Explicit Dynamic Contact Analysis

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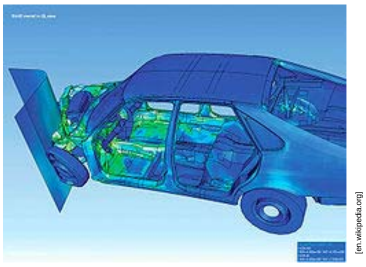
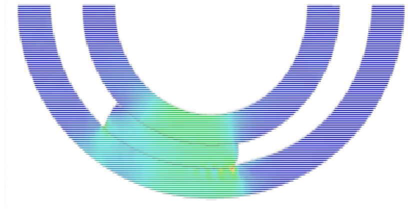


Crash tests are typically solved using explicit methods

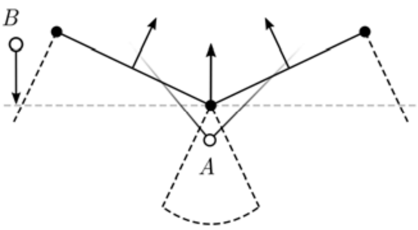
Goals and Motivation

- Explicit methods can be very efficient for certain types of problems, such as car crash simulations
- Contact plays an important role in the behaviour of many mechanical systems
- Test effects of mass scaling on contact response



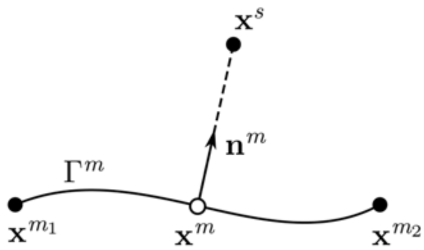
Algorithms successfully implemented and were able to solve complex problems

Approach



Blind-spots due to gaps in normal projection can lead to undetected contact. The solution is to split the surface into face, edge and vertex segments.

- Implementation of three contact algorithms and two search algorithms
- Contact virtual work is developed using penalty and Lagrange multiplier methods, then discretised using node-to-segment concept
- Surface topology stored explicitly, allowing for element-agnostic approach for contact search and resolution
- Bucket sort used to reduce time complexity of contact search



$$g_N(\mathbf{x}^s) = (\mathbf{x}^s - \mathbf{x}^m) \cdot \mathbf{n}^m$$

Node-to-Segment discretisation and gap function

Basic contact virtual work term

$$\delta W_{\text{cont}} = \int_{\partial \mathcal{B}_c^m} p_N \delta g_N(\mathbf{x}^s)\, \mathrm{d}a^m$$

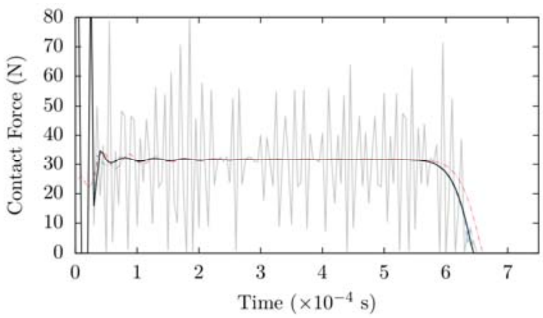
Coupled System for LMM Algorithms

$$\begin{bmatrix} \mathbf{M} & \mathbf{B} \\ \mathbf{B}^T & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{A} \\ \mathbf{F}_c \end{bmatrix} = \begin{bmatrix} \mathbf{F}_{\text{ext}} - \mathbf{F}_{\text{int}} \\ -\mathbf{P} \end{bmatrix}$$

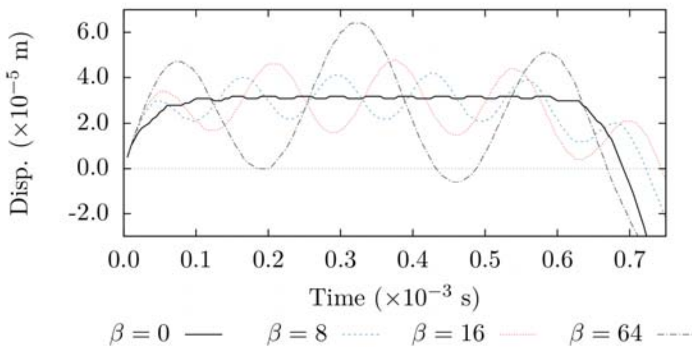
Contact Constraints

$$g_N(\mathbf{x}^s) \geq 0$$
$$p_N(\mathbf{x}^s) \leq 0$$
$$p_N(\mathbf{x}^s) g_N(\mathbf{x}^s) = 0$$

Examples



Under-prediction of contact force can result in much smoother response (black)



Large oscillations occur with mass scaling due to the added mass, resulting in unphysical effects.

Literature:

- Zhong, Z. H. (1993). Finite Element Procedures for Contact-Impact Problems. Oxford University Press, New York
- Wriggers, P. (2006). Computational Contact Mechanics. Springer, Berlin
- Yastrebov, V. A. (2013). Numerical Methods in Contact Mechanics. ISTE/Wiley

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