

SpaVisual User Manual

Steven Boer and Tjeerd van der Poel

2011 Edition, March 14, 2011

Report No. WA-1296

Table of contents

| | |
|---|------------|
| Preface | iii |
| 1 Introduction | 1 |
| 2 SpaVisual Overview | 3 |
| 2.1 Introduction | 3 |
| 2.2 Basic controls | 3 |
| 2.3 Visualization controls | 4 |
| 3 SpaVisual Commands | 11 |
| 3.1 Introduction | 11 |
| 3.2 Options structure interface | 11 |
| 3.3 DAT file interface | 12 |
| References | 23 |

Preface

This is the 2011 edition of the SPAVISUAL manual for the visualization of SPACAR results in MATLAB. The SPAVISUAL MATLAB toolbox is developed at the Laboratory of Mechanical Automation of the Department of Engineering Technology, University of Twente.

The latest version of SPAVISUAL included in the 2011 release of SPACAR, features a graphical user interface unlike previous SPAVISUAL releases. SPAVISUAL makes use of the latest SPACAR functions and is therefore not backwards compatible with older SPACAR releases. A new command style, to adjust visualization options, is also implemented. However, for backwards compatibility with ‘old style’ generated `dat` files, it still supports the old visualization commands from the visualization tool implemented by Jan Bennik.

March 14, 2011,

ir. S. E. Boer (Email: `s.e.boer@utwente.nl`) and dr. ir. G. W. van der Poel.

Introduction

SPAVISUAL is the visualization tool for SPACAR. It is a stand-alone function in MATLAB and can visualize deformation, vibration and buckling modes of 2-D and 3-D mechanisms. It can also visualize over- and underconstraints as well as stresses in beam type elements. SPAVISUAL shows beams, trusses and hinges (among others) in 2-D as well as in 3-D.

For users new to SPAVISUAL, Chapter 2 gives an overview of all SPAVISUAL functionalities and limitations and it explains the use of the graphical user interface.

For the more demanding user, a more elaborate overview of the SPAVISUAL commands and ways to interface with the program, are given in Chapter 3.

SpaVisual Overview

2.1 Introduction

Before a `SPAVISUAL` call can be made in `MATLAB`, a call to the `SPACAR` program must be made first. This requires the existence of a `dat` input file that defines the `SPACAR` model. The output of a `SPACAR` run is stored in `SPACAR` binary data files (`SBF`). These are files with extensions `sbd`, `sbn` and `ltv`. Depending on which `SPACAR` mode is used, the existence of one or more of these files and the input `dat` file, is required to run `SPAVISUAL`. For more information about the different `SPACAR` modes, the reader is referred to the `SPACAR` manual [1]. `SPAVISUAL` can be activated with the `MATLAB` command,

```
>> spavisual('filename')
```

Here, `filename` is the name of the `dat` input file without extensions. Drive or path specifications are not allowed in `filename`, so the `MATLAB` working directory should be set to the location of the `dat` input file.

In Section 2.2, the basic controls of the graphical user interface options are explained. And in Section 2.3, an overview is given of the different visualization modes with their controls.

2.2 Basic controls

The basic controls include: the animation of the `SPACAR` model, the recording of such an animation and how to hide parts of the GUI. In Figure 2.1, these controls are highlighted.

SPAVISUAL MENU

Controls the way the output window is displayed. It has four options,

HIDE UI OBJECTS

Hides the user interface options and controls. Useful for making clean pictures with the GUI controls removed.

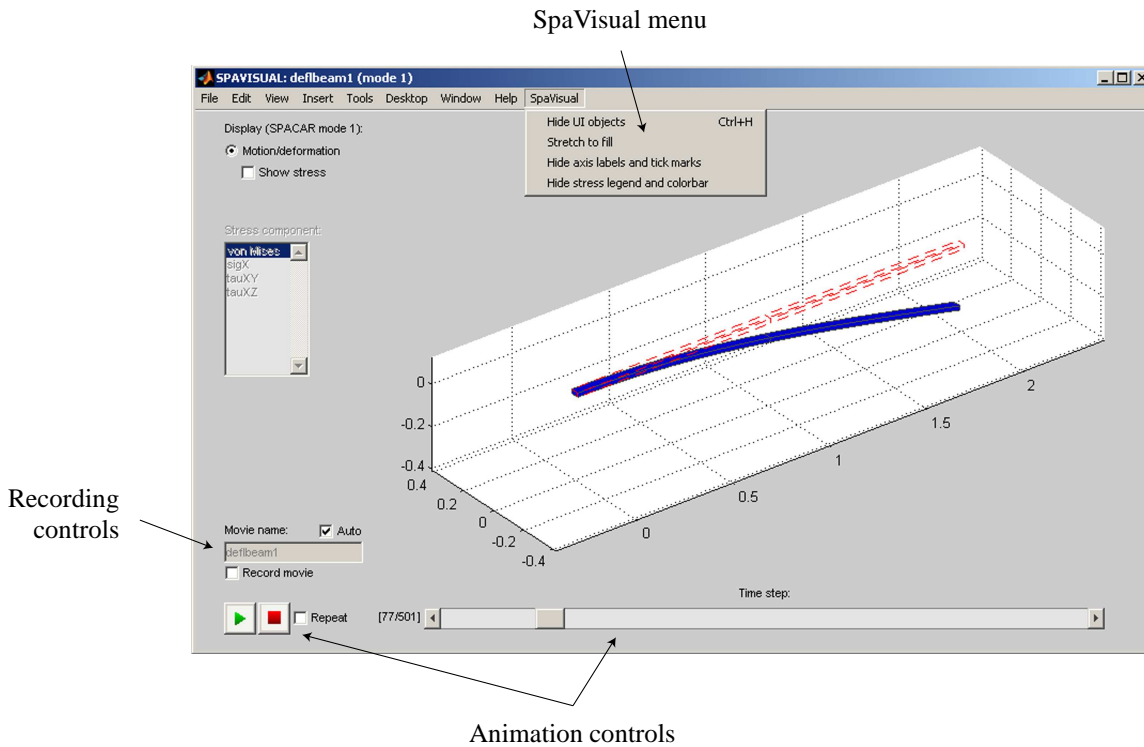


Figure 2.1: The graphical user interface.

STRETCH TO FILL

Stretches the axis to fill all available space. This option distorts the visualization of the model as the axis are generally not square anymore.

HIDE AXIS LABELS AND TICK MARKS

Visualizes only the model without the axes.

HIDE STRESS LEGEND AND COLORBAR

Hides stress information when stresses are shown.

ANIMATION CONTROLS

Controls the animation of the model by PLAY and STOP buttons and a slider. If the REPEAT checkbox is checked, the animation will automatically start again until the checkbox is cleared.

RECORDING CONTROLS

Options for recording a movie can be found here. By checking the RECORD MOVIE checkbox, a movie with the supplied movie name will be recorded once the user presses the PLAY button.

2.3 Visualization controls

Depending on which SPACAR mode is used to run the model, the functionality of SPAVISUAL changes and one or more of the following visualization modes can be selected:

- Deformation
- Stress analysis
- Vibration modes
- Buckling modes
- Underconstraint analysis
- Overconstraint analysis

In Table 2.1, an overview is given of the SPAVISUAL functionality for the different SPACAR modes.

Table 2.1: Overview SPAVISUAL functionality

| Visualization mode | SPACAR mode | Description |
|--------------------------|--------------------|---|
| DEFORMATION | all modes except 0 | Visualizes the deformed configuration as a function of time or per load step. |
| STRESS ANALYSIS | all modes except 0 | Visualizes the selected stress distribution in beam, truss and tube elements. |
| VIBRATION MODES | 3, 4, 7, 9 | Visualizes the selected vibration mode of the system for the current load step. |
| BUCKLING MODES | 8 | Visualizes the buckling mode after a SPACAR mode 8 run. |
| UNDERCONSTRAINT ANALYSIS | 0 | Visualizes the selected underconstraint mode of the system as a vibration. |
| OVERCONSTRAINT ANALYSIS | 0 | Visualizes the selected overconstraint mode of the system as a stress distribution. |

Stress analysis

The stress analysis is available in all SPACAR modes except the zeroth mode. To compute the stresses, first the cross-sectional stress resultants need to be determined. They are denoted by,

$$\begin{aligned}
 &F_x(\xi_x), \quad F_y(\xi_x), \quad F_z(\xi_x), \quad M_x(\xi_x), \quad M_y(\xi_x), \quad M_z(\xi_x), \\
 &\xi_x \in [0, 1],
 \end{aligned} \tag{2.1}$$

where F_x , F_y and F_z are the normal and shear forces, and M_x , M_y and M_z are torsion and bending moments, acting on the cross-section in its local directions at position ξ_x along the elastic line of the beam. The parameter ξ_x is made dimensionless with respect to the original length of the beam. Depending on the type of cross-section, the normal and shear stresses are computed from the cross-sectional stress resultants, resulting in,

$$\begin{aligned}
 \sigma_x(\xi_x, \xi_y, \xi_z) &= \sigma_x^{F_x}(\xi_x) + \sigma_x^{M_y}(\xi_x, \xi_z) + \sigma_x^{M_z}(\xi_x, \xi_y) \\
 \tau_{xy}(\xi_x, \xi_y, \xi_z) &= \tau_{xy}^{F_y}(\xi_x, \xi_y) + \tau_{xy}^{M_x}(\xi_x, \xi_y, \xi_z) \\
 \tau_{xz}(\xi_x, \xi_y, \xi_z) &= \tau_{xz}^{F_z}(\xi_x, \xi_z) + \tau_{xz}^{M_x}(\xi_x, \xi_y, \xi_z)
 \end{aligned} \quad , \quad \begin{aligned} &\xi_y \in [-1, 1] \\ &\xi_z \in [-1, 1] \end{aligned} \tag{2.2}$$

where $\sigma_x^{F_x}$, $\sigma_x^{M_y}$ and $\sigma_x^{M_z}$ are normal stresses caused by the normal force and the bending moments around the local y and z -axis, $\tau_{xy}^{F_y}$, $\tau_{xz}^{F_z}$ are shear stresses caused by the shear forces acting in the local y and z -direction, and $\tau_{xy}^{M_x}$ and $\tau_{xz}^{M_x}$ are shear stresses caused by torsion. The dimensionless parameters ξ_y and ξ_z , represent the location in the cross-section. Supported cross-sectional types in SPAVISUAL are: rectangular, rectangular hollow, circular and circular hollow. In Chapter 3 it will be explained how to change the cross-sectional properties to suit these cross-sectional types. More information about the computation of the cross-sectional stress resultants and stresses can be found in reference [2].

In Figure 2.2, stresses are computed for a deflected beam. A colorbar indicates the stress levels, with its range computed from the minimum and maximum occurring stress for all load or time steps. Also, a stress legend box appears, showing the maximum stress at the current load or time step. The location of this maximum stress is visualized in the model by a red dot. The colorbar and stress legend can be hidden with the option HIDE STRESS LEGEND COLORBAR in the SPAVISUAL MENU.

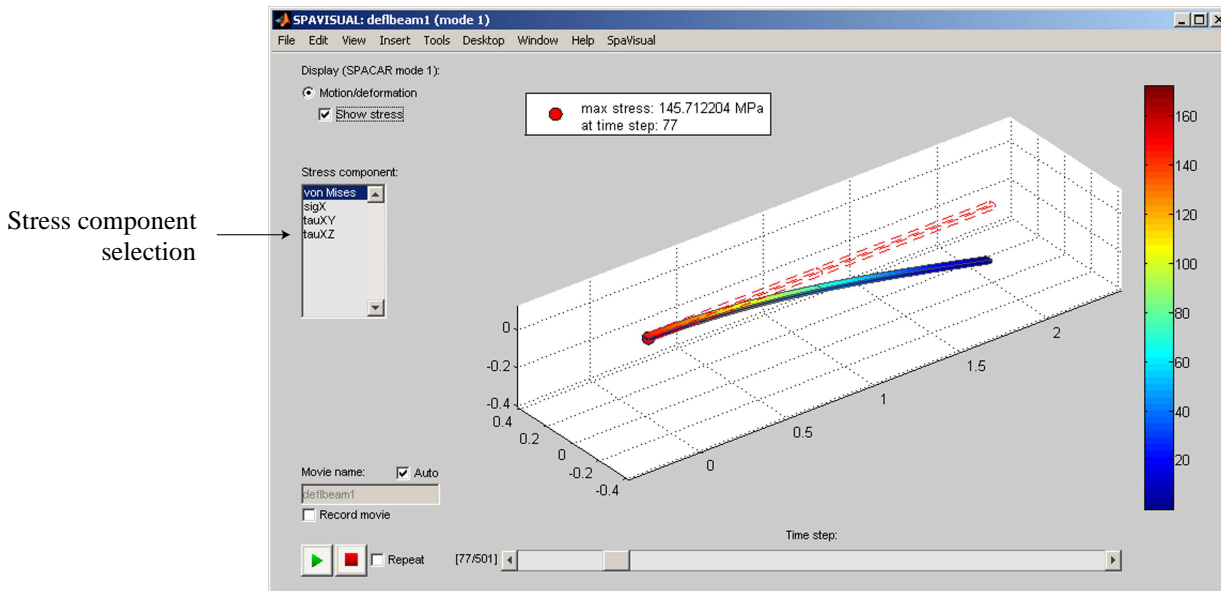


Figure 2.2: A 3D stress analysis.

Depending on the dimension of the SPACAR model, different results are visualized:

2D MODELS

By default, 2D models with beam type elements are drawn by lines. Since cross-sectional data is missing, actual stresses can not be computed. Instead, the cross-sectional stress resultants of Equation 2.1, can be visualized. In the STRESS COMPONENT selection box, the following options are available,

Fres

displays the 2-norm of the force vector along the beam

Fx

displays the normal forces F_x along the beam

- Fy
displays the local y -directional shear forces F_y along the beam
- Mres
displays the 2-norm of the moment vector along the beam
- Mz
displays the bending moments about the local z -axis along the beam

Assuming that the dimensions of the 2D model are supplied in meters [m], the dimension of the colorbar is in Newtons [N] or Newton meter [Nm], for forces and moments respectively.

3D MODELS

By default, 3D models with beam type elements are drawn with rectangular cross-sections. If the user did not explicitly supply the cross-sectional dimensions, default dimensions are used. The cross-sectional stresses of an element are computed with Equation 2.2. The following options, see Figure 2.2, are now available in the STRESS COMPONENT selection box,

- von Mises
displays the stresses computed according to the von Mises criterion
- sigX
displays the normal stresses, σ_x
- tauXY
displays the shear stresses in the local y -direction, τ_{xy}
- tauXZ
displays the shear stresses in the local z -direction, τ_{xz}

Assuming that the dimensions of the 3D model are supplied in meters [m], the dimension of the colorbar is in mega Pascals [MPa].

The user should be aware of the following pitfalls and limitations when interpreting the stresses:

- The computed stresses lose validity near supports or concentrated loads
- Thin walled assumptions are used for circular hollow cross-sections
- During deformation, it is assumed that the shape of the cross-section remains the same
- The cross-sectional dimensions that are used to compute the element stiffness properties in SPACAR, should be the same as the cross-sectional dimensions that are used to visualize the beam type element. For instance, if the elastic constants are computed using a circular cross-section, and the beam is visualized with a rectangular cross-section, incorrect relations are used to compute the stress components in Equation 2.2, which results in incorrect computed stresses.

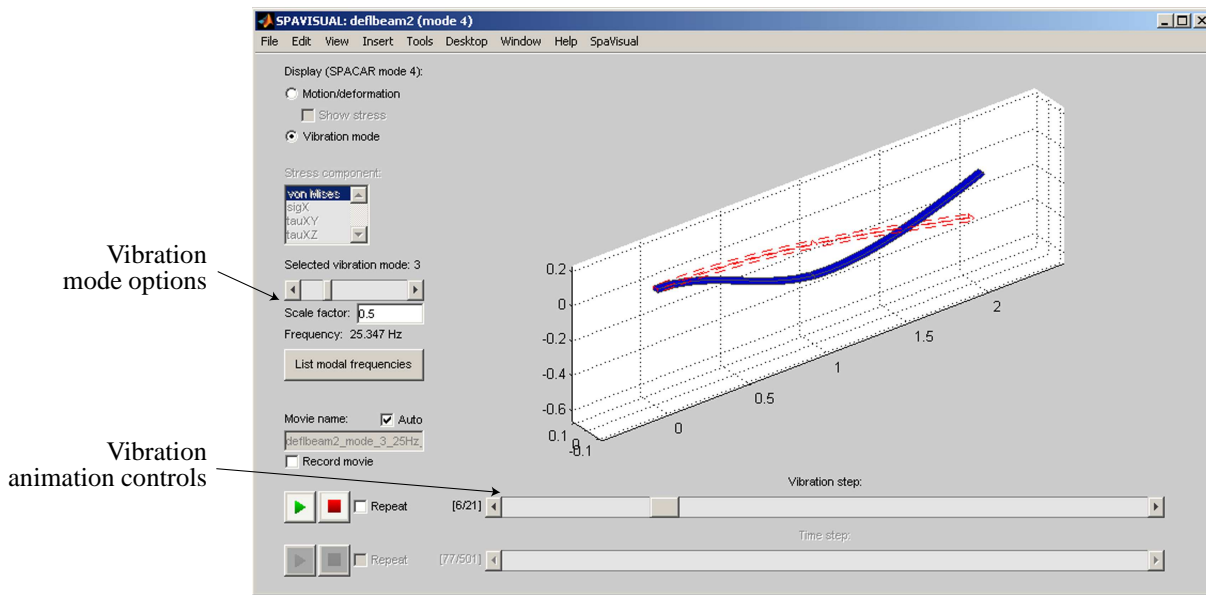


Figure 2.3: Vibration mode analysis.

Vibration and Buckling modes

Vibration modes can be visualized when data, from a SPACAR mode 3, 4, 7 or 9 run, is available. These SPACAR modes use linearization routines to compute the mass and stiffness matrix, M and K , per time or load step. The generalized eigenvalue problem is then solved to find the eigenmodes and eigenfrequencies,

$$Kv = \lambda Mv, \quad \lambda = \omega^2 \quad (2.3)$$

where v is an eigenmode with corresponding eigenvalue λ and eigenfrequency ω .

If the vibration mode analysis is turned on, new controls in the GUI become available,

VIBRATION MODE OPTIONS

Controls which vibration mode is shown. With,

- a slider to selected different vibration modes,
- a user supplied scale factor, to scale the eigenmode,
- a LIST MODAL FREQUENCIES button, to list all eigenfrequencies.

VIBRATION ANIMATION CONTROLS

Controls the vibration animation around the current configuration of the model. The current configuration of the model is represented by the red dotted lines.

When SPACAR is run in mode 8, SPAVISUAL visualizes buckling modes in a similar manner as the vibration modes. For more details about buckling analysis, the reader is referred to the SPACAR user manual [1].

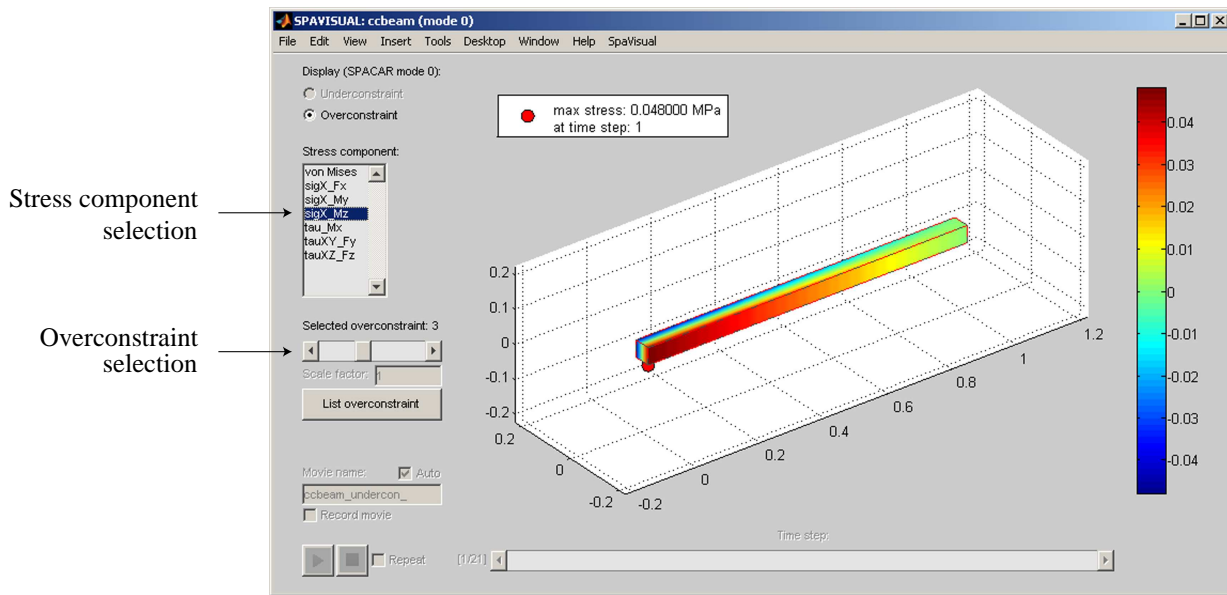


Figure 2.4: Overconstraint analysis.

Over- and Underconstraint analysis

When SPACAR is run in mode 0, it checks whether the supplied model is solvable, i.e. it determines if no over- or underconstraints are present. In SPAVISUAL, these over- and underconstraints can be visualized. This is useful for a designer to achieve an exact constraint design. It also helps the user to build a correct SPACAR model, since these over- and underconstraint tell the user where to add or remove degrees of freedom (DOFs) and releases in the model.

OVERCONSTRAINTS

Overconstraints appear when not enough releases are present in the model. In Figure 2.4, a clamped-clamped beam with no releases is shown. The overconstraint analysis determines that the model is six times overconstraint. To determine how to solve these overconstraints, they are visualized using imaginary stress distributions. The visualization controls for overconstraints are therefor similar to those of a stress analysis. It features a STRESS COMPONENT SELECTION box, where the individual stress components from Equation 2.2 can be selected,

von Mises

displays the stresses computed according to the von Mises criterion

sigX Fx

displays normal stresses, σ_x^{Fx} , caused by normal forces.

sigX My

displays normal stresses, σ_x^{My} , caused by bending moments about the local y -axis.

sigX Mz

displays normal stresses, σ_x^{Mz} , caused by bending moments about the local z -axis.

tau Mx

displays the 2-norm of the shear stresses, τ_{xy}^{Mx} and τ_{xz}^{Mx} , caused by torsion.

tauXY Fy

displays the shear stresses, τ_{xy}^{Fy} , caused by local y -directional shear forces.

tauXZ Fz

displays the shear stresses, τ_{xz}^{Fz} , caused by local z -directional shear forces.

Each stress component listed here is related to forces or moments in the local x -, y - and z -direction. If one of these stress distributions shows no stress, then there is no overconstraint in that particular direction. By looking at the stress distributions that do show stress, the direction and location of the overconstraint can be determined. Placing a release here will then solve this particular overconstraint. As an example, for the overconstraint shown in Figure 2.4, the third deformation component, which corresponds to the bending deformation mode about the z -axis at the p -side of the beam, needs to be released to solve the overconstraint.

An OVERCONSTRAINT SELECTION slider is available to navigate between different overconstraints if more than one overconstraint is present in the model. Also, the LIST OVERCONSTRAINTS button can be used to show which elements in the model have overconstraints.

UNDERCONSTRAINTS

Underconstraints appear when not enough DOFs or fixes are present in the model. Underconstraints are visualized by animating the unconstraint motion. The visualization controls are similar to the vibration mode analysis. If the underconstraint represents a desired DOF in the model, a DOF should be added to indicate it as such. Else, a fix should be added to suppress it.

SpaVisual Commands

3.1 Introduction

Asides from the GUI, there are more ways to interface with SPAVISUAL. Settings can be changed by supplying an additional options parameter when calling SPAVISUAL, or they can be predefined in the `dat` input file. Both methods will be explained in Section 3.2 and Section 3.3 respectively.

The types of settings that can be changed through the options structure or the `dat` file, are

- *Element settings* Includes settings that can change the cross-sectional properties like the element shape and dimensions, and graphical properties such as color and lighting.
- *Animation settings* Controls the way the model is animated. Here among others, figure axis settings and movie settings can be supplied.
- *Mode settings* Controls the way the different visualization outputs behave. Most options given here can also be changed in the GUI.

3.2 Options structure interface

Documentation for these options to come in future releases.

3.3 DAT file interface

To adjust the default settings of SPAVISUAL with the `dat` file, the user can supply commands at the end of the `dat` file after the `VISUALIZATION` keyword. The SPAVISUAL commands are controlled by keywords, which come into two groups: main and sub keywords. The sub keywords define settings related to the first preceding main keyword. The structure of the `VISUALIZATION` block in the `dat` file is then as follows,

```
VISUALIZATION

MAIN_KEYWORD      (arguments)
  SUB_KEYWORD      (arguments)
  SUB_KEYWORD      (arguments)
  ...

MAIN_KEYWORD      (arguments)
  SUB_KEYWORD      (arguments)
  ...

etc.
```

The keywords and arguments can be separated by one or more spaces or tabs, are case insensitive and any keywords following a `#`, `%` or `;` are treated as comments.

In the Sections ahead, the keywords that control the element, animation and mode settings are explained.

Keywords overview

This section provides an overview of all available visualization keywords. Detailed information about these keywords is given in the sections ahead.

Table 3.1: Keywords overview

| MAIN KEYWORDS SUB KEYWORDS | arguments |
|---|---|
| BEAMPROPS CROSSTYPE CROSSDIM NUMSECTIONS SHOWJOINTS | sequence of element numbers rect recthol circ circhol line list of cross-sectional dimensions integer 0 1 |
| TRUSSPROPS CROSSTYPE CROSSDIM | sequence of element numbers rect recthol circ circhol line list of cross-sectional dimensions |
| HINGEPROPS CROSSDIM | sequence of element numbers diameter and thickness |

| | |
|---|---|
| MAIN KEYWORDS SUB KEYWORDS | arguments |
| WHEELPROPS CROSSDIM | sequence of element numbers thickness |
| DONOTDRAW | sequence of element numbers or one of the following strings: beam rbeam tube truss hinge wheel plbelt |
| MESH TOT X, Y, Z, R, PHI | sequence of element numbers integer or: coarse normal fine integer |
| GRAPHICS LINESTYLE LINEWIDTH EDGEALPHA EDGECOLOR EDGELIGHTING FACEALPHA FACECOLOR FACELIGHTING BACKFACELIGHTING AMBIENTSTRENGTH DIFFUSESTRENGTH SPECULARSTRENGTH SPECULAREXPONENT SPECULARCOLORREFLECTANCE OPACITY LIGHTING | sequence of element numbers - -- : -. scalar scalar between 0 and 1 r g b color values, integers flat phong gouraud scalar between 0 and 1 r g b color values, integers flat phong gouraud lit reverse unlit scalar scalar scalar scalar scalar scalar between 0 and 1 flat phong gouraud |
| RANGE | m-by-1 matrix of time or load step indices |
| INITIAL VISIBLE COLOR LINESTYLE LINEWIDTH | 0 1 r g b color values, integers - -- : -. scalar |
| MOVIE MOVIEName RECORDMOVIE AVIType AVIOPTS | string 0 1 matlab videoIO fieldname and value |
| AXISPROPS VIEW LIMITS XLIM, YLIM, ZLIM | az el xmin xmax ymin ymax (zmin zmax) min max |

| | |
|--|--|
| MAIN KEYWORDS SUB KEYWORDS | arguments |
| TRAJECT VISIBLE COLOR | 0 1 r g b color values, integers |
| LIGHT VISIBLE COLOR STYLE POSITION | 0 1 r g b color values, integers infinite local x y z positions, in axes data units |
| USERPLOT | function name |
| MODESHAPE VIBRATION BUCKLING SCALEFACTOR MAXIMUM NUMCYCLES NUMFRAMES | integer integer scalar integer scalar integer |
| STRESS COMPONENT SHOWMAX | mises sigX tauXY tauXZ Fres Fx Fy Fz Mres Mx My Mz 0 1 |
| OVERCONSTRAINT | integer |
| UNDERCONSTRAINT | integer |

Element settings

This section lists the keywords that control the way elements in SPAVISUAL are visualized. The main keyword is given first, followed by its arguments and a description. After which the related sub keywords are listed with their arguments and description.

BEAMPROPS

Sequence of element numbers.

Main keyword for beam element settings. Selects beam elements from the supplied element numbers. Settings from the sub keywords, are assigned to these beam elements only. If no arguments are specified, all beam type elements are selected. Beam type elements are (p1)beam, (p1)rbeam and (p1)tube. Appropriate sub keywords are:

CROSSTYPE

rect (default 3D) | recthol | circ | circhol | line (default 2D)

Determines the cross-sectional type. The specified arguments represent respectively, rectangular, rectangular hollow, circular and circular hollow cross-sections. For 3D models, the line argument forces the element to be represented by a line. This

allows the visualization of the cross-sectional stress resultants, similar to a stress analysis for 2D models. Vice-versa, if for 2D models cross-sectional data is supplied, the stress components from Equation 2.2 can be visualized.

It is not allowed to mix the `line` argument, with the other arguments.

CROSSDIM

List of cross-sectional dimensions.

Determines the dimensions for the supplied cross-sectional type in the beam element local directions. Possible arguments per cross-sectional type are listed below.

Table 3.2: Cross-sectional dimension arguments

| Cross-sectional type | Dimension arguments | | | |
|----------------------|---------------------|----------------|--------------|-------------|
| <code>rect</code> | height | width | | |
| <code>recthol</code> | height | width | inner-height | inner-width |
| <code>circ</code> | diameter | | | |
| <code>circhol</code> | diameter | inner-diameter | | |

For the computation of the stress components from Equation 2.2, the dimensions listed in Table 3.2 are assumed to be supplied in meters.

NUMSECTIONS

integer (default = 10)

Determines the number of sections in which the element is divided. More sections, results in smoother visualization of beams under bending.

SHOWJOINTS

0 | 1 (default)

Toggles the visualization of joints for 2D beams.

TRUSSPROPS

Sequence of element numbers.

Main keyword for truss element settings. Selects truss elements from the supplied element numbers. Settings from the sub keywords, are assigned to these truss elements only. If no arguments are specified, all truss type elements are selected. Truss type elements are `truss` and `pltruss`. Appropriate sub keywords are:

CROSSTYPE

`rect` | `recthol` | `circ` (default 3D) | `circhol` | `line` (default 2D)

Determines the cross-sectional type. See `BEAMPROPS` for more information.

CROSSDIM

Sequence of cross-sectional dimensions.

Determines the dimensions for the supplied cross-sectional type. See Table 3.2 for more information.

HINGEPROPS

Sequence of element numbers.

Main keyword for hinge element settings. Selects hinge elements from the supplied element numbers. If no arguments are specified, all hinge type elements, `hinge` and `pltor`, are selected. Its only sub keyword is:

CROSSDIM

diameter (default = 0.01) and thickness scalar (default = 0.002).

Determines the diameter and thickness of the selected hinge elements.

WHEELPROPS

Sequence of element numbers.

Main keyword for wheel element settings. Selects wheel elements from the supplied element numbers. If no arguments are specified, all wheel type elements, `wheel` and `plwheel`, are selected. Its only sub keyword is:

CROSSDIM

thickness scalar (default = 0.002)

Determines the thickness of the selected wheel elements.

DONOTDRAW

Sequence of element numbers or one of the following strings

`beam` | `rbeam` | `tube` | `truss` | `hinge` | `wheel` | `plbelt`

Determines which elements not to draw. The string arguments, also work for their 2D equivalent elements.

MESH

Sequence of element numbers.

Main keyword for mesh settings of beam type elements for stress analysis. Mesh settings are assigned to beam or truss type elements from the supplied element numbers. The mesh settings determine the number of evaluation points in the elements. The following sub keywords control the mesh settings:

TOT

integer or one of the following strings

`coarse` | `normal` | `fine`

Determines the total amount of evaluation points. The number of evaluation points represented by the string arguments, is different for the 1D line cross-sectional type and the other 2D cross-sectional types, see Table 3.3.

X, Y, Z, R, PHI

integer

Determines the amount of evaluation points in the x-, y-, z-, radial or rotational direction. If one or more of these sub keywords are not specified, values are assigned automatically to have an aspect ratio of about 1 for the distance between the evaluation points.

Table 3.3: Number of evaluation points represented by the string arguments

| Cross-section dimension | coarse | normal | fine |
|-------------------------|--------|----------------|-------|
| 1D | 5 | 50 (default) | 100 |
| 2D | 100 | 1000 (default) | 10000 |

GRAPHICS

Sequence of element numbers.

Main keyword for graphics settings of elements. If no arguments are specified, the graphics settings are assigned to all elements in the model. The sub keywords determine element lighting, color and other graphical properties. Supported sub keywords are:

| | |
|--------------------------|------------------------------|
| LINestyle | - -- : -. none |
| LINEwidth | scalar |
| EDGEalpha | scalar between 0 and 1 |
| EDGEcolor | r g b color values, integers |
| EDGElighting | flat phong gouraud |
| FACEalpha | scalar between 0 and 1 |
| FACEcolor | r g b color values, integers |
| FACElighting | flat phong gouraud |
| BACKFACElighting | lit reverse unlit |
| AMBIENTstrength | scalar |
| DIFFUSEstrength | scalar |
| SPECULARstrength | scalar |
| SPECULAREXponent | scalar |
| SPECULARCOLORreflectance | scalar |

See the MATLAB manual [3] on patch properties for more information on these sub keywords. If the line cross-sectional type is used (default for 2D models), only the sub keywords LINestyle, LINEwidth and FACEcolor function.

Other graphical sub keywords are,

OPACITY

scalar between 0 and 1.

Changes element opacity. This option changes both the EDGEalpha and FACEalpha option simultaneously.

LIGHTING

flat | phong | gouraud

Changes element lighting. This option changes both the EDGELIGHTING and FACELIGHTING option simultaneously.

Animation settings

This section lists the keywords that define animation properties of SPAVISUAL, such as movie options, axis properties, lights etc.

RANGE

m-by-1 matrix of time or load step indices.

Sets the animation range. The `range` keyword accepts any valid MATLAB code defining a row vector, such as:

`2:2:10` or `[1 4 6 ...]`

The indices should be defined in ascending order. If this is not the case they will be put in ascending order.

INITIAL

-

Main keyword for initial configuration settings. For deformation analysis, the time or load step at which the initial configuration is drawn, is by default set to 1 or the first value supplied in RANGE. For vibration analysis, the initial configuration is drawn at the time or load step at which the vibration analysis is activated. Sub keywords that define the initial configuration settings are:

VISIBLE

0 | 1

Toggles the visibility of the initial configuration.

COLOR

r g b color values, integers.

Sets the line color of the initial configuration.

LINESTYLE

- | -- | : | -. | none

Sets the line style of the initial configuration.

LINEWIDTH

scalar

Sets the line width of the initial configuration.

MOVIE

-

Main keyword for movie settings. Movie settings can be changes using the following sub keywords:

MOVIENAME

string

Determines the movie name. This option can also be set in the GUI.

RECORDMOVIE

0 | 1

Toggles the recording option. This option can also be set in the GUI.

AVITYPE

matlab (default) | videoIO (only available if installed)

Determines which recording toolbox to use. By default, MATLAB recording functions are used to generate a movie. However, if the VIDEOIO toolbox is available on the MATLAB path, its recording functions can also be used.

AVIOPTS

fieldname and value.

Sets the avi object properties. Arguments for AVIOPTS are a fieldname with a value. Valid fieldnames for default MATLAB recording functions are:

```
colormap  
compression  
fps  
keyframe  
quality  
videoname
```

See the `avifile` function in the MATLAB manual [3] for more information.

For the VIDEOIO toolbox, see the `videowriter` function for possible fieldnames with values.

AXISPROPS

-

Main keyword for figure axes properties. Sub keywords that define the axes properties are:

VIEW

az el

Sets the viewpoint. See the `view` function in the MATLAB manual [3] for more information.

LIMITS

xmin xmax ymin ymax (zmin zmax)

Sets the axes limits. See the `axis` function in the MATLAB manual [3] for more information.

XLIM, YLIM, ZLIM

min max

Sets the individual axis limits. See the `xlim`, `ylim` and `zlim` functions in the MATLAB manual [3] for more information.

TRAJECT

-

Main keyword for trajectory visualization options. Trajectory visualization is only available if a trajectory is supplied in the SPACAR model. Its sub keywords are:

VISIBLE

0 | 1

Toggles the visibility of the traject.

COLOR

r g b color values, integers.

Sets the line color of the traject.

LIGHT

light object number(s)

Main keyword for light object settings. If no arguments are specified, the settings will be applied to all available light objects. If no light objects exist, one will be created to apply the settings to. The light object settings are controlled by the following sub keywords:

VISIBLE

0 | 1

Toggles the visibility of the light objects.

COLOR

r g b color values, integers.

Sets the light color.

STYLE

infinite (default) | local

Sets the light style.

POSITION

x y z positions, in axes data units.

Sets the light position.

USERPLOT

function name

Adds a user defined plot to the GUI axes. The function name should be a valid m-file available on the MATLAB path. It needs two inputs and one output, such as

```
function funHandles = fun(axesHandle, funHandles)
```

Here `axesHandle` is the GUI axes handle and `funHandles` are the handles of the user defined plots. If in SPAVISUAL, the user defined plot function is called for the first time, `funHandles` will be empty. SPAVISUAL expects the function to return the handles

of the created objects. Note that the user defined function is called every time or load step in SPAVISUAL.

By manipulating the axes properties with the user supplied function, it is possible to dynamically change the viewpoint and other axes settings as time progresses.

Mode settings

This section lists the keywords that control visualization mode specific properties. Most of these options are also available in the GUI.

MODESHAPE

-

Main keyword for vibration or buckling mode related settings. Its sub keywords are:

VIBRATION

integer

Determines the initial selected vibration mode. Can also be changed in the GUI.

BUCKLING

integer

Determines the initial selected buckling mode. Can also be changed in the GUI.

SCALEFACTOR

scalar

Sets the scale factor. Can also be changed in the GUI.

MAXIMUM

integer

Determines the maximum number of computed mode shapes.

NUMCYCLES

scalar

Scales the amount of cycles the mode shape is animated.

NUMFRAMES

integer

Sets the amount of frames used to animate one mode shape cycle.

STRESS

-

Main keyword for stress analysis related settings. Its sub keywords are:

COMPONENT

mises (default) | sigX | tauXY | tauXZ | Fres | Fx | Fy | Fz | Mres | Mx | My | Mz

Determines the initial selected stress component. Can also be changed in the GUI.

SHOWMAX

0 | 1

Toggles the visibility of the max stress location.

OVERCONSTRAINT

integer

Determines the initial selected overconstraint. Can also be changed in the GUI.

UNDERCONSTRAINT

integer

Determines the initial selected underconstraint. Can also be changed in the GUI.

References

- [1] Aarts, R. G. K. M., Meijaard, J. P., Jonker, J. B., *SPACAR User Manual 2009*, Technical Report WA-1180, University of Twente, Faculty of Engineering Technology, Mechanical Automation Laboratory, March 2009.
- [2] Boer, S. E., Aarts, R. G. K. M., Brouwer, D. M., Jonker, J. B., Multibody Modelling and Optimization of a Curved Hinge Flexure, In The 1st Joint International Conference on Multibody System Dynamics, Lappeenranta, Finland, May 25-27, 2010.
- [3] The Math Works Inc., *Getting Started with MATLAB*, version 7, Revised for MATLAB 7.1 (Release 14SP3), September 2005.