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Contact Mechanics Computing & Consulting

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Subject	Student assignments and internships with respect to the CONTACT software

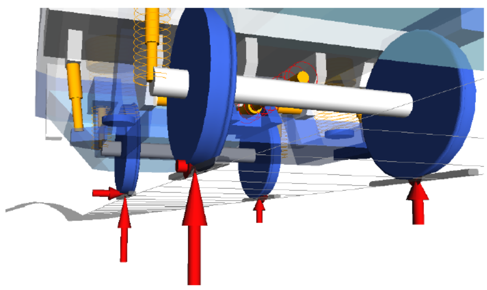
1 The company

VORtech is a Delft-based engineering company, specialized in the development of high quality computational and simulation software. This software is used in areas such as water management, process industry, geophysics, air pollution, traffic and climate models. The company was founded in 1996 and curently holds 25 employees.

2 The application area

Frictional contact mechanics is about the detailed forces and deformations that occur between two objects that are pressed together in rolling motion. Technologically important examples are the interaction between railway wheels and rails and between different rollers in printers and copiers. Questions that are addressed concern for instance

- the risk of derailment of trains, their dynamic motion and ride quality,
- analysis of wheel and rail wear and crack development, as function of the wheel and rail geometry,
- in the case of printing devices: image quality and paper feed problems.



The CONTACT software is designed to analyze such problems. It was developed by professor Kalker of Delft University of Technology and is considered among the world's best methodologies in the field. VORtech acquired the software in 2000 and is actively extending and commercializing the software for railway applications.

3 The technology

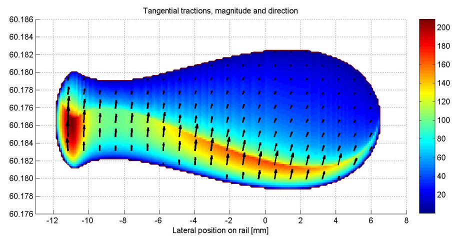
CONTACT is based on mechanics principles, particularly the laws of 3D elastostatics. These describe the relation between stresses exerted on the bodies' surfaces and the deformations and stresses that occur inside of them. Using a boundary element method, the problem is to find the force distribution on the surfaces such that the contact conditions are satisfied:

- in the contact area, there's no gap between the two bodies,

- outside the contact area, the bodies exert no stress on each other,
- the tangential stress cannot exceed the traction bound, i.e. maximum friction,
- where the tangential stress is less than the maximum, the bodies' surfaces stick together,
- where sliding occurs, the stress is on the maximum value and opposing the sliding motion.

This leads to two systems of equations and constraints:

1. the normal contact problem, that describes the pressures and where the contact is located,
2. the tangential problem, that describes the frictional stresses and where sticking and slipping occurs.



These systems use dense coefficient matrices with nice, regular structures. Particularly for the normal problem this allows for fast computations using the Fast Fourier Transform.

4 The assignments

Various topics are of interest for the further development of CONTACT. These topics can be taken on as an assignment for bachelor or master's theses or in an internship at VORtech.

1. **Speed-up using the Graphics Processing Unit**. Fast solvers have been developed on the basis of the Conjugate Gradient method employing the FFT technique. It is thought that the FFTs can be accelerated further using the GPU. If this is true, already for relatively small FFTs, then the program can be accelerated as a whole. This is a topic in scientific computing suited for an internship or bachelor thesis.
2. **Tangential problem solver**. Fast CG+FFT solvers are now available for the normal problem and for instationary rolling. However, the steady rolling problem still uses an old solver based on the Gauss-Seidel technique. This has poor scalability: computation times increase rapidly when the discretization grid is refined. A new iteration method is needed for this steady rolling that exploits the speed of FFTs. The challenge is to find an appropriate view on the problem that allows for standard techniques like Jacobi, steepest descent or IDR to be used (master student, numerical analysis).
3. **Falling friction formulas**. Measurements often show a reduction of friction at an increased rate of sliding. This is implemented in CONTACT at the expense of slow calculations, using an ad-hoc solver for the non-linear feedback mechanism. Mathematical analysis of the problem is desired, to better understand the behavior and find faster solution techniques. This can be investigated by a master student in applied mathematics.
4. **Corrugation modelling**. In railways, uneven wear creates corrugated (wavy) rail surfaces that bring noise and damage and reduced rail service life. No good explanation

has yet been found as to the mechanism that initiates and promotes this uneven wear. A new explanation has been put forward that involves the wheelset dynamics interacting with detailed contact mechanisms. This can be tested by analysis and simulation, by a student of applied mathematics or mechanical engineering.

5. **Conformal contact problems**. One basic assumption in CONTACT is that the contact patch between wheel and rail is almost flat. This is a restriction for the computation of contact between the wheel flange-root and the rail gauge corner, where the contact patch is clearly curved. The way forward in this is to extend CONTACT with information that is computed using the finite element method. However, the FEM-problem has specific demands: it must be really accurate and fully automated. Therefore this introduces new puzzles to solve.

6. **GUI in Matlab or Java**. CONTACT is programmed in Fortran and uses a textual input-file. A graphical interface is desired where the input can be filled more easily by the end user. This makes for a nice internship assignment for a student with interest in the application domain and enthusiasm for programming.

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