Umeå University - UMIT Research Lab
Interactive multiphysics and
complex mechanical systems group
Martin Servin

Thesis proposal - förslag på examensarbeten

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2015-06-01
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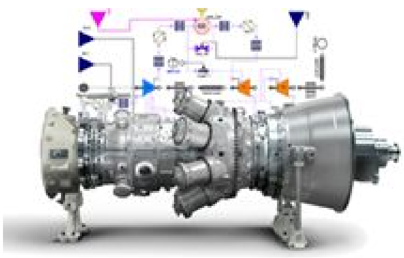
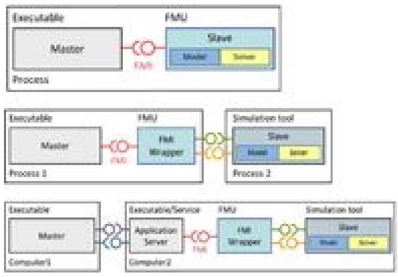
Algorithms and software for co-simulation

Co-simulation is when software packages are coupled together as black boxes and this poses a number of stability problems. Algorithms and numerical methods are being investigated at UMIT in conjunction with a large project involving Scania and Volvo Cars, but there is a need to perform large scale testing and analysis of these. Of interest here is a study of adaptive time stepping if possible at all.





Prerequisites

Applicants are educated in and interested in applied mathematics, computing science and/or computational mechanics and physics. This particular project requires good knowledge of numerical methods for ordinary differential equations and object oriented programming.

Interactive multiphysics and complex mechanical systems at UMIT Lab

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Further information

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Project Virtual Truck and Bus, Simovate, Functional Mock-up Interface

Simulation of mining vehicles and granular crash berms

with Newcastle University in Australia

Requires immediate interest notification for visa application to Australia!

Mining haul trucks are used for transporting ore material between the mine pit and to crushers and further mineral processing units. These machine may have a weight up to 600 tons. In case of accidents the damages and costs may be substantial. Crash berms (sv. kraschvallar) are constructed from rocks and soil to increase safety.



The aim of the project is to find an optimal geometry/material for the berm and to determine their energy absorption capacity. This requires modeling and simulation of a haul truck running into a crash berm. The specific aims of the thesis can be summarized as follows.

- model calibration of granular material and haul truck based on full-scale experiments
- exploration of the crash berm design space using rigid multibody simulation
- identification of optimal parameters and of critical scenarios

Expenses covering a trip and three months stay in Newcastle is offered. This requires immediate interest notification for visa application to Australia!

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UMIT Research Lab and Centre for Geotechnical and Materials Modelling

UMIT Research Lab at Umeå University is a multidisciplinary research environment with 50 associated researchers and engineers from computing science, mathematics and physics with excellent research in scientific, high-performance distributed and visual computing and its applications in science and industry. The Centre for Geotechnical and Materials Modelling is located at Newcastle University in Australia.

Further information

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Klaus Thoeni, Klaus.Thoeni@newcastle.edu.au, Centre for Geotechnical and Materials Modelling, Newcastle University, Australia

Nonsmooth, analytical models for electric machinery for multidomain simulations

The variational principle of classical mechanics can be used to simulate multidomain physical systems, including multibody dynamics, electronics, hydraulics, and electric machinery. This can also be combined with methods for nonsmooth mechanics, i.e., systems subject to discontinuities such as impacts, contacts, switching modes, etc.

We have previously developed methods for rigid multibody with frictional contacts, non-smooth hydraulics and non-smooth electronics, all of which turned out to be much faster than available software packages for the same level of accuracy.

Extending this to include electrical motors will allow for comprehensive simulation of robots for instance, but also electric cars and such.

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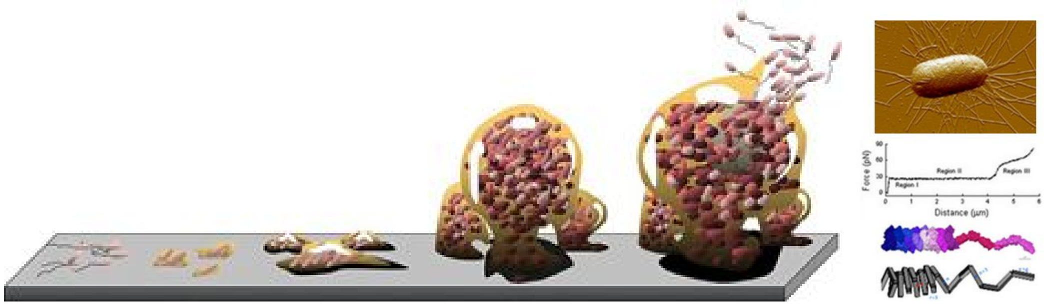
Multibody dynamics modeling of bacterial biofilm

A biofilm is a collection microorganisms that are coupled together on a surface. Bacterial biofilms may form on living or non-living surfaces and can be prevalent in natural, industrial and hospital settings. . Understanding the dynamical properties of biofilms is essential to develop new methods, drugs and materials that prevent bacteria from spreading. With the rapid increase of multiresistent diseases this is becoming ever more important.

The goal of the project is to be able to efficiently simulate biofilms made of many thousands bacterias coupled by pili organelles with complex dynamics. The bacterias (2μm long) are modeled as potentially contacting rigid bodies. The pili organelles are modeled as piecewise nonlinear springs. The challenge is to formulate the model as a multibody system with constraints and nonsmooth dynamics such that fast and stable time-integration algorithms can be applied to achieve fast simulations.



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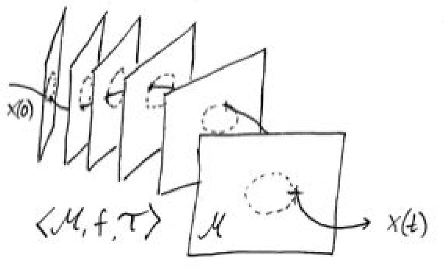
Simple adaptive time step for low order stepping scheme

When integrating mechanical systems with constraints and contacts such as heavy vehicle, it is important to keep the time step sufficiently small to get good results, but not too small to slow down the simulation more than necessary.



We are looking at a simple method which considers the "curvature" of constraints to make a guess on whether or not the time step is too large. Since the dynamics is discontinuous when there are contacts, the standard step doubling methods cannot be used. This new method requires investigation with regards to stability and efficiency.

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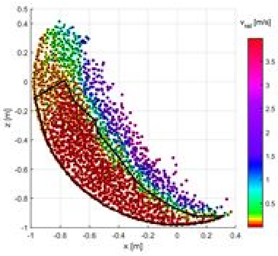
Jamming phenomena in flowing granular media

Computer simulations are indispensable for understanding the nature of granular materials. It is also an important tool for design and optimization in the industries of processing, manufacturing, storage, and transportation of granular materials, including grains, minerals, pharmaceutical pills, pellets, sand, and rocks. Granular materials consist of many macroscopic particles, from microns to meters in size, which interact strongly with each other through contact forces. The systems composed of these materials are strongly dissipative and meta-stable with critical phenomena like jamming and avalanches, and they exhibit phenomena on several very different lengths and timescales. The materials can switch quickly between solid, liquid, and gaseous form.



The thesis proposal is to focus on jamming phenomena in granular flows where the solid and liquid phases are simultaneously present. In particular, the conditions for stable flows and transitions between different flow states in rotating drum geometry are investigated. For slow rotation the material flow occur into a “plug zone” or rigid co-rotation with the drum and with a gravity driven shear flow on top. At higher rotational velocity convection cells can occur. This is important knowledge for mixing and milling of materials in mineral and pharmaceutical industries.

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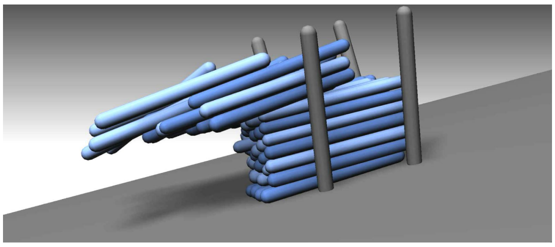
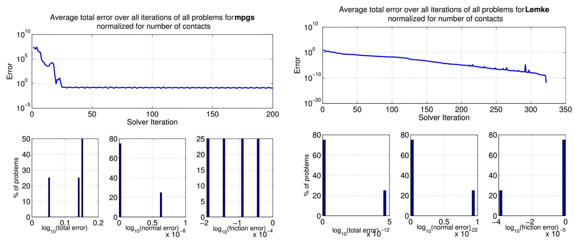
Benchmarking of frictional contact solvers

Solving for contact forces in multibody systems subject to frictional contacts is a difficult and open problem. Though many solvers are available, they compute approximations which aren't always satisfactory, they can fail on some problems, and their performance varies significantly.

No one has yet investigated the performance of available solvers extensively. We put a new framework together to make this possible but still missing here are comprehensive statistical tests to be able to understand the performance of a variety of solvers on a very large collection of problem sets. In fact, even simple validation tests on reference problems are missing at this point.

The goal here is to construct a fully automated computational and analysis pipeline which produces complex figures providing a deep understanding of the global performance on a solver on many problem, or relative performance between solvers.





Prerequisites

Applicants are educated in and interested in applied mathematics, computing science and/or computational mechanics and physics. Knowledge of numerical linear algebra and capability of processing and presenting data in graphical figures is favorable.

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J. Lu et al, Standard Interface for data analysis of solvers in multibody dynamics, The 4th Canadian Conference on Nonlinear Solid Mechanics (CanCNSM 2013) pdf

Graph partitioning and load balancing for sparse matrix solvers

Sparse parallel factorization of LDL update and downdate with applications to quadratic programming (QP); block pivot methods for QPs (smoothing, splitting, application to frictional contacts, direct iterative hybrid solver); splitting techniques for frictional LCP solver; GPGPU techniques (sparse direct LDL solver, CG preconditioning, application to QP contact problems). Hierarchical data formats for sparse matrices. Load balancing algorithms. Quantitative comparisons to existing libraries.

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Applicants are educated in and interested in applied mathematics, computing science and/or computational mechanics and physics. This particular project requires good knowledge of numerical linear algebra and parallel computing.

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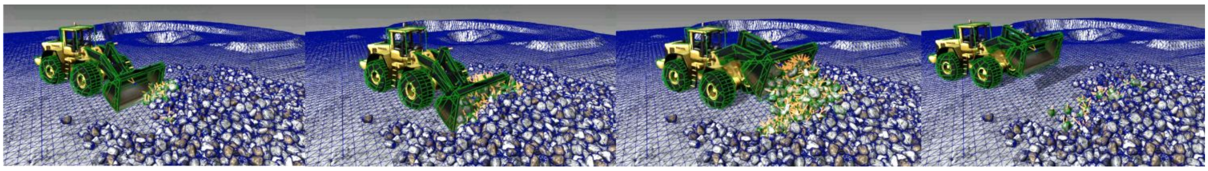
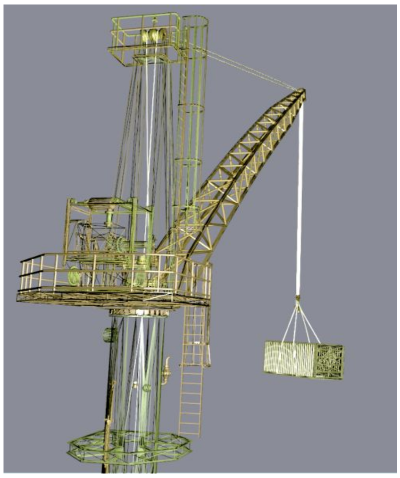
Merging and splitting bodies dynamically

For high performance simulations of rigid multibodies, it is necessary to avoid computing the motion of bodies whose motion is completely determined by others. For instance, in a large stack of objects, the ones in the middle of the stack are jammed and move along with their neighbors. The goal is to understand when and how it is suitable to replace a collection of bodies with an aggregate, and to break this aggregate when the external forces require it.





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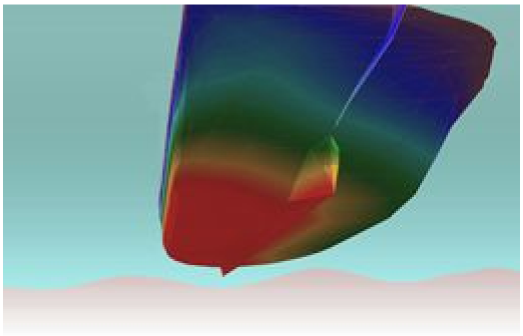
Simulating ships moving in shallow waters



Ship simulation is important to train sailors in heavy sea conditions. Though there are simplified physical models and simulation techniques to compute the interaction between the ship and the water, these can be improved.

An alternative application to this which requires even more simplification is computer games involving boats and water scooters.

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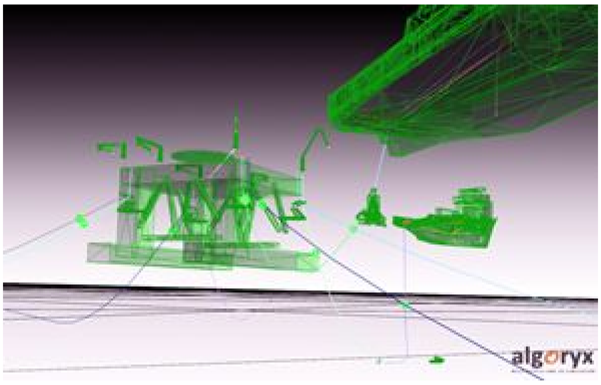
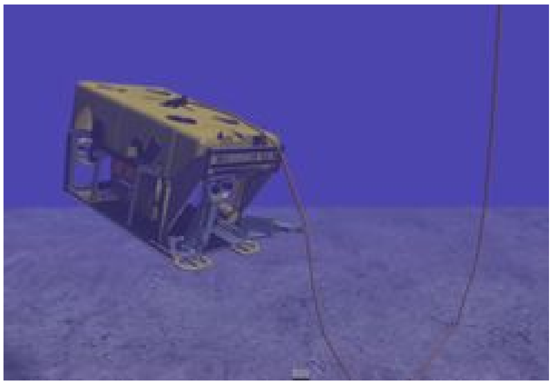
Added mass computations

Ships and other immersed vessels must accelerate the fluid in which they move. This gives them additional inertia called added mass. There is software available for doing this but some interesting simplifications and extensions are possible, such as taking consideration of propellers, finite sea depth, etc.

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Stable joint kinematics using Euler angles.

In simulating cables which can undergo large deformations, computing Euler angles between discretized elements poses problems since there are degenerate configurations. One normally uses quaternions for this but this leads to a nonlinear elasticity law. Models based on Euler angles are always linear, however.

There are techniques to avoid the singular configurations in Euler angles representations of rotations but these aren't entirely satisfactory for this particular case.

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Modeling hydraulic components with non-smooth methods

Hydraulic machinery is designed to act very quickly and at the human scale, much of the dynamics appears instantaneous. It is possible to model and simulate this type of machinery with "non-smooth" method which replace very steep curves with inequalities and instantaneous changes. That has shown to be more accurate and more efficient.

But hydraulic systems contain very many special components which respond to suddenly to changes in pressure, and new non-smooth models are needed for these, and some existing ones need to be validate. This is the case for special pumps designed to slow down when pressure build up, safety valves which open quickly when pressure is to high but shut down also quickly when it is safe to do so, as well as devices which have "analog" logic components to distribute pressure where needed. Essentially, hydraulic components are designed to behave like diodes, transistors, and logic gates, and there are very few mathematical models for this.

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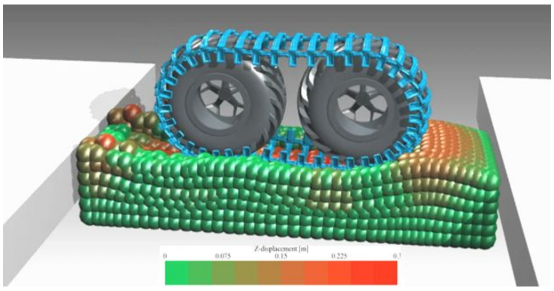
Modeling tracked vehicles on soft terrain

Operator training using virtual environments is commonly used today and increasingly so. But there are limits on computational resources in this context so one is always looking for models which are simple enough to allow fast simulations, but still physically correct.

Tracks on vehicle involve hundreds of parts and models are needed now to simulate just as many as needed to capture the dynamics between the tracks and the soil, but with as few variables as possible. This involves dynamic resolution based on forces and tension, kinematic reduction, and geometric analysis of contacts between track elements and the ground.



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Control of granular systems

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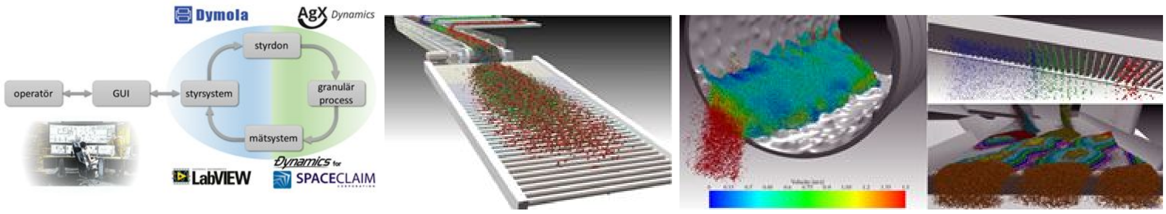

The goal of the project is to develop control methods for granular transportation and processing systems using particle simulation. The control objective may be efficient and stable pelletization or minimization of wear and attrition of material and equipment.

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