# Contact force simulation based on Convolutional Neural Network

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## Abstract

*The document is the description of a 30 ECTS master's thesis at Department of Computer Science, University of Copenhagen. The project starts on 5th February, 2018 and will be due on 5th August, 2018. A tentative date for the presentation is 5th September, 2018. The project will be supervised by Kenny Erleben.*

## 1. Description

### 1.1. Motivation

Some research groups applied machine learning method successfully in liquid simulations. However, for rigid body problems it is still not clear how to approach the technicalities in applying deep learning. We try to learn how contact forces work inside piles and stacks based on deep learning method(Convolutional Neural Network).

### 1.2. Perspective

#### Creating data

In order to create data accessible to learning, we will map a discrete element method into a continuum setting use techniques from smooth particle hydrodynamics.
We generate $K$ random setups of piling of objects. Initially we have $N$ bodies randomly placed inside a world box at a height between $0 < h_{\min} < h_{\max}$. We make each of the initial state run with objects falling under gravity. The each run for $T$ times steps and in each time step we generate $3D$($D$ stands for vector quantities for any momentum field) images at any state.
Finally, we get a total of $K \times T \times 3D$ images for learning.

#### Convolutional Neural Network

Since CNN's great performance in computer vision tasks, we wish to use a convolution neural network for learning how the momentum images are mapped into the contact force images. The CNN structure(including the number of layers, the number of filters in each convolution layer and the full connection layer) should be designed based on the generated data.

## 2. Learning Goals

This section goes into further details about the work in the thesis by listing the individual learning goals.

1. Describe the contact force problem among rigid objects by building Newton-Euler equations.
2. Analyze possible kernels which can work for simulator and compare the performances of different kernels on mapping the state of the simulator onto a grid.
3. Analyze and compare the performance of different grid-sizes on the chosen kernel.
4. Design one convolution neural network to transfer momentum images into contact force images.
5. Design one experiment to determine the accuracy of several force solutions.
6. Describe the questions and issues during the learning process, and reflect on how to make learning model work better.
7. Design one experiment about training both normal forces and friction forces as one map.
8. Design one experiment about training normal forces and friction forces as two maps.
9. Compare the two results from two experiments.

**Note:** *If the whole idea might not work. We may end up learning that we can not use grids to learn how contact force are distributed inside piles of rigid bodies.*