PARADYME
Vehicle Analysis and Design using Dedicated Computer Models

Introduction
The Vehicle Dynamics department of TNO Road-Vehicles Research Institute in the Netherlands is involved in modelling and simulation projects. Manufacturers of road-vehicles and vehicle research institutes are using expertise and experience from TNO in the application of complex and accurate computer simulation models of a large range of road vehicles.
Simulations are typically used for validation of product performance and dynamic analysis of vehicle behaviour and is becoming more and more important in the development of new products. In this respect it is used as an evaluation and optimization tool during product development.

From frequent discussions with industrial partners, a number of conclusions were drawn with respect to the use of simulation models:
- Designing and constructing in exchangeable components has a high priority in product innovation,
- Given the current complexity of products, product optimization demands for an advanced calculation support. Simulations are gaining more acceptance in offering a feasible solution to this demand,
- Flexibility in adjusting calculation programs to the in-house company situation is considered an important feature,
- Vehicle models must give a detailed description of the suspension components. This places a heavy constraint on making economically feasible models.

The above considerations have motivated TNO in developing a modelling method using a model component database with strict separation between model component parameters and model component topology.

Modelling and Simulation from a database
Significant improvement of modelling efficiency is gained by a library of vehicle component models. The structure of this library allows for easy removal, modification or introduction of new parts to be developed for a specific user. As a result, each individual user receives a minimal set of components required for creating his models.
The product is called PARADYME which stands for PAramatrised Rational Assembly of DYnamic Model Equations ().
It is defined as a software layer around the simulation program BAMMS, an in-house development of TNO and the Delft University of Technology. As BAMMS interprets macros stored in ASCII files, new program features are introduced or removed as easy as moving files.

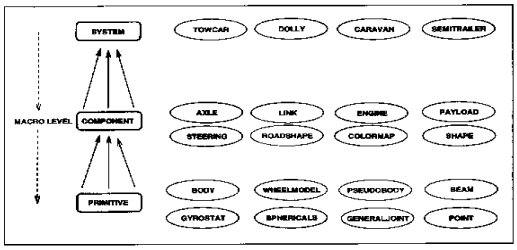

Figure 1:
Hierarchical structure of PARADYME models

Design philosophy
A number of macros are defined in a hierarchy of model components. With these macros, models of vehicles and vehicle combinations are defined and stored in an intelligible hierarchical approach. Each level in this hierarchy is supported by data structures containing vehicle component parameters.
The defined levels in the higher keys are:
- In the top level macros, complete vehicle body units are modelled. Each system defines an unique reference frame and can be used to carry a number of components,
- The component level contains typical vehicle components such as axles, engines and connections to other vehicle systems. Each of the existing components may have a varying number of component types. For instance, the axle component can be used to define different axle type models varying from a simplified rigid axle to a fully geometrical described air spring axle,
- All model components are defined using primitives. Primitives are macros already defined in BAMMS. Sample primitives are a Body, Beam or WheelModel.

Each level in the macro hierarchy is supported by data files defining parameters for each part of a complete vehicle. Parameter data files define numerical and textual data to be stored in a PARADYME model. Thus, all model parameters are available on-line and can be viewed using the hierarchy within the vehicle system. All parameter data files are written in a text editor format to be included automatically in ready to publish model documentation.

Modelling approach and features
A short summary of features in PARADYME models:
- Full non-linear three dimensional body dynamics is described using Newton-Euler equations,
- Simulations are performed in stand-alone Fortran 77 programs made with the symbolic modelling environment,
- Models contain all equations to describe the static and dynamic behaviour of the vehicle system.

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- All model parameters (such as stiffness, damping, inertia, geometry, initial values and interpolation spline tables) can be viewed and adjusted before, after, or during a simulation,
- Simulations can be executed interactively and in batch. Simulation models inherit the modelling program user interface,
- Both modelling and simulation sessions offer a number of debugging tools,
- The range of analysis tools includes:
- Direct graphical feedback using wire frame animation with full user access,
- X-y plotting using any model variable in a variety of layouts and (user defined or automatic) scales,
- Eigenfrequency analysis, root-loci calculation and mode visualisation,
- Fourier analysis on any signal generated in the simulation or on measurement signals,
- Time domain simulation using both fixed step integrators and variable step integrators with automatic error control.
- Tyre slip behaviour is modelled using the latest dynamic version of the Magic Formula,
- User defined macros can be defined and utilized 'on the fly' to automate complex analyses. In , frequency transfer functions are used to obtain a comfort index based on accelerations in a passenger bus,
- PARADYME models are available on MS-DOS and on UNIX (Silicon Graphics) hardware platforms.

Price and Conditions

The price is depending on the amount of work to be carried out, as PARADYME will be more or less tailer made. TNO will stay the owner of the program and the accompanying documentary. A user licence of PARADYME is bought under the conditions as settled in a software licence agreement.

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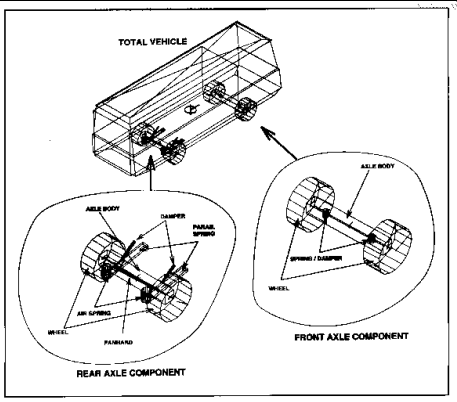

Figure 2:
Model of a bus indicating system, component and primitive levek

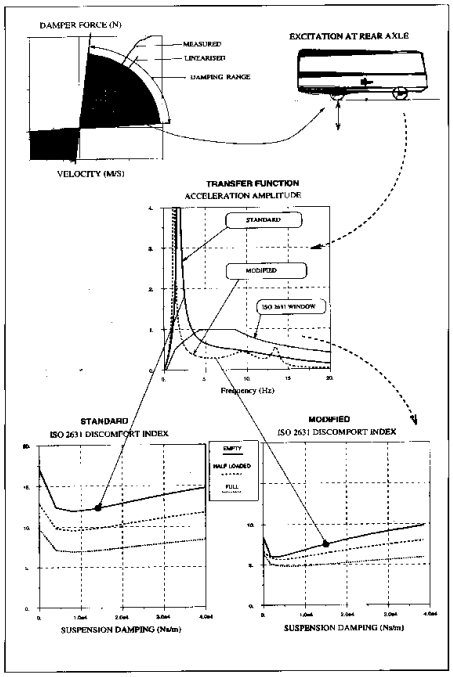

Figure 3:
Example of a fully automated frequency domain type of analysis

The TNO Road-Vehicles Research Institute forms an integral part of the Netherlands Organization for Applied Scientific Research (TNO), an independent contract organization with a staff of over 4.200 employees. The TNO Road-Vehicles Research Institute provides a comprehensive range of R&D and consultancy services covering road vehicles and related components and offers clients access to the wealth of knowledge expertise and facilities.

The Vehicle Dynamics Department carries out research into road-vehicles for many leading industrial companies, government authorities and other institutions such as consumer organizations. The main fields of interest are:
- vehicle handling and control,
- tire-road contact,
- smart vehicles,
- modelling and simulation of the behaviour of vehicles,
- transport problems of the disabled,
- the performance of light vehicles.

The joint research group, the Delft Vehicle Dynamics Research Centre (DVR) composed of scientists and engineers of the TNO Road-Vehicle Research Institute and the Delft University of Technology is engaged in fundamental and applied research on the dynamic characteristics of road vehicles.

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