Development of a SIMPACK User Routine for Dynamic Light Rail Vehicle Gauging Simulations

Gero Zechel, Michael Beitelschmidt (TU Dresden)
Helmut Netter (Bombardier Transportation)
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Gauging basics
- Vehicles have to fit the structure gauge / minimum clearance outline
- Vehicles may not touch platforms or catenary masts
- Vehicles may not touch in two-way traffic

Challenges
- Complex kinematics and dynamics of modern LRV
- Huge variety of vehicle configurations
- Unique infrastructures in cities worldwide

Target
- Flexible and efficient method to simulate the dynamic vehicle envelope
- Embedded in full-scope MBS simulations in each vehicle development phase

Questions
- Which additional inputs are needed?
- How can the dynamic vehicle envelope be described and calculated precisely during simulation?
- What outputs are needed and valuable?
Vehicle shape

- The contour is described at relevant cross sections (horizontally and vertically)
- *Input functions* can be used to describe cross sections (vehicle width over length or height)
- The position and orientation can be defined by *Body Fixed Markers*

Model integration

- *SIMPACK User Result Element* written in Fortran
- *Result Elements* of this Type can be included multiple times for each needed cross section in the model
- Full GUI Integration in *Model Setup: Input Functions and Markers* can be picked from Drop-Down-Menus
- *Result Elements* run offline in the *Measurement* stage
- They are called beforehand, at each measurement step and afterwards
Memory allocation

- *Result Elements* can allocate memory via *SIMPACK Access Functions*
- It is persistent during the full measurement run

Four data arrays are used

1. global and persistent variables
   track length, step sizes, data structure dimensions etc.

2. time-domain data set
   absolute positions at certain time steps, used for visualization and for sanity checks

1. infrastructure related data set
   reference system is a grid on top of the track centerline, updated at each measurement step

2. vehicle related data set
   reference system is the vehicle x- or z-axis, updated at each measurement step
Algorithm for each measurement step

- Scan contour functions in mm-steps
- Calculate isys-position of each of these contour points
- Determine the distance to the plane on top of the track centerline

- **Update infrastructure related data**
  - Match the measured distance to one square of the grid on top of the track centerline
  - Check if a new maximum distance is observed at this grid field
  - If so, store this value and the index of the responsible contour point

- **Update vehicle related data**
  - Check if a new maximum distance is observed for this contour point
  - If so, store this value and the index of the track point where the distance is reached
Filtering infrastructure related data
- Dimension of the output data can be reduced by condensing maximum distances over multiple grid fields
- By condensating fields vertically, maximum distances from the track centerline can be gained
- By condensating fields horizontally, conventional plots of the structure gauge of longer track sections can be gained

Postprocessing
- The calculated one-dimensional output vectors can be easily plotted in the SIMPACK Postprocessor
- There, the results of all cross sections of a vehicle can be overlayed
5 Output examples

- Simple five-car kinematic model (left)
- Maximum distance of the first three cars from the track centerline is plotted
- It can be easily determined
  - which car takes the most space
  - where along the track the most space is needed
Finding the causes

- The indexes of the contour points that are responsible for the maximum distance can be plotted in the same figure.
- It can be determined what contour point causes the maximum distance from the track centerline at each point of track.

Dynamic vehicle outline

- The maximum distances in the vehicle related data set can be plotted beside the static contour.
- Critical contour points are getting apparent.
Top-down view
- The absolute positions of the vehicle contours can be plotted using the time-domain data set.
- The example plot shows the contours of the first three cars at certain time steps.
- Together with the track centerline and the dynamic envelopes of the cars, this visualizes the overall kinematics.
Plotting safety margins

- The dynamic envelope can be plotted projected onto the ground
- This can be highly useful when analysing two-way traffic situations
Conventional gauge

- The structure gauge / minimum clearance outline can be gained from the same data set
- This example shows the influence of a wind load on a straight track
6 Conclusion

- Seamless integration of a gauging tool into SIMPACK achieved
- By using Result Elements, Input Functions, Body Fixed Markers and Output Channels it can be used throughout SIMPACK (Model Setup GUI, Databases, ParVar, SIMPACK Postprocessor)
- High precision in calculating and storing the dynamic envelope
- Low CPU time and low memory footprint
- Gauging simulations are feasible throughout vehicle development
»Wissen schafft Brücken.«