# Simulation in Computer Graphics - Exercises

Computer Graphics - Computer Science Department - University of Freiburg

# Mass-spring systems

The goal of this exercise is to simulate deformable, volume-preserving objects with mass-spring sytems.

### Introduction

The goal of this exercise is to implement volume-preserving deformable objects that are represented with tetrahedra. The geometry of various objects is provided in `dcstructure`-files, where mass-point positions and tetrahedra are defined. Distance- and volume-preserving forces should be implemented as well as various integration schemes.

### Forces

- Implement distance-preserving spring forces.
- Implement spring-damping forces.
- Implement forces that preserve the volume of the tetrahedra.
- Deformation energy should be considered in the energy computation.

### Integration schemes

- Implement Verlet. Try to come up with an implementation that does not need to store $\mathbf{x}_{t-h}$ with a particle. Hint: This is possible if the velocity update is $\mathbf{v}_{t+h} = \frac{1}{h}(\mathbf{x}_{t+h} - \mathbf{x}_t)$.
- Implement a fourth-oder Runge-Kutta variant.
- Implement implicit Euler with Conjugate Gradient. Try to avoid the explicit representation of the sparsely filled system matrix. To keep it simple, only distance spring forces should be considered.

### Analysis

- Realize model-dependent parameters, i.e. timestep and stiffness constants for the forces. This allows to compare different models with different parameter sets.
- Try to perform more than one simulation step before visualizing the result.