PROJECT CHRONO

Project Chrono

Overview, structure, capabilities

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Project Chrono

- Growing ecosystem of software tools
- Multi-physics simulation engine

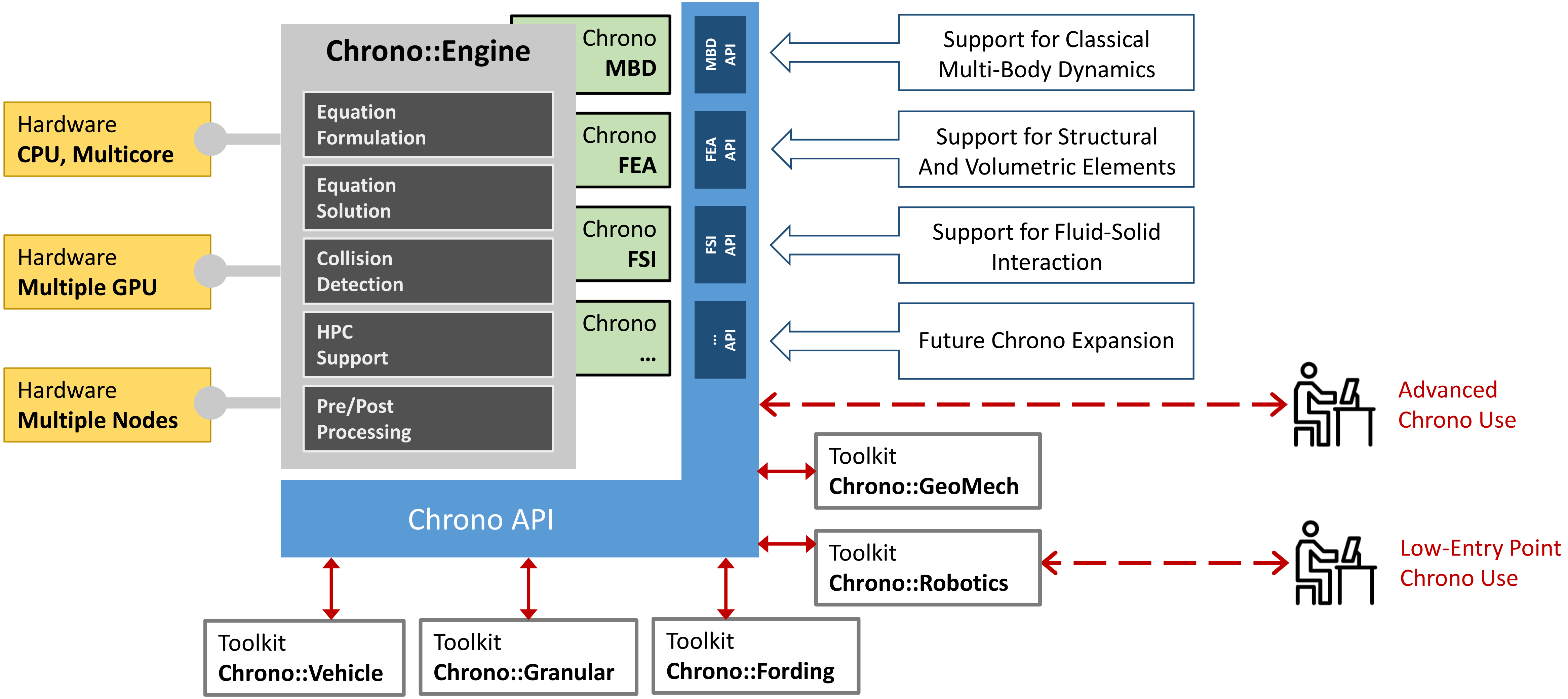
- Open source, released under permissive BSD-3 license

- Provides support for simulation of
    - Many-body dynamics
    - Nonlinear Finite Element Analysis
    - Fluid-Solid Interaction Problems

What is Chrono

- Middleware: can be embedded in third-party applications
- Modular: based on optional linking of specialized modules
- Expandable: via C++ inheritance
- Efficient: fast and robust data structures and algorithms
- Cross-platform: builds on Windows, Linux, OS X (MSVC, GCC, ICC, clang)

Modular and hierarchical structure

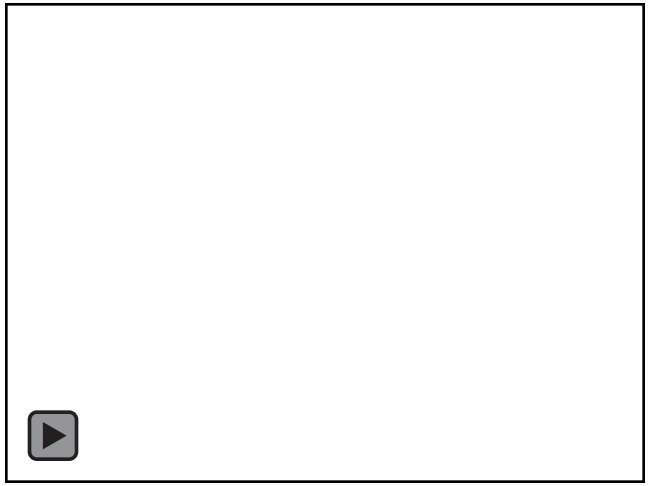


Chrono modules

Module	Description
Chrono::Engine	Core Functionality
CASCADE	Interoperability with CAD tools
COSIMULATION	Support for co-simulation
FEA	Finite Element Analysis
FSI	Fluid-Solid Interaction
IRRLICHT	Runtime Visualization with Irrlicht
MATLAB	Interoperability with MATLAB
MKL	Interface to Intel MKL
OGRE WIP	Runtime Visualization with Ogre
OPENGL	Runtime Visualization with OpenGL
PARALLEL	Parallel (multi-core) simulation module
POSTPROCESS	Tools for post-processing (POV-Ray output, Gnuplot)
PYTHON	Python Interoperability
VEHICLE	Template-based Ground Vehicle Modeling and Simulation

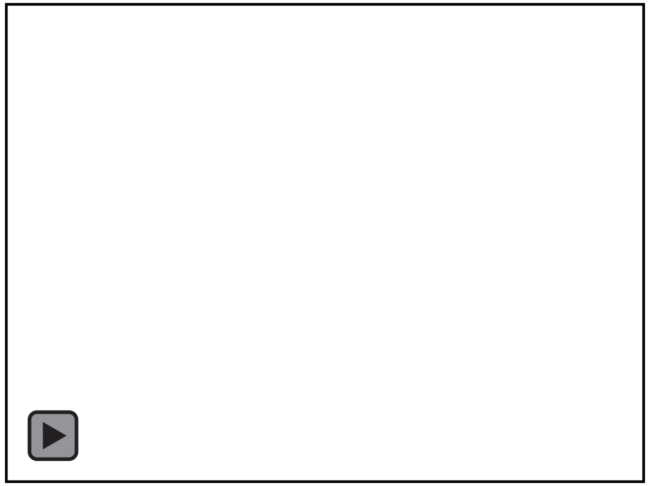
Modeling features

- Rigid bodies, markers, forces, torques
- Springs and dampers, with user-defined non-linear features
- Wide set of joints, e.g. spherical, revolute, prismatic, universal, etc.
- Impose trajectories to parts and markers
- Constraint motion on splines, surfaces, etc.
- Constraints can have limits (e.g. elbow joint)



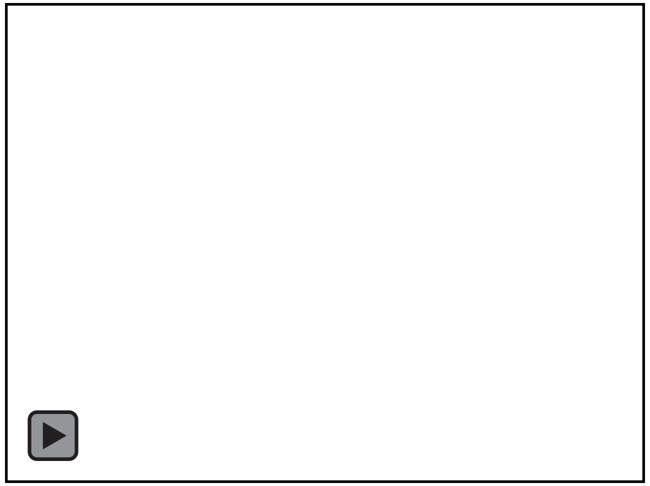
Modeling features

- Custom constraint for motors, reducers etc.
- Custom constraint for linear motors.
- 1-DOF elements for powertrains, drivelines, etc.
- Brakes and clutches, with stick-slip effect



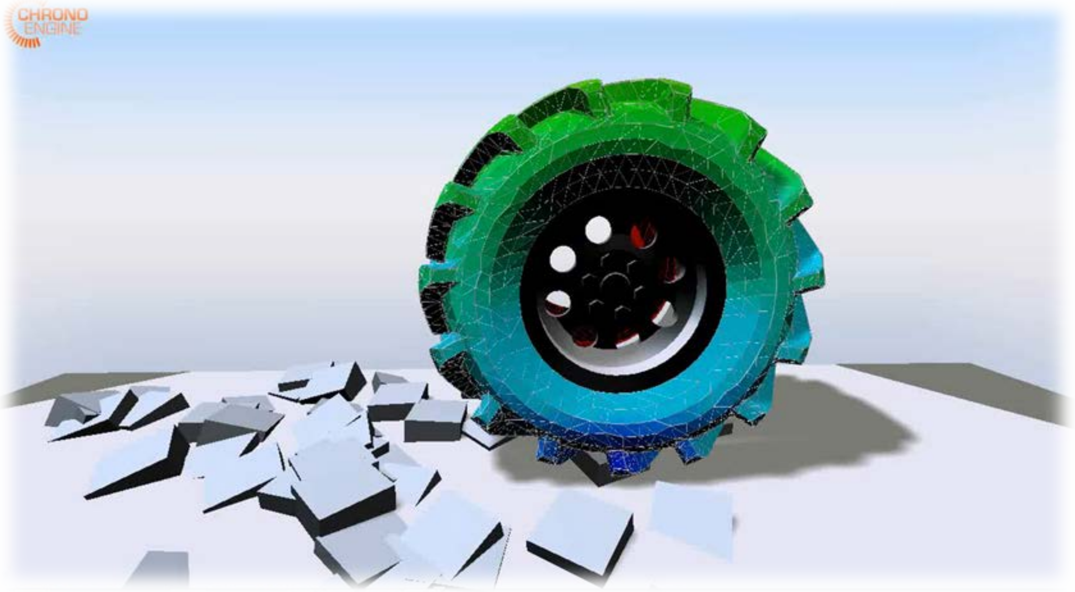
Modeling features

- Fast collision detection algorithms
- Collision families and groups
- Coloumb friction model, with stick-slip
- Rolling and spinning friction
- Restitution coefficients for rebouncing
- Collision detection between compound shapes
- Bodies activation/deactivation and sleeping
- Conveyor belts



Chrono::FEA module

- Co-rotational formulation
  - Bar element, Euler beam, Hexa8, Hexa20, Tetra4, Tetra10
- ANCF
  - Cable element, Shell element (isotropic, orthotropic, composite)
- Other
  - EAS brick element (isotropic and hyperelastic Mooney-Rivlin)
- Support for concentrated and distributed loads
  - Linear, surface, volumetric
  - Built-in classes for pressure, gravitational forces
- Support for constraints
  - Between two nodes, node and point on body, gradient and body direction
- Support for contact (penalty-based formulation)
  - Mesh-mesh and mesh-rigid
  - Surfaces represented as node clouds or triangular mesh



Chrono::Vehicle module

- Chrono vertical app (module)
  modeling, simulation, and visualization of wheeled ground vehicles and (soon) tracked vehicles
- Middleware: can be embedded in third parties software
- Modular: vehicle are modeled from instances of subsystems (suspension, steering, driveline, etc.)
- Flexible: use parameterized templates
- Expandable, via C++ inheritance
  - New subsystems
  - New templates for existing subsystems
  - New vehicle types
- Dependencies: Chrono::Engine and (optionally) the Chrono::Irrlicht and Chrono::FEA modules

Chrono::Parallel module

- Chrono vertical app (module)
  - library for OpenMP-based parallel simulation of Chrono models

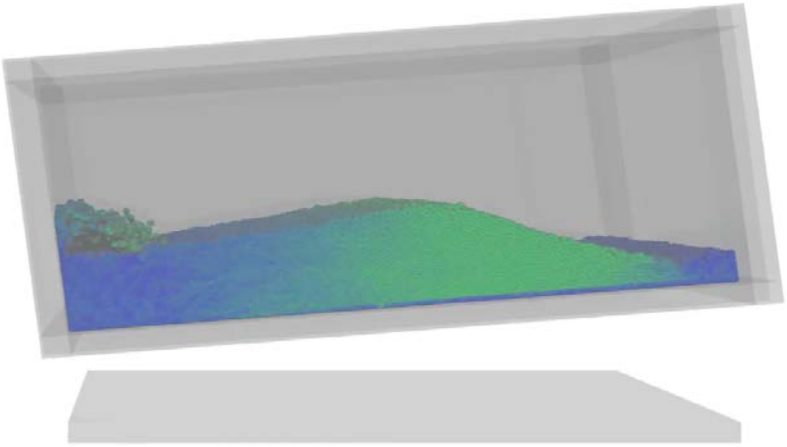
- Middleware: can be embedded in third parties software

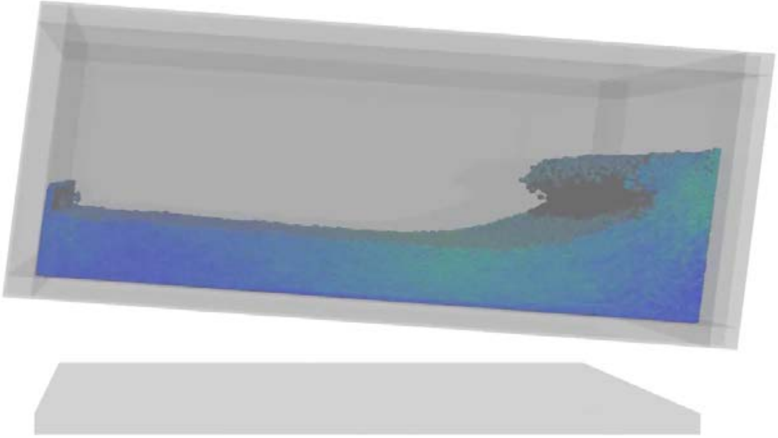
- Chrono-Parallel relies on Chrono for all its modeling capabilities
- Supports a subset of Chrono modeling elements:
  - Rigid bodies with frictional contact (DEM-C or DEM-P)
  - Kinematic joints (revolute, spherical, translational, etc.)
  - Force elements (spring-dampers, actuators, etc.)
  - 1-D shafts and associated elements and constraints (shaft-body connection, gears, motors, etc.)
- No support for FEA
- Implements only the *Implicit Euler Linearized* time-stepper

- Chrono-Parallel uses different data structures and algorithms

Chrono::FSI module

- Current State
  - Fluid interaction with multibody dynamics.
    - MBD includes contact and constraint
    - Supports flexible beam
  - Heterogeneous computing
    - GPU-based parallelism for fluid and OMP/AVX/SSE parallelism for MBD
  - Constraint-based fluid simulation
- Under development
  - Implicit incompressible CFD approach for fluid dynamics
  - Support for fluid interaction with flexible plate and shell
  - Distributed memory parallelism using Charm++





Code availability and documentation

Chrono source code

- Project Chrono GitHub repository https://github.com/projectchrono/chrono

- Clone/fork `develop` branch

- Planned major release: January 2017

Chrono dependencies and requirements

- C++ 11
  - Visual Studio 2013 or newer
  - GCC version 4.9 or newer
- Various Chrono modules have additional external dependencies
  - Chrono::Parallel: OpenMP, Blaze (v 2.4), Boost, Thrust
  - Chrono::OpenGL: GLEW, GLFW, GLM
  - Chrono::Python: SWIG, Python 3
- Build system based on CMake

Chrono documentation and support

- Project website: http://projectchrono.org/

- Documentation (doxygen): http://api.chrono.projectchrono.org/
    - Installation guides
    - API documentation
    - Manuals, white papers, tutorials, etc.

- Support:
    - User mailing list (Google group): http://projectchrono.org/forum/
    - Bug tracking, issue tracking, and feature requests through GitHub