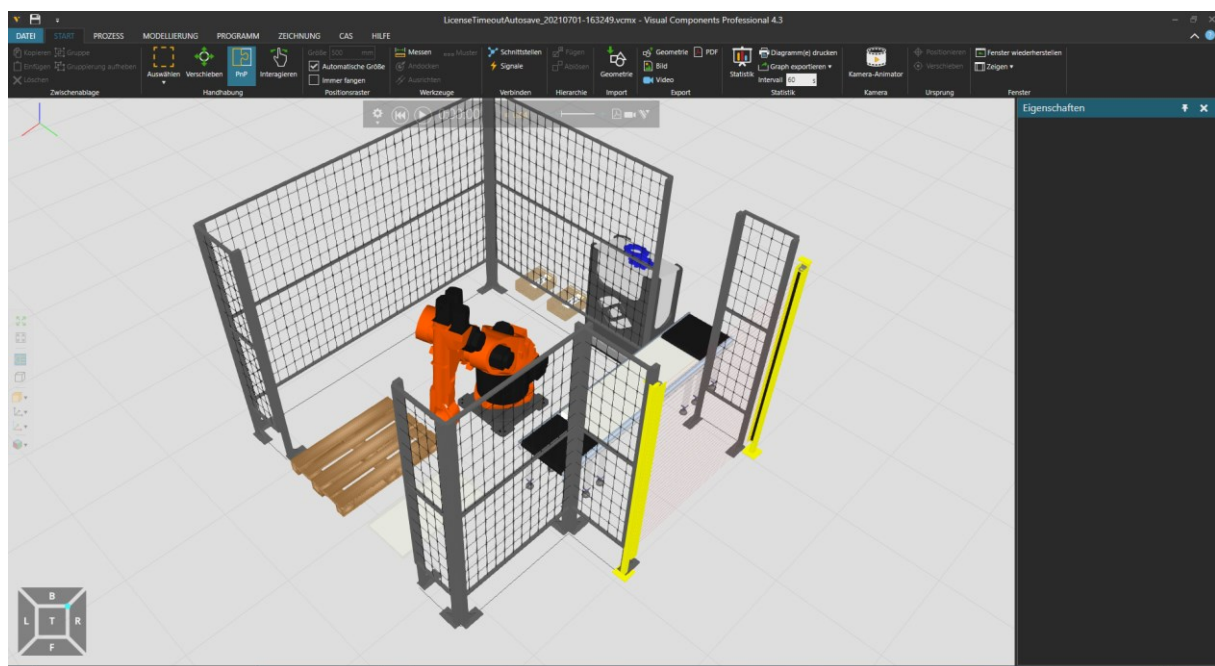


Figure 1: Robotic application in Visual Components - starting situation

The Interface

To access the interface for the calculation of the minimum required separation distance, click on the robot to be analyzed. The “CAS” tab on the right side (Figure 2) shows the robot parameters and the toggle switches for activating the SSM calculation.

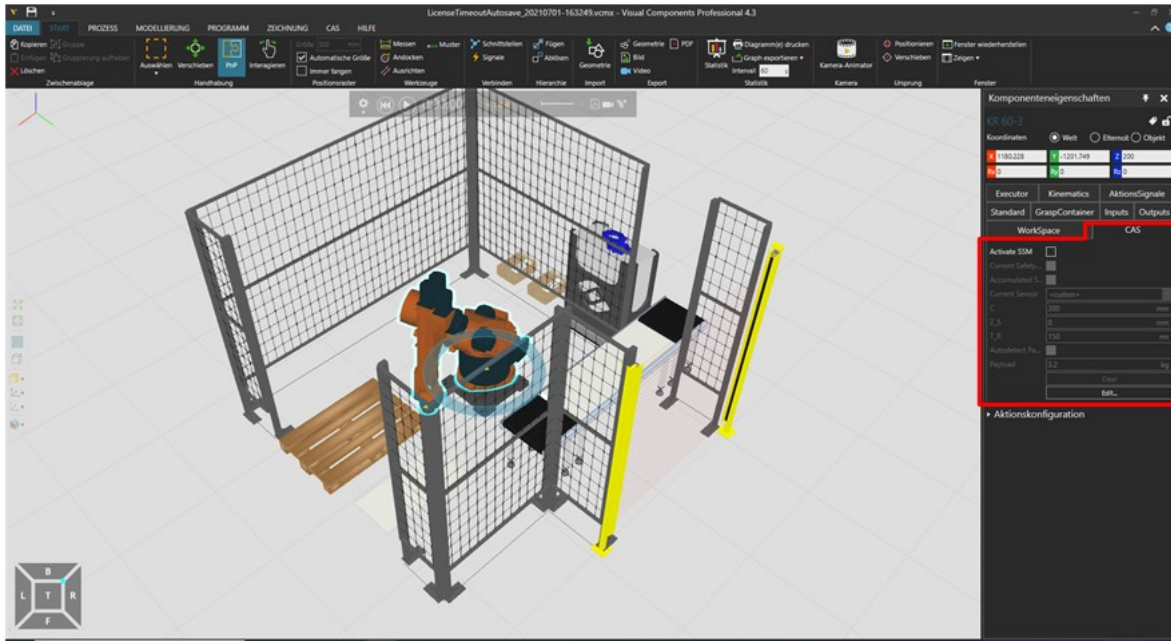


Figure 2: Clicking on the robot opens the Component Description Window (right pane). The CAS tab (highlighted red) has all the controls for the robot parameters and the safety analysis tools.

Figure 3 shows a closer view of the interface and highlights the four main elements. These will be discussed in more detail in the following.

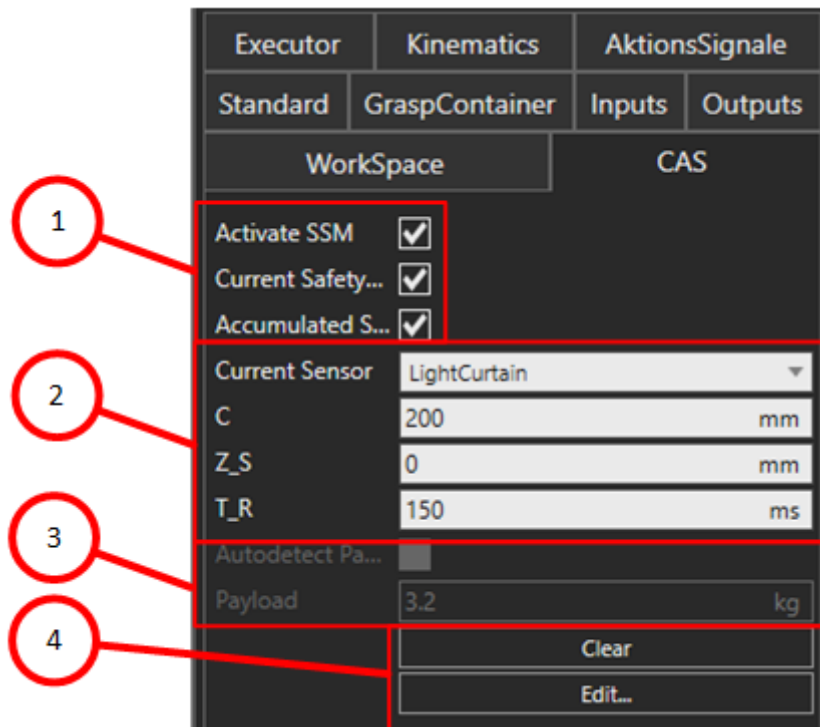


Figure 3: The four main elements of the interface, including 1) Toggle switches for activating the visualization, 2) Sensor configuration, 3) Payload information (not available in free-version), 4) Robot braking parameter editor.

The first toggle switch “Activate SSM” (Position 1 in Figure 3) starts the calculation. The user can then choose to display only the instantaneous safety area “Current Safety Area”, only the accumulated safety area “Accumulated Safety Area” or both (see Figure 4, compare to Figure 2 with toggle switches deactivated).

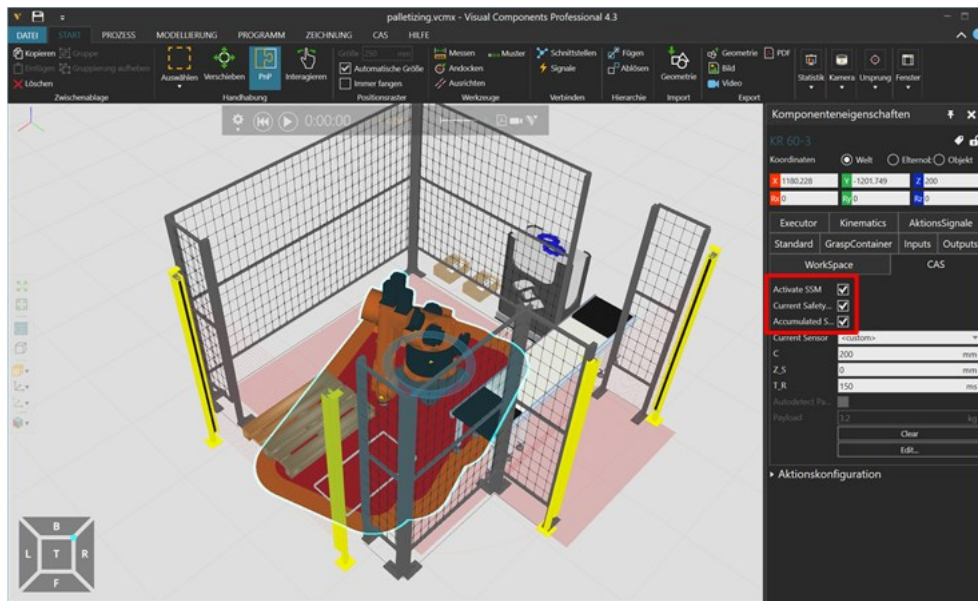
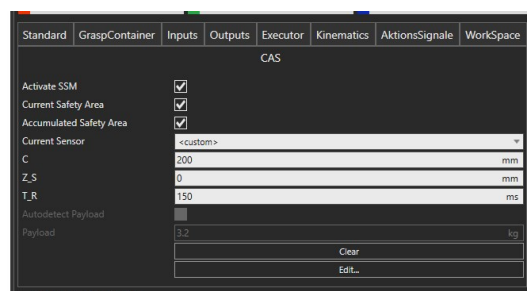


Figure 4: Toggle switches for activating the SSM calculation and the current and accumulated safety areas.

Before starting the simulation, it is important to also include a safety sensor that is compatible with the SSM plug-in (from the folder “components” in the eCatalog). All sensors included in the scene are available in the drop-down menu “Current Sensor”. Choose the sensor that should be used for the calculation of the minimum required separation distance (Figure 5).

Note: As a default, there is always a sensor called “<custom>” that allows for the designer to get started quickly.



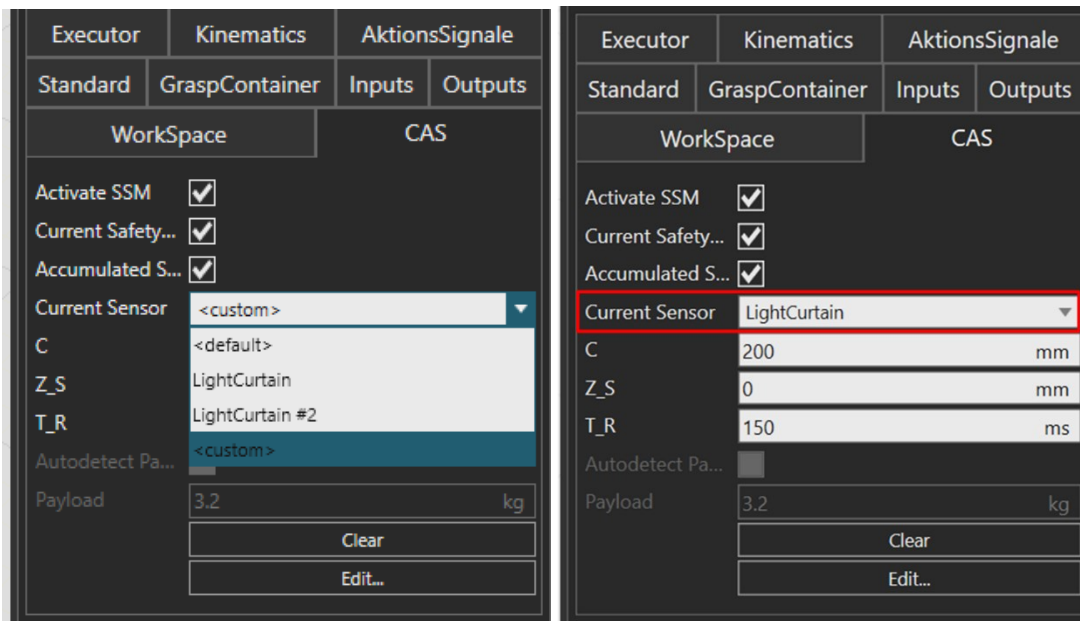


Figure 5: Choosing sensor to use for the safety zone calculation from drop-down menu (left) and the chosen sensor (right)

At this point it is possible to start the simulation. The safety zones (in this case both current and accumulated) are visible on the floor (Figure 6).

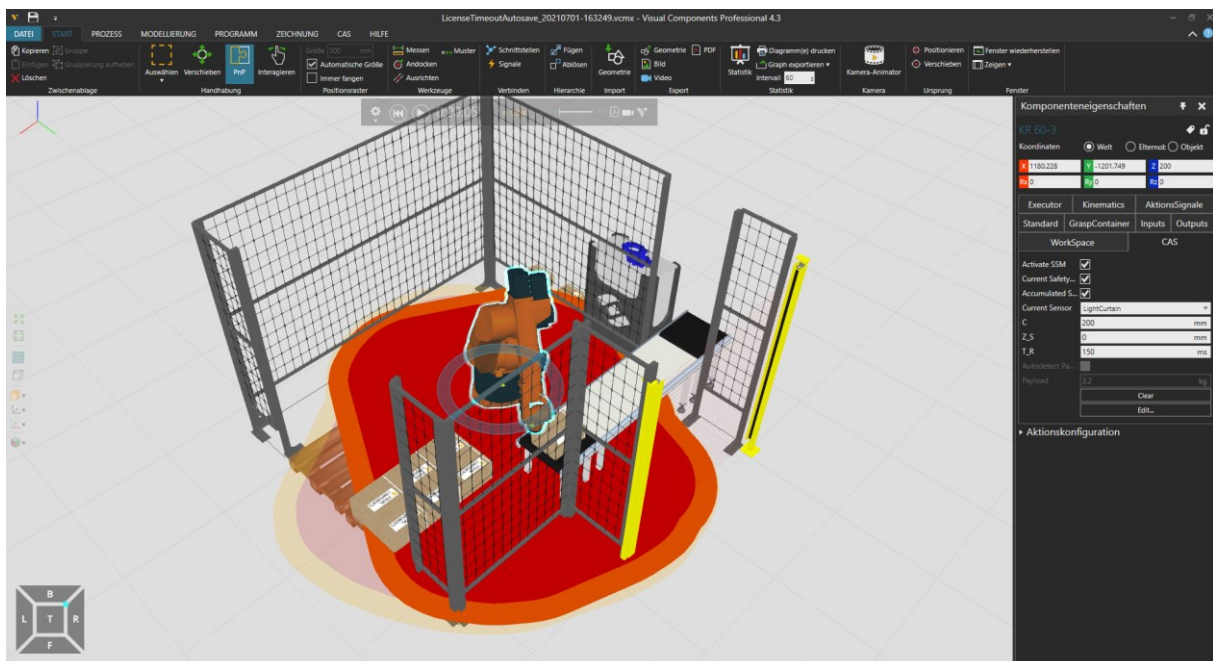


Figure 6: Robot simulation with minimum required separation distance (current in dark red) and accumulated (in lighter red) on the floor.

Parameterizing components

The calculation of the minimum required separation distance is heavily dependent on the parameters of the system elements such as the reaction time of the safety sensor, the type of sensor, the sensor resolution, and robot-specific parameters like the braking time and braking distance of the robot.

In the following sections, the available methods for viewing and setting these parameters will be described.

Robot parameters – braking time and braking distance

The most important robot parameters are the braking time and braking distance. These depend heavily on a number of parameters such as the robot speed, the payload, and the configuration (i.e. how far extended the robot is). Robot manufacturers typically these values for discreet speeds, payloads, and configurations (usually for 33%, 66%, and 100% of the maximum possible value for each of the three parameters).

Adding braking parameters

These parameters are not currently defined in the robot libraries provided by Visual Components, therefore it may be necessary to input these values. This can be done in two ways. To check if the robot has braking time and distance values, click on the button “Edit” at the bottom of the CAS Tab (see Position 4 in Figure 3 and the pop-up window in

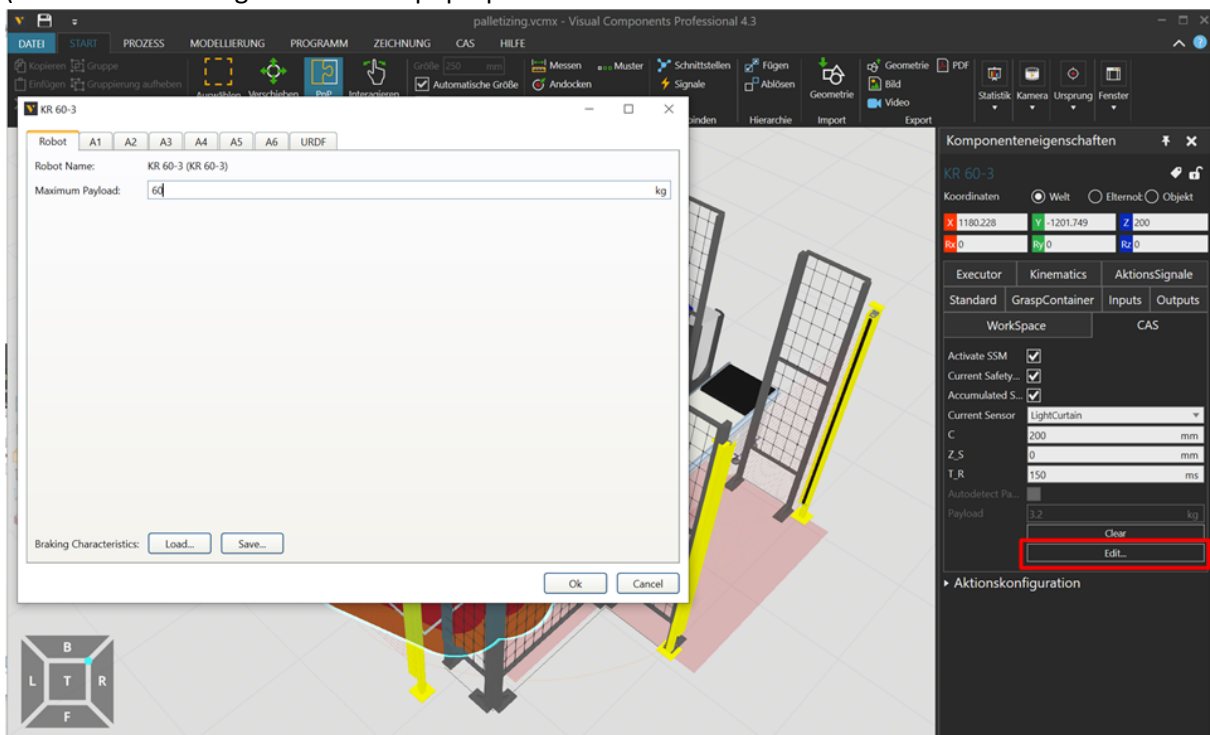


Figure 7).

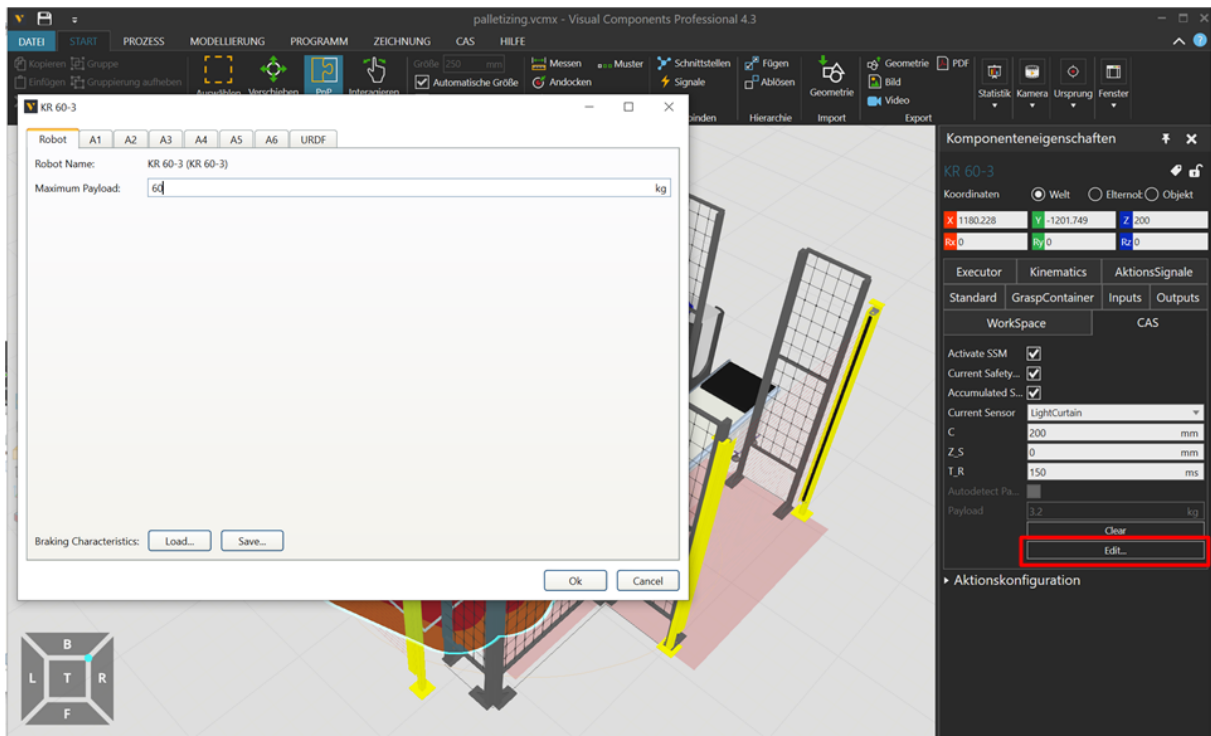


Figure 7: Editing robot braking time and braking distance parameters

The user can then either import or manually input braking times and distances into the pop-up window.

Note: Manual input of braking times and braking distances is considered the “default” option, as these values are likely not available in digital form.

Import

To import braking characteristics from an electronic data sheet using the specified format, use the “Load” button.

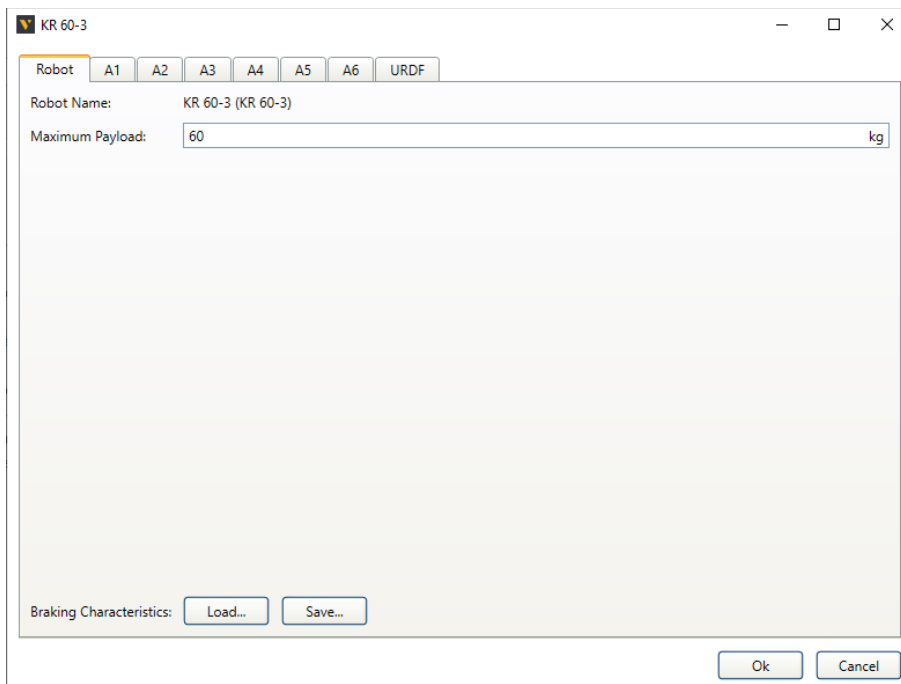


Figure 8: Close-up view of pop-up window for editing robot payload and braking characteristics

The system looks for a DAT-file that is formatted like the default.dat file located in the installation.

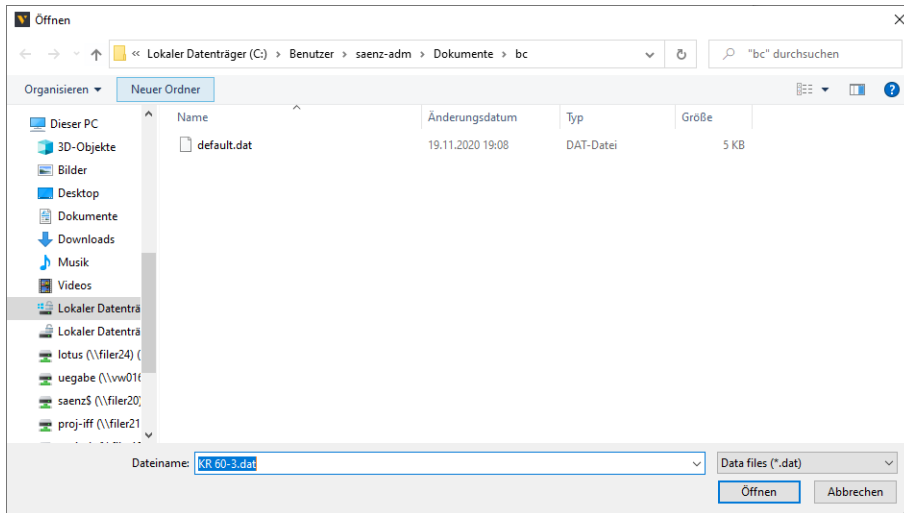


Figure 9: The import function looks for a *.dat file to read.

Manual input

If the user does not have a DAT file available for the robot type they are using (which is considered to be the normal case), it is possible to manually input values per joint. Please note the units, in degrees and seconds. After the user is finished, they need to click on the “Save” button at the bottom of the pop-up window.

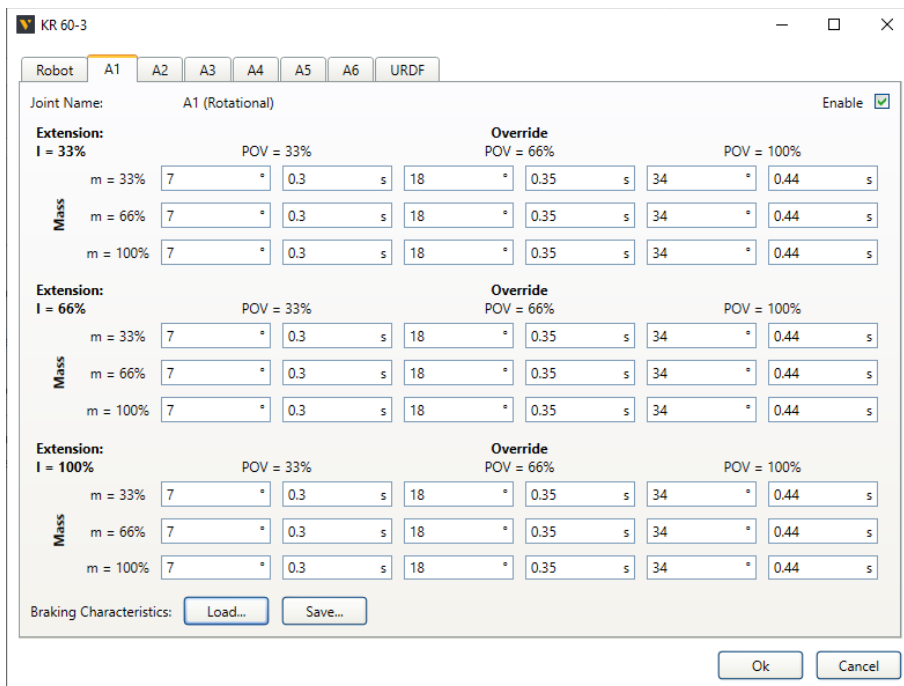


Figure 10: Pop-up window for manually entering braking distances and times per joint (here for joint A1)

Note: There are individual tabs for each of the robot joints (compare Figure 10 with Figure 11).

Note: If no information is available for specific joints (typically robot manufacturers only offer data for the first three or four joints), you can leave those joints blank. The system will automatically use the braking parameters for the nearest robot joint with non-zero values.

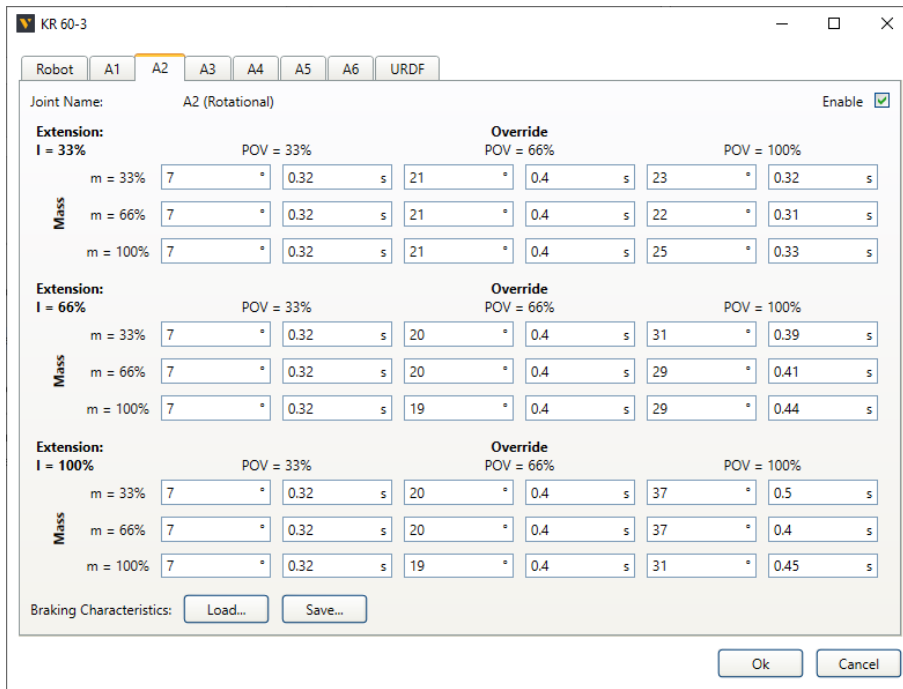


Figure 11: Pop-up window for manually entering braking distances and times per joint (here for joint A2)

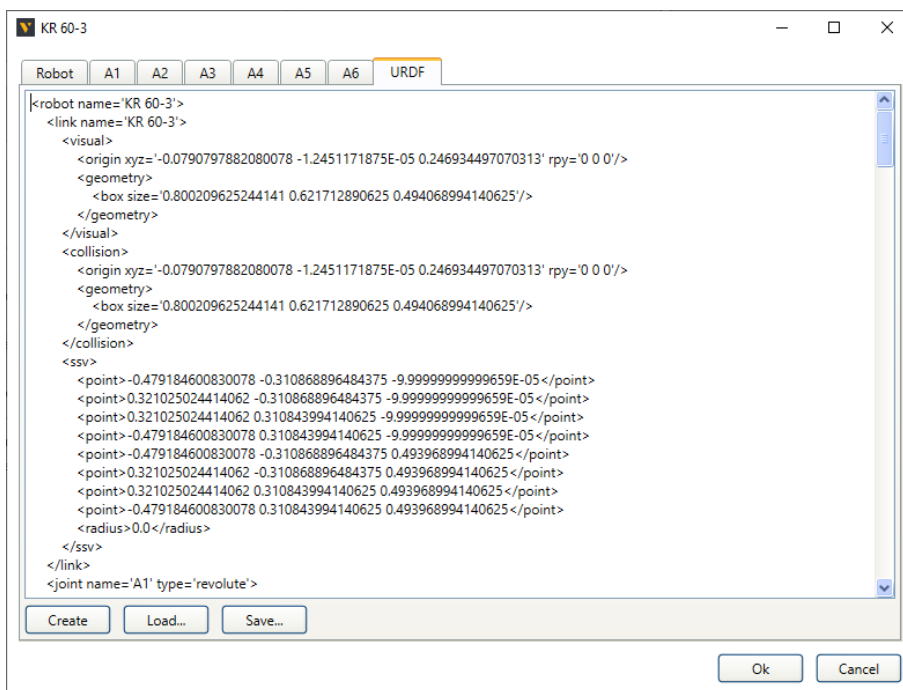


Figure 12: URDF model information for the robot type used. This can also be imported or manually entered.

Note: A URDF file of the robot is automatically generated from Visual Components models. This functionality is for expert users who want to refine the automatically generated values.

Safety sensors

Safety sensors are required in order to calculate the minimum required separation distance. As noted previously, there is a default safety sensor called "<custom>" in case no safety sensor has been inserted into the scene.

Note: While it is possible to insert multiple safety sensors into the application, the calculation of the minimum required separation distance only works for a single chosen sensor. If the user wants to use one sensor for a specific area and another for a separate area, they need to consider each individually.

In this section, we will show how to choose a safety sensor for use in the simulation and give an overview of the different safety sensors that are available for use with the plug-in.

Adding CAS-enabled sensors to the application

In order to add a safety sensor to the application, the user should click on the “eCatalog” tab on the left pane, and then click on the folder that was created during the installation titled “components” (Figure 13). The user will see a number of components including sensors. These can be dragged into the scene and positioned using the normal Visual Components functionality.

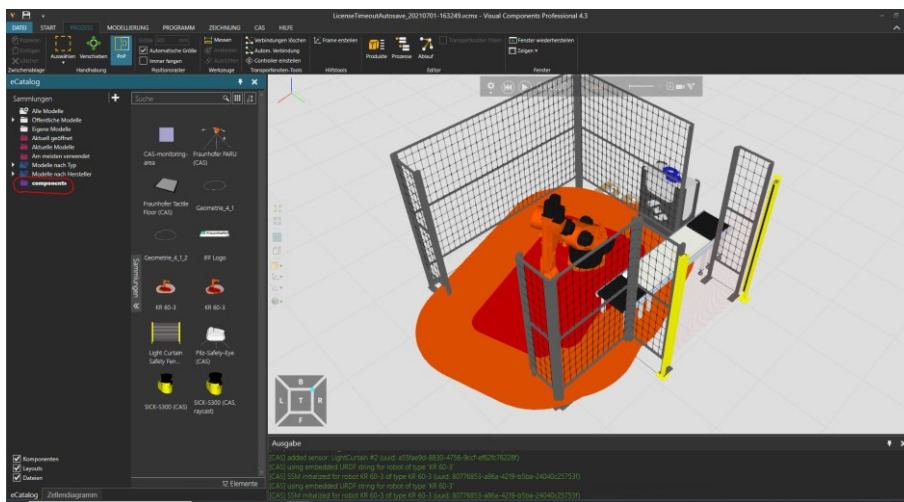


Figure 13: Adding sensors to application that can be used for calculation of safety distance

Changing sensor parameters

The CAS tab (when a robot has been clicked on) shows the chosen sensor parameters (C-Value, Uncertainty, and reaction time). These parameters can be changed for a specific sensor by clicking on the sensor and then editing the values in the CAS tab.

Warning: Changing the sensor-related parameters in the robot CAS tab will not edit the sensor’s values, but will rather change the sensor choice to “<custom>”. To change the sensor’s parameters, click on the sensor and edit the values in the associated CAS Tab (Figure 14 and Figure 15). Use “Enter” to submit the changed parameter.

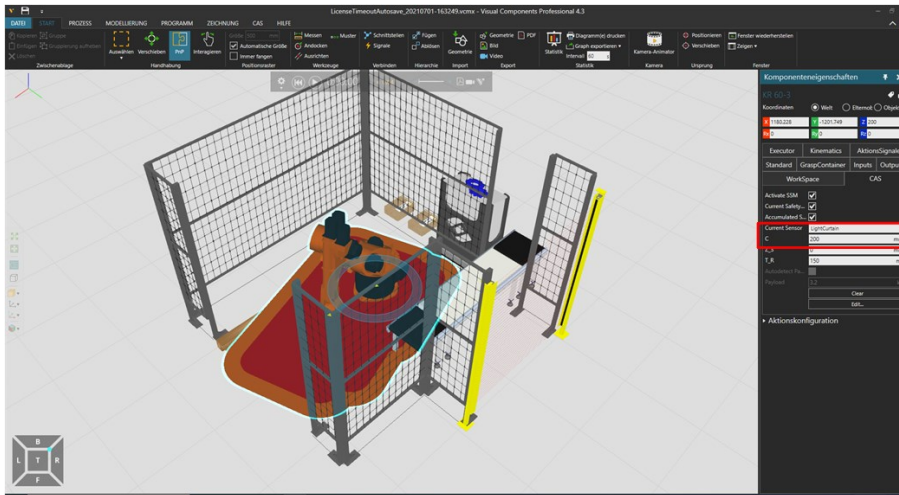


Figure 14: Starting situation - Light Curtain with a C-value of 200 mm chosen for the scenario.

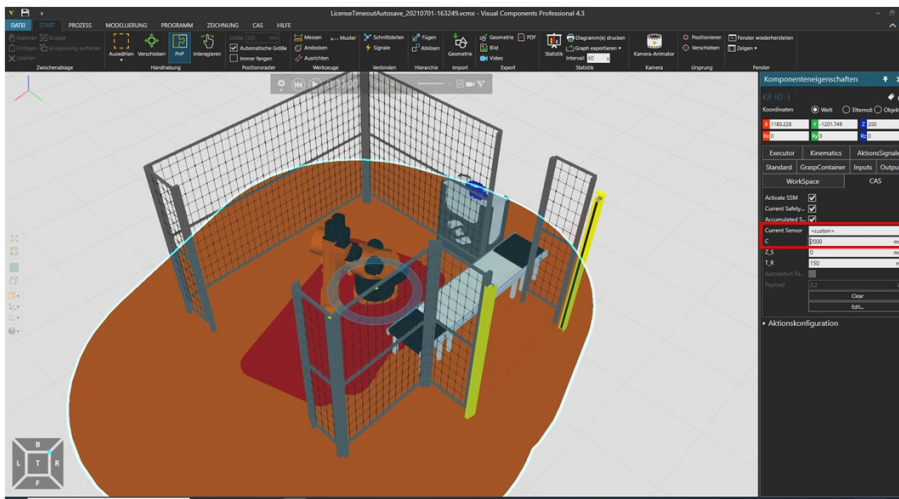


Figure 15: Changing the C-Value in the robot's CAS tab from 200 to 2000 mm switches the Active sensor to "<custom>". The size of the safety zone is updated.

The following sensor types are currently available for use with the safety planning tool:

- Laser scanner
- Light curtain
- Overhead safety camera
- Floor mat
- Combined camera and projector

CAS-Monitoring-Area

The CAS-monitoring-area component in the CAS library can be added to an application to define areas that the robot must not leave ("Workspace") or areas that the robot is not allowed to enter ("Safetyspace").

After inserting a CAS-monitoring-area into an application, the designer typically positions it and defines the size in x- and y-directions (through standard Visual Components functionality).

Clicking on the CAS-monitoring-area and then using the CAS tab on the right panel, the designer can choose between the two types of monitoring area (Figure 16).

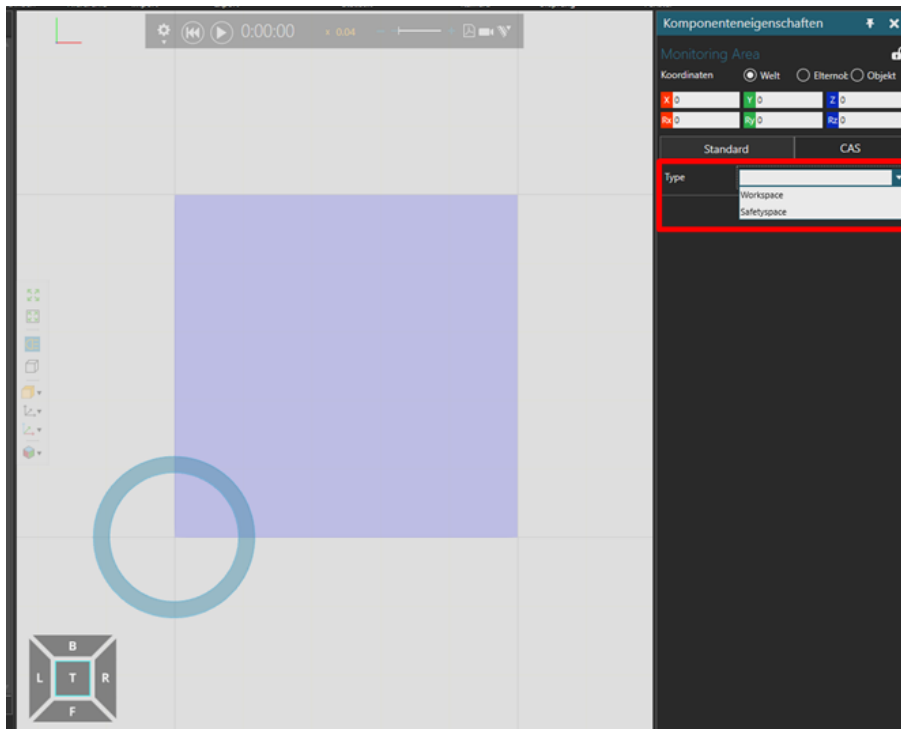


Figure 16: Choosing the type of CAS-monitoring-area in the CAS tab.

Workspace

The option “Workspace” defines an area that the robot is intended to work in. When the robot’s minimum required separation distance leaves the area outlined by the “workspace”, then the CAS-monitoring-area changes color from blue to red. This is simply a tool to help the designer understand the application.

Safetyspace

The option “Safetyspace” defines an area that a human is supposed to work in and that should not be entered by the robot (or its separation distance). When the robot’s minimum required separation distance enters a CAS-monitoring-area designated as Safetyspace, it changes color from blue to red.

Running the simulation

Understanding the visualization

As previously mentioned, the visualization shows the instantaneous and accumulated results of the calculations to determine the minimum required separation distance based on the parameters for the robot and safety sensor. The current version only allows for one combination of robot and safety sensor. As previously noted, when working with fences or multiple entry areas (like in the example in Figure 16), the user will need to execute the simulation for each individual sensor.

The simulation helps understand how specific robotic parameters such as speed and trajectory influence the size of the safety distance. Furthermore, it can help with the placement of safety sensors (e.g. how far away does a light curtain need to be) and it allows for fast testing of various options.

The current version does not automatically configure the safety sensors. As an example, changing the oversampling parameter of a laser scanner (how many cycles are repeated to generate a single signal when an object has been detected) has a large effect on the reaction time of the sensor. The user therefore needs to understand the operating principle of the sensors used in order to choose the correct C-value and cycle time. This information is always available in the sensor data sheets.

FAQs

Glossary

CAS – Computer-aided safety

Appendix

Background to calculation of the protective separation distance for Speed and Separation Monitoring

The time-dependent protective separation distance $S_p(t)$ is given by the following equation (according to ISO-TS 15066:2016):

$$S_p(t) = S_h(t) + S_r(t) + S_s(t) + C + Z_d + Z_r \quad (1)$$

$S_p(t)$ depends on the velocity of the robot, its braking behavior and a couple of time-invariant parameters mostly related to the installed safety sensors that measure the separation distance.

The contribution of the moving human to $S_p(t)$ is $S_h(t)$ and is calculated as follows:

$$S_h(t) = \int_t^{t+T_{rs}} v_h(\tau) d\tau \quad . \quad (0)$$

It depends on the velocity of the human at time t , which is $v_h(t)$, during the stopping duration T_{rs} that is the time the robot needs from detecting the violation of the required separation distance to stopping all joints to velocity zero. The total duration is $T_{rs} = T_r + T_s$, including both the reaction time T_r and the stopping time T_s .

The reaction time T_r is defined as the delay from detecting the violation of the required separation distance to shortly before initiating the brakes. Accordingly, the duration from this particular moment to the one at which all axes reach velocity zero is the braking time T_s . The contribution of the robot movement to $S_p(t)$ is divided into $S_r(t)$ and $S_s(t)$, which represent the displacement of the robot particles during the reaction time T_r and T_s respectively

$$S_{r,i}(t) + S_{s,i}(t) = \int_t^{t+T_r} v_{r,i}(\tau) d\tau + \int_{t+T_r}^{t+T_r+T_s} v_{r,i}(\tau) d\tau = \int_t^{t+T_r+T_s} v_{r,i}(\tau) d\tau \quad . \quad (3)$$

Another contribution of the robot included in (1) is Z_r , which is the position uncertainty of the robot. The influence of the safety sensor is expressed by its non-detectable overreaching distance C and its minimal spatial resolution Z_d also denoted as the position uncertainty of a person in the collaborative workspace.

The plug-in solves this equation for a specific combination of robot and safety sensor.