Intro to Bullet Physics

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From the User Manual

"Bullet Physics is a professional open source collision detection, rigid body and soft body dynamics library. The library is free for commercial use under the ZLib license."

Main Features

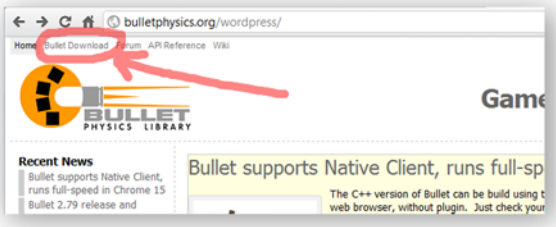
- Open source C++ code under Zlib license and free for any commercial use on all platforms including PLAYSTATION 3, XBox 360, Wii, PC, Linux, Mac OSX and iPhone
- Discrete and continuous collision detection including ray and convex sweep test. Collision shapes include concave and convex meshes and all basic primitives

Main Features

- Fast and stable rigid body dynamics constraint solver, vehicle dynamica, character controller and slider, hinge, generic 6DOF and cone twist constraint for ragdolls
- Soft Body dynamics for cloth, rope and deformable volumes with two-way interaction with rigid bodies, including constraint support
- Maya Dynamica plugin, Blender integration, COLLADA physics import/export support

Where is it Used?

http://bulletphysics.org



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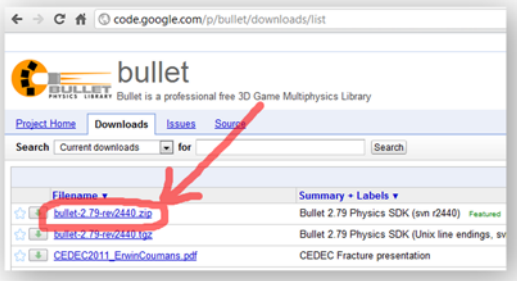

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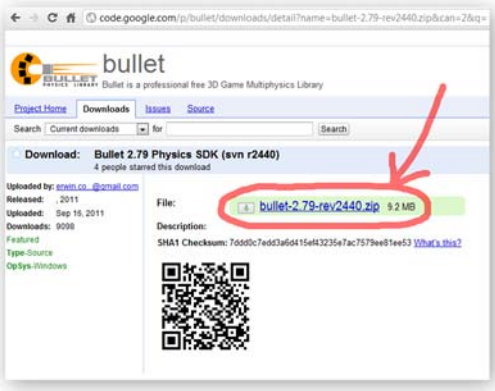

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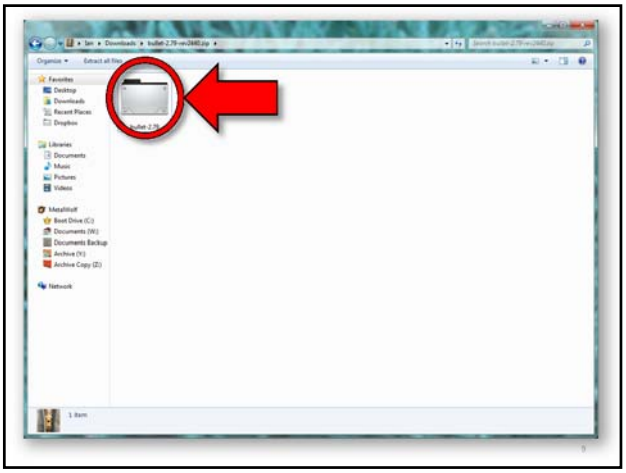

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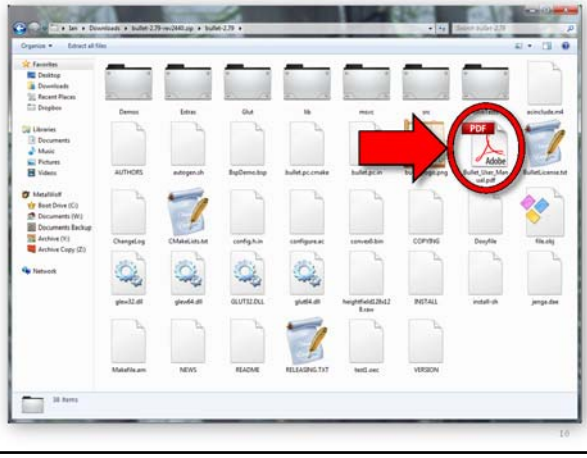

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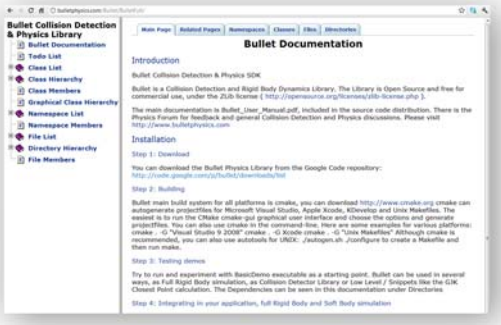
http://bulletphysics.com /Bullet/BulletFull/



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Adding Bullet Physics to Your Code

Add these Projects to your Solution:

`BulletDynamics.vcxproj`
`BulletCollision.vcxproj`
`LinearMath.vcxproj`

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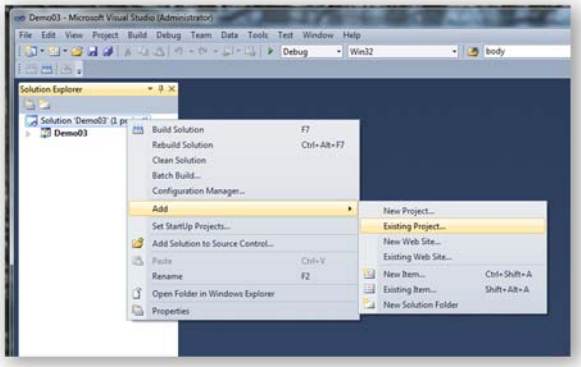

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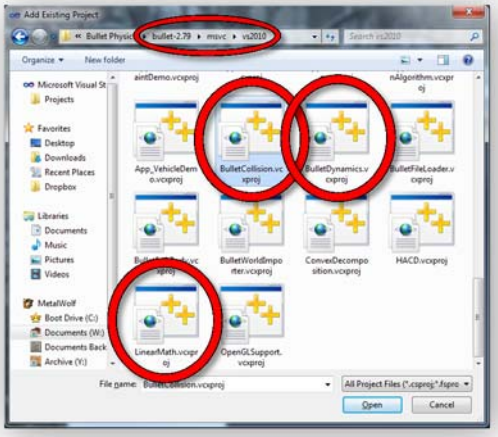

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Adding Bullet Physics to your Code

- Add the include path: `Bullet-2.79\src`
- Add the library path: `Bullet-2.79\lib`
- Add to your source file the line

```
#include "btBulletDynamicsCommon.h"
```

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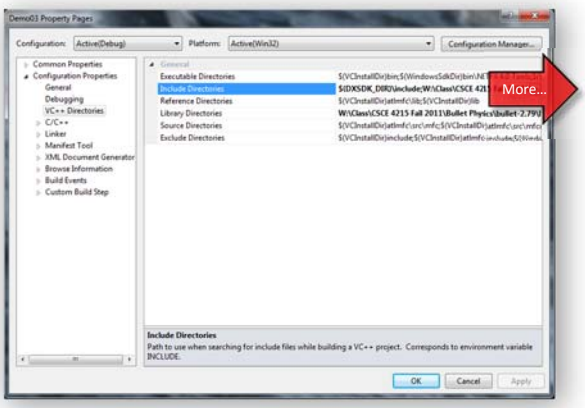

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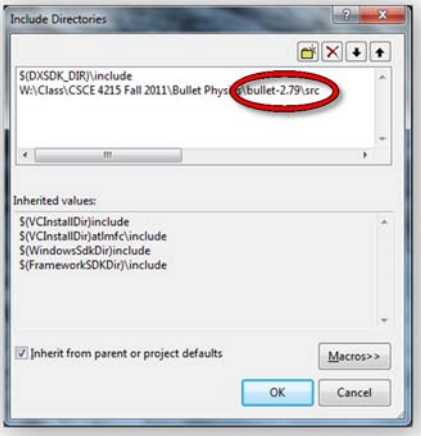

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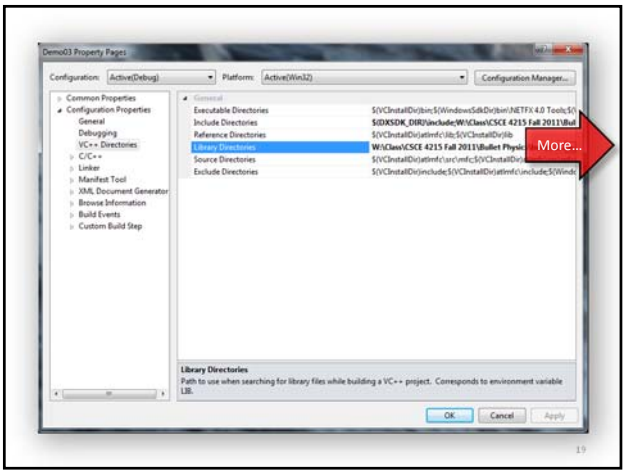

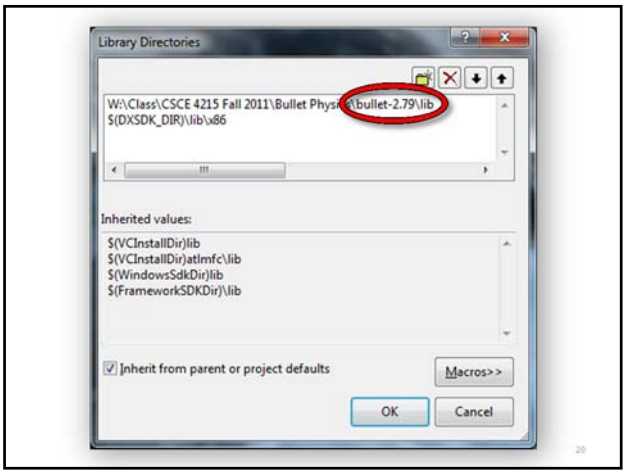

Adding Bullet Physics to Your Code

- Check out `CcdPhysicsDemo` how to create a `btDiscreteDynamicsWorld`, `btCollisionShape`, `btMotionState` and `btRigidBody`.
- Each frame call the `stepSimulation` on the dynamics world, and synchronize the world transform for your graphics object.

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Adding Bullet Physics to Your Code

Basic order of operations:

- Create Core Objects
- Physics Loop Stuff (repeat until done)
- Clean up

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Core Objects

- `btDefaultCollisionConfiguration`
- `btCollisionDispatcher`
- `btBroadphaseInterface`
- `btSequentialImpulseConstraintSolver`
- `btDiscreteDynamicsWorld`

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Physics Loop Stuff

1. Add rigid bodies, soft bodies, etc.
2. Modify physics parameters
3. Step simulation
4. Return to Step 1, until end of Physics Loop.

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Cleanup

1. Delete objects created in Physics Loop
2. Clear various arrays
3. Delete core objects

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Software Design

Bullet has been designed to be customizable and modular. The developer can, for example,

- use only the collision detection component
- use the rigid body dynamics component without soft body dynamics component
- use only small parts of a the library and extend the library in many ways

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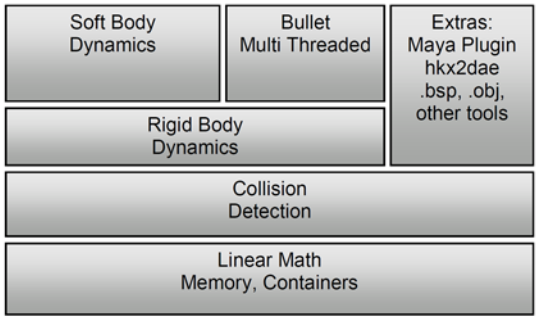
Components



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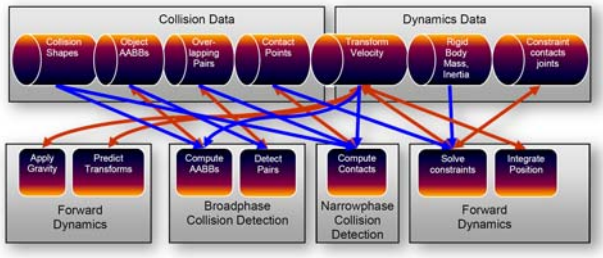
Rigid Body Physics Pipeline



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Dynamics World

A *dynamics world* provides a high level interface that manages your physics objects and constraints, and implements the update of all objects each frame.

```
btDiscreteDynamicsWorld*
 dynamicsWorld = new
  btDiscreteDynamicsWorld(
  dispatcher, overlappingPairCache,
  solver, collisionConfiguration);
```

Next: How the parameters were created.

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collisionConfiguration and dispatcher

```
//default setup for memory, collision
btDefaultCollisionConfiguration*
 collisionConfiguration = new
  btDefaultCollisionConfiguration();
//use default collision dispatcher
btCollisionDispatcher*
 dispatcher = new
   btCollisionDispatcher(
    collisionConfiguration);
```

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overlappingPairCache and solver

```
//btDbvtBroadphase is a good general
//purpose broadphase
btBroadphaseInterface*
 overlappingPairCache = new
  btDbvtBroadphase();
//the default constraint solver
btSequentialImpulseConstraintSolver*
 solver = new
  btSequentialImpulseConstraintSolver;
```

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Adding Objects

Create a `btRigidBody` and add it to the `btDynamicsWorld`. To construct a `btRigidBody` or `btCollisionObject`, you need to provide:

- Mass, positive for dynamic moving objects and zero for static objects
- `CollisionShape`, like a `Box`, `Sphere`, `Cone`, `Convex Hull` or `Triangle Mesh`
- Material properties like friction and restitution

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Adding a Rigid Body body

```
btRigidBody::btRigidBodyConstructionInfo
 rbInfo(mass, myMotionState, colShape,
  localInertia);
btRigidBody* body = new
 btRigidBody(rbInfo);
dynamicsWorld->addRigidBody(body);
```

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mass, localInertia and myMotionState

```
btScalar mass(1.f);
btVector3 localInertia(0, 0, 0);
btTransform startTransform;
startTransform.setIdentity();
startTransform.setOrigin(
  btVector3(2, 10, 0));
btDefaultMotionState*
  myMotionState = new
   btDefaultMotionState(
    startTransform);
```

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colShape

```
btCollisionShape* colShape = new
  btSphereShape(btScalar(1.));
colShape->calculateLocalInertia(
  mass, localInertia);
```

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Frame Update

- Once a frame, call `stepSimulation` on the dynamics world.
- The `btDiscreteDynamicsWorld` automatically takes into account variable timestep by performing interpolation instead of simulation for small timesteps.
- It uses an internal fixed timestep of 60 Hertz.
- `stepSimulation` will perform collision detection and physics simulation.
- It updates the world transform for active objects by calling the `btMotionState`'s `setWorldTransform`.

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Rigid Body Dynamics

Rigid body dynamics is implemented on top of the collision detection module. It adds forces, mass, inertia, velocity and constraints.

- `btRigidBody` is the main rigid body object.
- Moving objects have non-zero mass and inertia.
- `btRigidBody` is derived from `btCollisionObject`, so it inherits its world transform, friction and restitution, and adds linear and angular velocity.
- `btTypedConstraint` is the base class for rigid body constraints, including
  - `btHingeConstraint`,
  - `btPoint2PointConstraint`,
  - `btConeTwistConstraint`,
  - `btSliderConstraint`, and
  - `btGeneric6DOFconstraint`.

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Object Types

There are 3 different types of objects in Bullet:

1. Dynamic (moving) rigid bodies
   - positive mass
   - every simulation frame it will update its world transform
2. Static rigid bodies
   - zero mass
   - cannot move but can collide
3. Kinematic rigid bodies
   - zero mass
   - can be animated by the user, but there will be only one-way interaction: dynamic objects will be pushed away, but there is no influence from them.

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Center of Mass

- The world transform of a rigid body is in Bullet always equal to its center of mass, and its basis also defines its local frame for inertia.
- The local inertia tensor depends on the shape, and the `btCollisionShape` class provides a method to calculate the local inertia, given a mass.
- This world transform has to be a rigid body transform, which means it should contain no scaling, shear etc.
- If the collision shape is not aligned with the center of mass transform, it can be shifted to match with a `btCompoundShape`, using the child transform to shift the child collision shape.

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`MotionState`

- `MotionState`s are a way for Bullet to get the world transform of objects being simulated into the rendering part of your game.
- Your game loop will iterate through all the objects before each frame render. For each object, update the position of the render object from the physics body using `MotionState`s.
- Other benefits of `MotionState`s:
  - Computation involved in moving bodies around is only done for bodies that have moved.
  - You don't just have to do render stuff in them. They could be effective for notifying network code that a body has moved and needs to be updated across the network.
  - Interpolation is usually only meaningful in the context of something visible on-screen. Bullet manages body interpolation through `MotionState`s.

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`MotionState`

`MotionState`s are used in two places in Bullet.

1. When the body is first created. Bullet:
   - Grabs the initial position of the body from the `MotionState` when the body enters the simulation
   - Calls `getWorldTransform` with a reference to the variable it wants you to fill with transform information
   - Calls `getWorldTransform` on kinematic bodies.
2. After the first update, during simulation. Bullet calls the `MotionState` for a body to move it around
   - Bullet calls `setWorldTransform` with the transform of the body, for you to update your object appropriately
   - To implement one, simply inherit `btMotionState` and override `getWorldTransform` and `setWorldTransform`.

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`btDefaultMotionState`

- Although recommended, it is not necessary to derive your own `MotionState` from `btMotionState` interface.
- Bullet provides a default `MotionState` that you can use for this. Simply construct it with the default transform of your body:

```
btDefaultMotionState* ms = new
  btDefaultMotionState();
```

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Render Frames and Physics Frames

By default, Bullet physics simulation runs at an internal fixed frame rate of 60 Hertz. Your render loop will have a different or even variable frame rate. To decouple the render frame rate from the simulation frame rate, an automatic interpolation method is built into `stepSimulation`:

- If the application delta time is smaller then the internal fixed time step, Bullet will interpolate the world transform and send it to the `btMotionState`, without performing physics simulation.
- If the application time step is larger than 60Hz, one or more simulation steps can be performed during each `stepSimulation` call. The user can limit the maximum number of simulation steps by passing a maximum value as second argument.

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Some Bullet Physics Demos

1. Cloth (DirectX 11)
2. Cloth (OpenCL)
3. Spiders
4. Forklift
5. Ragdoll

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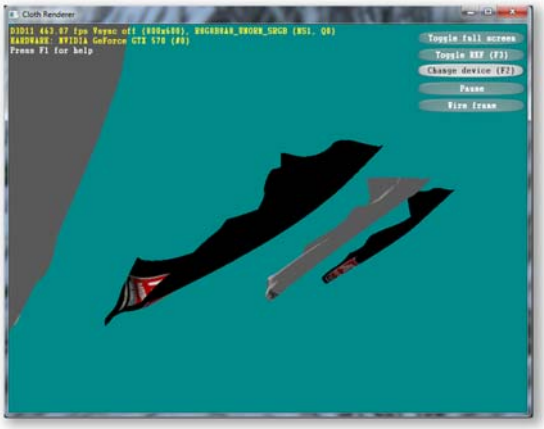

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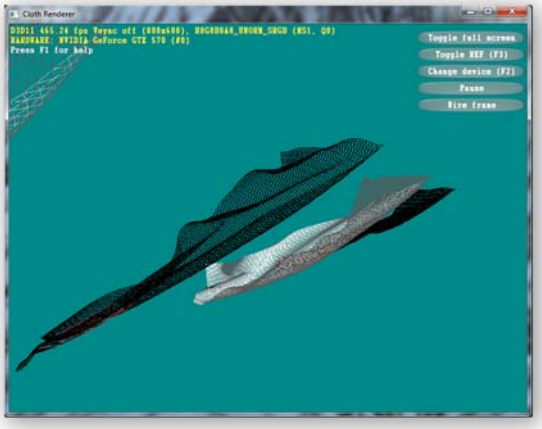

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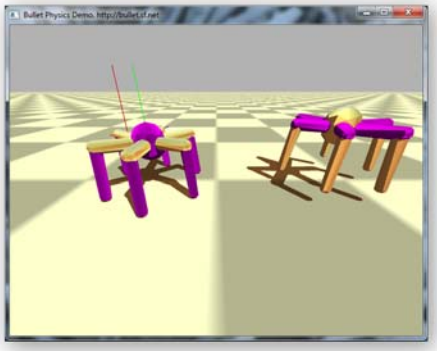

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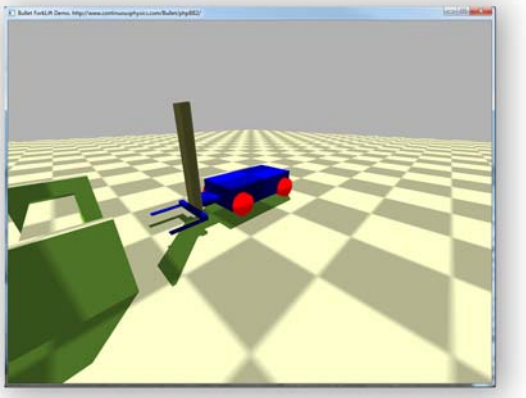

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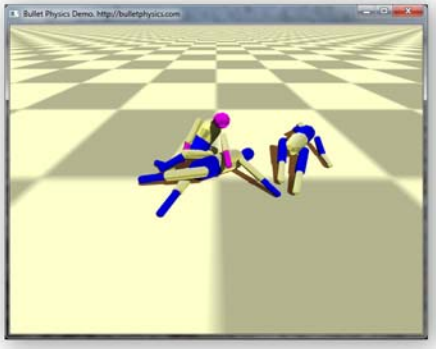

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