

Summary of work during the Summer School

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Outline

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Introduction

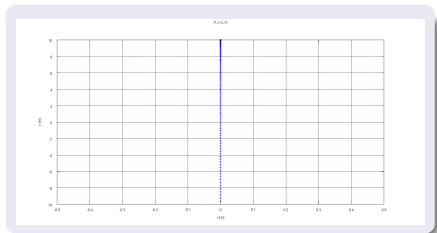
I started my work with reading articles (the most important was [1]) and books chapters. I was trying to implement step by step impact phenomena next. I have implemented 5 examples, which I will show you next. Unfortunately not everything is correct.

Examples - introduction

- Data
 - $m = 1\text{kg}$ - sphere mass
 - $J = 0.01\text{kgm}^2$ - sphere moment of inertia
(used only in Example 01)
 - $r = 2m$ - sphere radius
(except Example 01 where radius is not necessary)
 - Q - generalized forces vector
 - cr - coefficient of restitution
 - q_0 - initial coordinates vector
 - dq_0 - initial velocities vector
 - t - simulation time

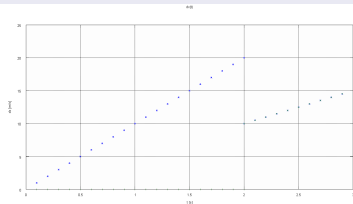
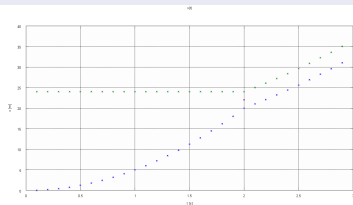
Example 01 - 1 sphere in 1D ($t = 2$ s)

- falling sphere
with $g_y = -9.81m/s^2$
- integration method - ODE45



Example 02 - 2 spheres 1D ($t = 3$ s)

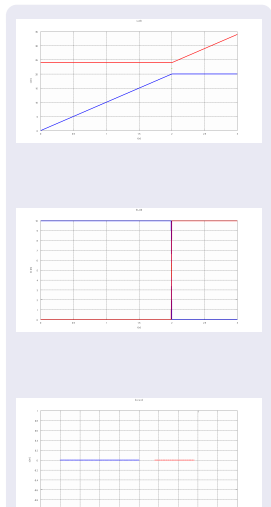
- $t_i = 2$ s - impact time (counted)
- integration method - ODE45 (2 integrations)



Example 03 - 2 spheres in 1D ($t \approx 3$ s)

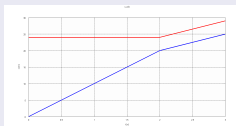
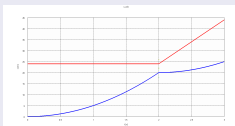
- integration method - explicit Euler
- contact detection

```
Q=[0;0];  
cr=1;  
q0=[0;24];  
dq0=[10;0];
```

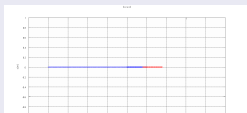
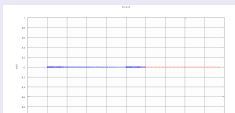
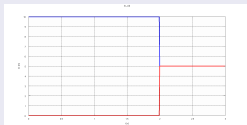
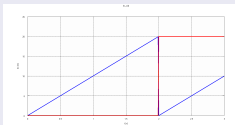


Example 03 - 2 spheres in 1D ($t \approx 3$ s)

$Q=[10;0];$
 $cr=1;$
 $q0=[0;24];$
 $dq0=[0;0];$

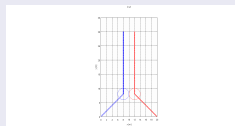
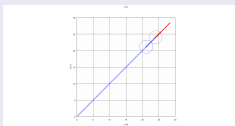


$Q=[0;0];$
 $cr=0;$
 $q0=[0;24];$
 $dq0=[10;0];$



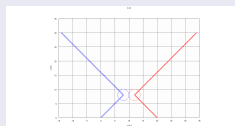
Example 04 - 2 spheres in 2D ($t \approx 3$ s)

$Q=[0;0;0;0];$
 $cr=0;$
 $q_0=[0;0;24;24]$
 $dq_0=[10;10;0;0]$



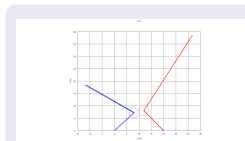
$Q=[0;0;0;0];$
 $cr=0;$
 $q_0=[0;0;20;0]$
 $dq_0=[10;10;-10;10]$

$Q=[0;0;0;0];$
 $cr=1;$
 $q_0=[0;0;24;24]$
 $dq_0=[10;10;0;0]$



$Q=[0;0;0;0];$
 $cr=1;$
 $q_0=[0;0;20;0]$
 $dq_0=[10;10;-10;10]$

- explicit Euler
- contact detection



$Q=[0;0;0;0];$
 $cr=1;$
 $q_0=[0;0;20;0]$
 $dq_0=[10;9;-10;10]$

Example 05 - 4 spheres 2D ($t \approx 1$ s)

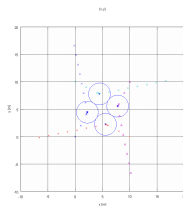
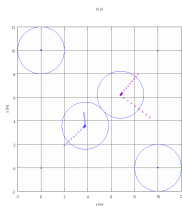
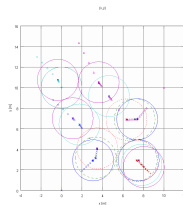
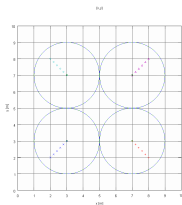
- explicit Euler
- contact detection
- only inelastic impact ($cr=0$)
- algorithm 1 from [1]:

Algorithm 1 `Inelastic_Impact`($\mathbf{q}, \mathbf{p}, \mathbb{A}$)

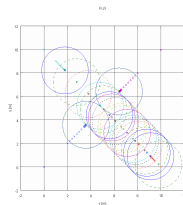
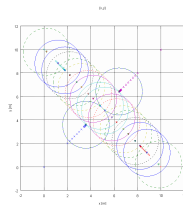
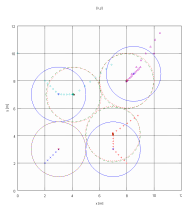
1: $\mathbf{G} \leftarrow \mathbf{G}_{\mathbb{A}}(\mathbf{q})$ 2: $\lambda \leftarrow \operatorname{argmin}_{\mathbf{y}} \left(\frac{1}{2}(\mathbf{G}\mathbf{y} + \mathbf{p})^T \mathbf{M}^{-1}(\mathbf{G}\mathbf{y} + \mathbf{p}) : \mathbf{y} \geq 0 \right)$ 3: **return** λ

$$\dot{\mathbf{q}}^+ = \dot{\mathbf{q}}^- + \mathbf{M}^{-1} \mathbf{G}_{\mathbb{A}} \lambda.$$

Example 05 - 4 spheres 2D ($t \approx 1$ s)



Example 05 - 4 spheres 2D ($t \approx 1$ s)



HPC

- I have read all ME964 lectures materials and watched about half the lecture videos
- I have worked on Euler cluster

Information

This work has been supported by the European Union in the framework of European Social Fund through the Didactic Development Program of the Faculty of Power and Aeronautical Engineering of the Warsaw University of Technology.



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Sources:

- [1] Breannan Smith et al, *Reflections on Simultaneous Impact*, ACM Transactions on Graphics (TOG) - SIGGRAPH 2012 Conference Proceedings, Volume 31 Issue 4, July 2012;
- [2] Janusz Fraczek, Marek Wojtyra;
Dynamika układów wieloczłonowych, Treść wykładu; lecture materials; Warsaw 2009;
- [3] *Podstawy robotyki, Treść wykładu*; lecture materials; Warsaw 2009/2010;
- [4] FreeMat help;
- [5] other materials;