REALISTIC IMPACT ANALYSIS OF STRUCTURES

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INTRODUCTION

The modelling of highly nonlinear dynamic phenomena in solid and structural mechanics has been of extensive interest over recent years. In particular, the numerical simulation of dynamic contact problems has been of great importance due to its frequent application to a wide range of engineering problems.

In this context, structural engineers have been concerned with the response of building structures under extreme dynamic loading. A majority of catastrophic structural collapse events are initiated or followed by extreme impact loading scenarios.

DYNAMIC CONTACT ALGORITHMS

1. Conventional Penalty Method

- ✗ Achieving both energy conservation and zero gap constraint is a ‘trial and error’ task, often requiring an extremely small time-step
- ✗ Persistent contact force is not predicted accurately

2. Proposed Regularised Penalty Method [1]

- ✓ A novel regularised penalty formulation is developed for the well-known trapezoidal rule time integration scheme
- ✓ Unlike the conventional method, the new method achieves energy conservation and zero gap constraint with relatively large time-steps (i.e. improved computational efficiency)
- ✗ Persistent contact force is not predicted accurately

3. Lagrangian Gap/Velocity Constraint

Issues with Gap Constraint :

- ✗ The method is numerically unstable with regard to dynamic contact analysis and can lead to energy blow up in the system
- ✗ Persistent contact force is not predicted accurately

Issues with Velocity Constraint :

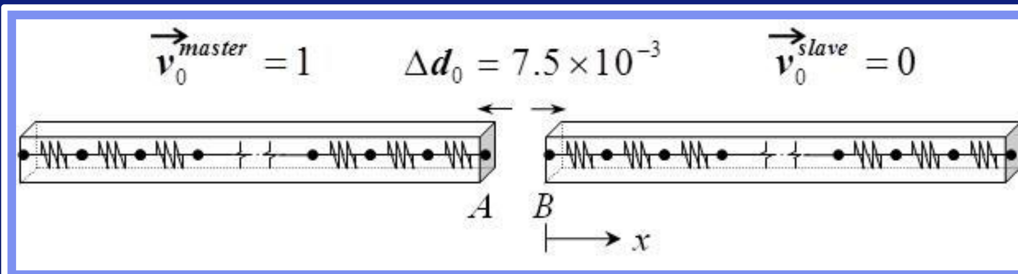
- ✗ Persistent contact force is not predicted accurately

4. Proposed Lagrangian DVA Constraint

- ✓ A **novel** and **superior energy controlling-algorithm** is proposed which enforces the zero gap **DISPLACEMENT** (D) constraint, and in the presence of persistent contact will achieve the zero **VELOCITY** (V) and **ACCELERATION** (A) gap constraint
- ✓ **Predicts accurately the persistent contact force,** which is of great importance in friction dynamic contact analysis, regardless of the analysis time-step size or numerical dissipation of the time integration scheme

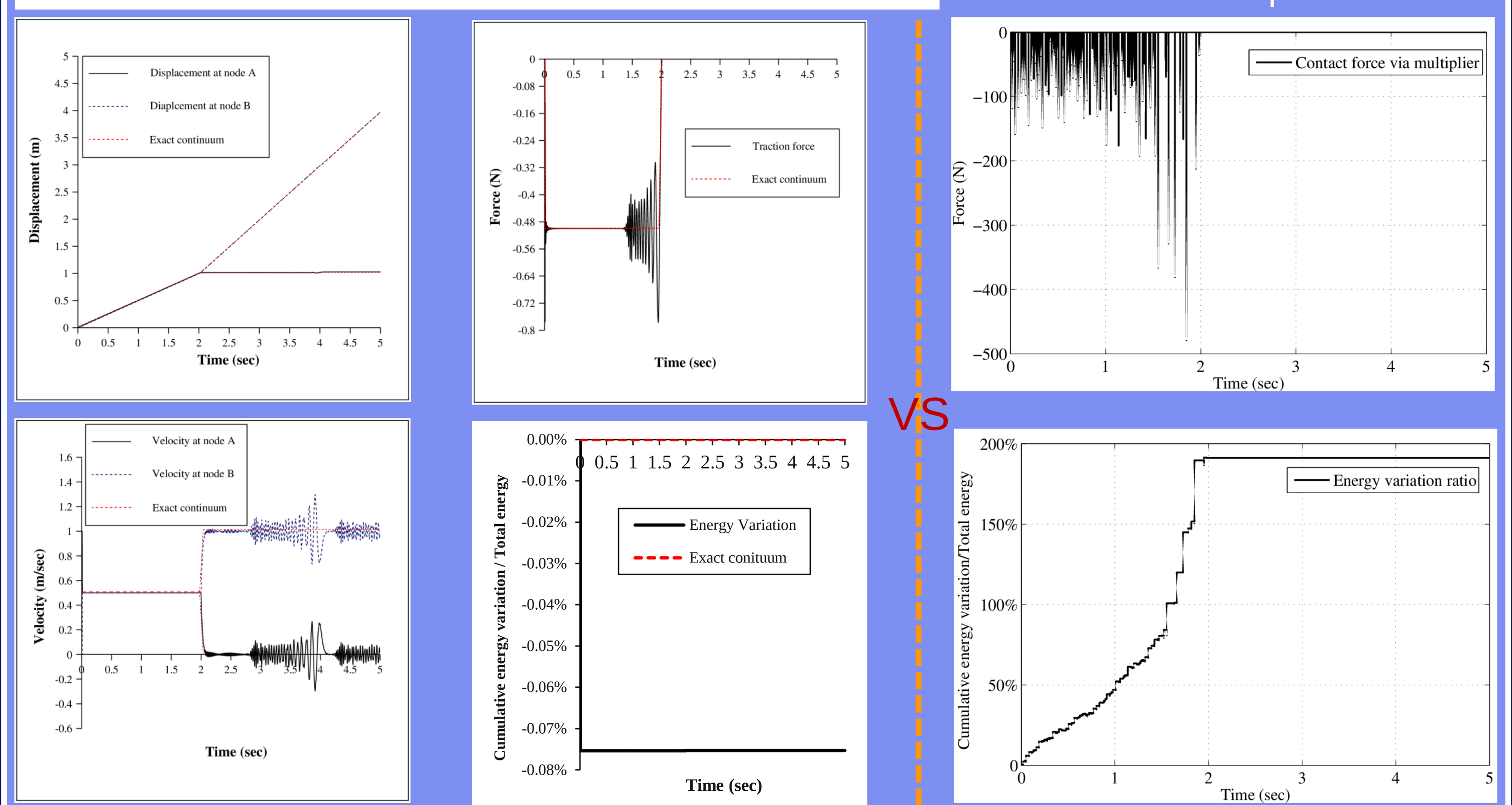
NUMERICAL EXAMPLES

1) Impact of two collinear elastic rods (DVA algorithm)



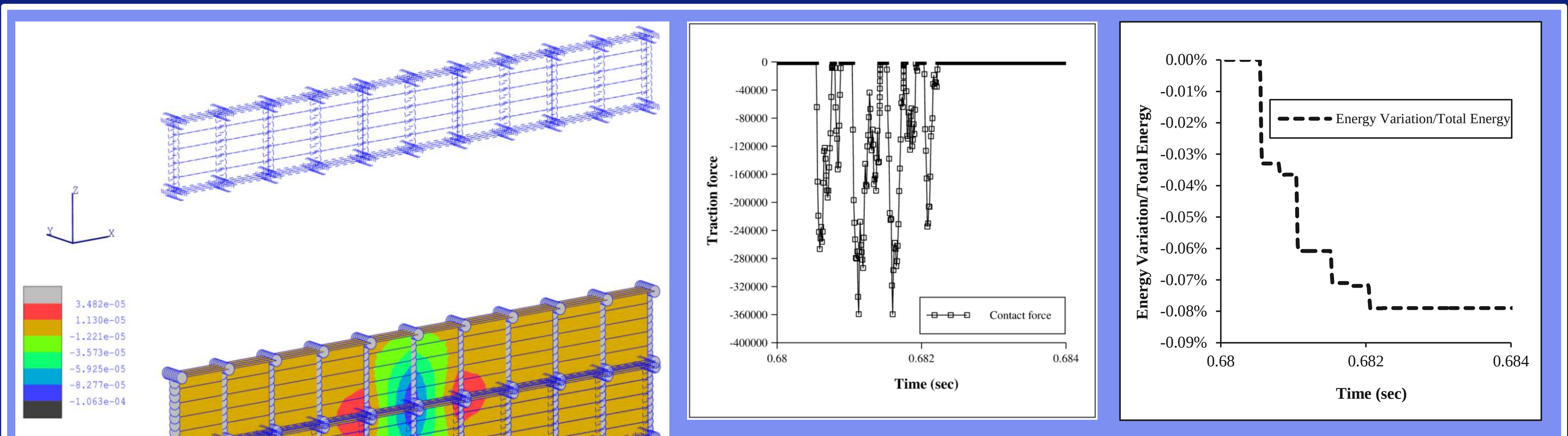
Number of elements	Elastic modulus [N/m^2]	Density [kg/m^3]	Area [m^2]
100	1	1	1

Table1. Properties



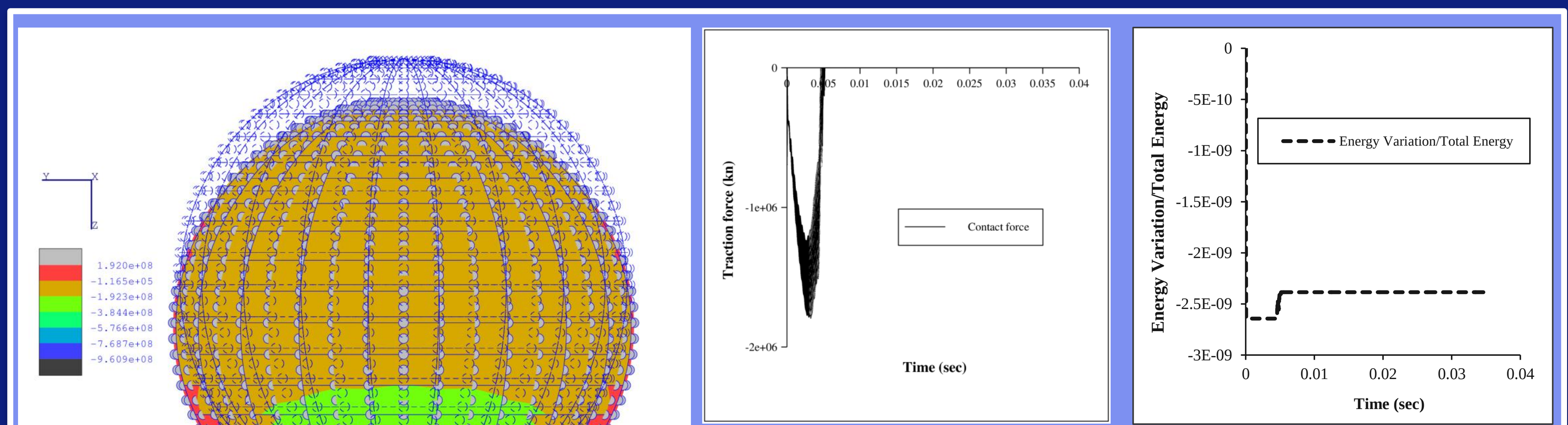
✓ Proposed DVA algorithm VS ✗ Conventional gap constraint

2) Impact of two orthogonal steel beams (DVA algorithm)



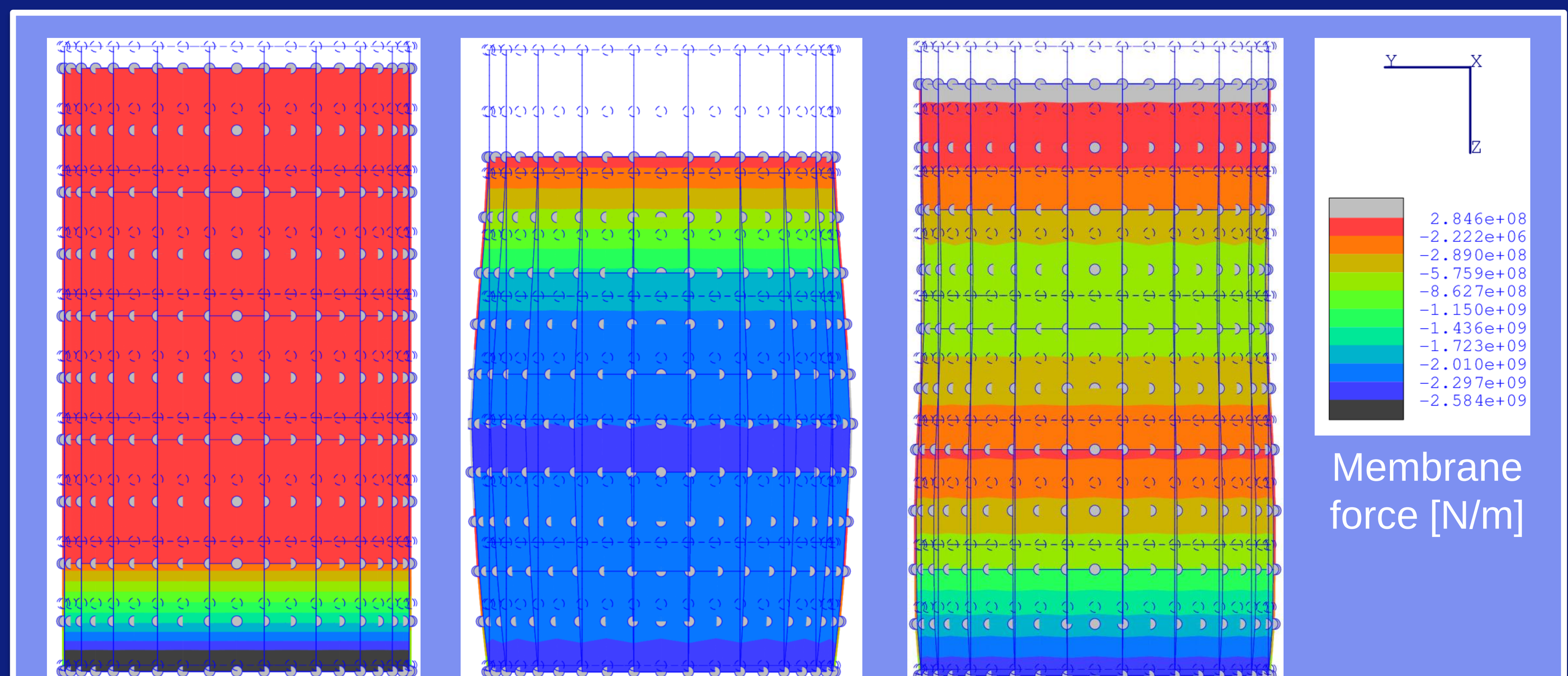
a) Persistent contact force history
b) History of energy variation ratio

3) Impact of steel sphere with rigid surface (DVA algorithm)



a) Persistent contact force history
b) History of energy variation ratio

4) Impact of 3D steel cylinder (DVA algorithm)



a) Initial impact (t=40µsec)
b) Fully compressed (t=230µsec)
c) Rebound t=360µsec

Membrane force [N/m]

REFERENCES

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2. Zolghadr Jahromi, H. and B.A. Izzuddin. *Energy conservation of the Newmark method for dynamic contact analysis. Proc. of 19th UK National Conference of the Association for Comput. Mech. in Eng., ACME, 2011.*