INFOMGP - Game Physics

GMT Master Program
Period III, 2017

Lecturer: Amir Vaxman
What is Game Physics?

• Understanding the laws of the real world and simulating them computationally.

• Applications?

Science

Position Based Fluids [Macklin and Müller 2013]

Games

BeamNG

Movies

Industry

ModuleWorks GmbH

2012 (bullet)

Game Physics – Introduction
Physics is Interaction

• Objects interact through forces:
  • Between remote objects (gravity, magnetism)
  • Between objects in contact (friction, collision).
  • Within an object (chemical ties).

• Game physics: analyzing and simulating interaction.
  • Kinematics: descriptions of motion.
    • Position, velocity and acceleration.
  • Dynamics: forces and their effect.
    • Mass, inertia, collisions, momentum, energy.
Challenges

- Discretization.
  - Stability & Convergence.
  - Preventing errors.

- “How deep do we go”?
  - Efficiency vs. accuracy.

- How to do “well enough”.
  - Visually convincing.
  - Reasonable approximation.

[Rick & Morty, Adult Swim, 2013]

[Our Method
10 iteration, 50 ms
Liu et al., Fast Simulation of Mass-Spring Systems]

[Exact Solution
Newton’s Method, 13 s]
Control

• How do we control dynamics to achieve a kinematic effect?
  • Active control.
    • Characters and hinges.
    • Simulator (driving, flying, engine).
  • Passive/resulting control.
    • Collision detection & resolution.
    • Determining kinematics.
    • Soft deformation.

[Deul et al., Position-Based Rigid Body Dynamics, 2014]
The Players in the Field

• **Objects** as collections of **points** (molecules).

• **Rigid** bodies.
  • Deform as a single piece.

• **Soft** bodies.
  • Each point deforms locally in a continuum.

• **Detachable** bodies.
  • Several objects either stick together or break apart.
There Will Be Math

• Linear Algebra.
  • Vector spaces and matrices.
  • Linear transformations.
• Multivariate Calculus.
  • Differential calculus.
  • Integration.
• Basic measurements.
  • SI units.
Learning Objectives & Deliverables

- **Understand** classical continuum mechanics, and **solve** theoretical problems in motion and dynamics.
  - **Deliverable:** 1\textsuperscript{st} home exam.
- **Understand** common methods to discretize both space and time, and **apply** to the problems at hand.
  - **Deliverable:** 2\textsuperscript{nd} home exam.
- **Have a working knowledge** of multivariate & vector calculus and tensor algebra, in the context of game physics.
- **Implement** game physics principles. **Deliverables:**
  - 3-4 practical assignments.
  - Free-form mini-project.
- **Note:** course has no written exam.
Lectures

• 13-14 frontal lectures.
• Topics:
  • Rigid-body physics & simulation.
  • Calculus and algebra.
  • Collision detection & resolution.
  • Time integration.
  • Space discretization.
  • Soft-body physics & simulation.
  • Fluid physics & simulation.
Home Exams

- Exercise sheets.
- 2 x 10% of grade.
- Individual work.
- Two weeks deadline per each.
  - First starts today!
- Topics (roughly):
  - Continuous mechanics.
  - Discretization & simulation.
Practical Assignments

• Implement techniques shown in class.
  • GUI Skeleton given with many things already implemented.
• 4 x 15% of grade.
  • Alternatively (3 x 20% of grade).
• Work in pairs.
• Topics:
  • rigid body motion & collision.
  • position-based constraints.
  • soft-body deformation.
  • fluid simulation.
• Two weeks deadline per each.
  • Alternating with the home exams to some extent.
• Checked in person with lecturer.
  • On dedicated lecture times.
  • 10 minutes slots.
  • Resubmission possibility: when faults are found.
Mini-project

• Freeform; any game physics subject you want.
• Work in pairs.
• Be creative, but modest!
• Project proposal must be approved by lecturer by 1/Mar/2017.
• Project presentation in class.
  • Instead of original exam date (13/Apr/2017).
• Grade: 20% basic (up to course 100%).
• Peer- and lecturer- reviewed 3 best places.
  • 10% - 5% - 3% bonus points to entire course!
“And Who Are You, The Proud Lord Said”

- Assistant Professor in group **Geometric Computing**.
- Researching: **Geometry Processing**
- GMT Projects/Master theses available:

- Unconventional Meshes
- Mesh Design & Deformation
- Vector Fields
- Architectural Design
- Medical Visualization
- Shape Analysis & Simulation