# pybullet quickstart guide

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# Introduction

pybullet is an easy to use Python module for physics simulation, robotics and machine learning. With pybullet you can load articulated bodies from URDF, SDF and other file formats. pybullet provides forward dynamics simulation, inverse dynamics computation, forward and inverse kinematics and collision detection and ray intersection queries.

Aside from physics simulation, there are bindings to rendering, with a CPU renderer (TinyRenderer) and OpenGL visualization and support for Virtual Reality headsets such as HTC Vive and Oculus Rift. pybullet has also functionality to perform collision detection queries (closest points, overlapping pairs, ray intersection test etc) and to add debug rendering (debug lines and text). pybullet has cross-platform built-in client-server support for shared memory, UDP and TCP networking. So you can run pybullet on Linux connecting to a Windows VR server.

pybullet wraps the new Bullet C-API, which is designed to be independent from the underlying physics engine and render engine, so we can easily migrate to newer versions of Bullet, or use a different physics engine or render engine. By default, pybullet uses the Bullet 2.x API on the CPU. We will expose Bullet 3.x running on GPU using OpenCL as well.

pybullet can be easily used with TensorFlow and frameworks such as OpenAI Gym.

## Hello pybullet World

Here is a pybullet introduction script that we discuss step by step:

```
import pybullet as p
physicsClient = p.connect(p.DIRECT)
p.setGravity(0,0,-10)
planeId = p.loadURDF("plane.urdf")
cubeStartPos = [0,0,1]
cubeStartOrientation = p.getQuaternionFromEuler([0,0,0])
boxId = p.loadURDF("r2d2.urdf",cubeStartPos, cubeStartOrientation)
p.stepSimulation()
cubePos, cubeOrn = p.getBasePositionAndOrientation(boxId)
```

```
print(cubePos,cubeOrn)
p.disconnect()
```

# connect, disconnect

After importing the pybullet module, the first thing to do is 'connecting' to the physics simulation. pybullet is designed around a command-status driven API, with a client sending commands and a physics server returning the status. pybullet has some build-in physics servers: DIRECT and GUI. DIRECT connection will execute the physics simulation and rendering in the same process as pybullet.

## connect using DIRECT, GUI

The DIRECT connection sends the commands directly to the physics engine, without using any transport layer, and directly returns the status after executing the command.

The GUI connection will create a new graphical user interface (GUI) with 3D OpenGL rendering, within the same process space as pybullet. On Linux and Windows this GUI runs in a separate thread, while on OSX it runs in the same thread due to operating system limitations. The commands and status messages are sent between pybullet client and the GUI physics simulation server using an ordinary memory buffer.

It is also possible to connect to a physics server in a different process on the same machine or on a remote machine using SHARED_MEMORY, UDP or TCP networking. See the section about Shared Memory, UDP and TCP for details.

Unlike almost all other methods, this method doesn't parse keyword arguments, due to backward compatibility.

The connect input arguments are:

| | | | |
|---|---|---|---|
| required | connection mode | integer: DIRECT, GUI, SHARED_MEMORY, UDP, TCP | DIRECT mode create a new physics engine and directly communicates with it. GUI will create a physics engine with graphical GUI frontend and communicates with it. SHARED_MEMORY will connect to an existing physics engine process on the same machine, and communicates with ot over shared memory. UDP will connect to an existing physics server over UDP networking. |
| optional | key | int | in SHARED_MEMORY mode, optional shared memory key. When starting ExampleBrowser or SharedMemoryPhysics_* you can use optional command-line --shared_memory_key to set the key. This allows to run multiple servers on the same machine. |
| optional | UdpNetworkAddress | string | IP address or host name, for example "127.0.0.1" or |

| | | | |
|---|---|---|---|
| | (UDP and TCP) | | "localhost" or "mymachine.domain.com" |
| optional | UdpNetworkPort (UDP and TCP) | integer | UDP port number. Default UDP port is 1234, default TCP port is 6667 (matching the defaults in the server) |

connect returns a physics client id or -1 if not connected. The physics client Id is an optional argument to most of the other pybullet commands. If you don't provide it, it will assume physics client id = 0. You can connect to multiple different physics servers, except for GUI.

For example:

pybullet.connect(pybullet.DIRECT)
pybullet.connect(pybullet.SHARED_MEMORY,1234)
pybullet.connect(pybullet.UDP,"192.168.0.1")
pybullet.connect(pybullet.UDP,"localhost", 1234)
pybullet.connect(pybullet.TCP,"localhost", 6667)

## connect using Shared Memory

There are a few physics servers that allow shared memory connection: the App_SharedMemoryPhysics, App_SharedMemoryPhysics_GUI and the Bullet Example Browser has one example under Experimental/Physics Server that allows shared memory connection. This will let you execute the physics simulation and rendering in a separate process.

You can also connect over shared memory to the App_SharedMemoryPhysics_VR, the Virtual Reality application with support for head-mounted display and 6-dof tracked controllers such as HTC Vive and Oculus Rift with Touch controllers. Since the Valve OpenVR SDK only works properly under Windows, the App_SharedMemoryPhysics_VR can only be build under Windows using premake.

## connect using UDP or TCP networking

For UDP networking, there is a App_PhysicsServerUDP that listens to a certain UDP port. It uses the open source enet library for reliable UDP networking. This allows you to execute the physics simulation and rendering on a separate machine. For TCP pybullet uses the clsocket library. This can be useful when using SSH tunneling from a machine behind a firewall to a robot simulation. For example you can run a control stack or machine learning using pybullet on Linux, while running the physics server on Windows in Virtual Reality using HTC Vive or Rift.

One more UDP application is the App_PhysicsServerSharedMemoryBridgeUDP application that acts as a bridge to an existing physics server: you can connect over UDP to this bridge, and the

bridge connects to a physics server using shared memory: the bridge passes messages between client and server. In a similar way there is a TCP version.

### disconnect

You can disconnect from a physics server, using the physics client Id returned by the connect call (if non-negative). A 'DIRECT' or 'GUI' physics server will shutdown. A separate (out-of-process) physics server will keep on running. See also 'resetSimulation' to remove all items.

## setGravity

By default, there is no gravitational force enabled. *setGravity* lets you set the default gravity force for all objects.
The setGravity input parameters are: (no return value)

| | | | |
|---|---|---|---|
| required | gravityX | float | gravity force along the X world axis |
| required | gravityY | float | gravity force along the Y world axis |
| required | gravityZ | float | gravity force along the Z world axis |
| optional | physicsClientId | int | if you connect to multiple physics servers, you can pick which one. |

## loadURDF

The loadURDF will send a command to the physics server to load a physics model from a Universal Robot Description File (URDF). The URDF file is used by the ROS project (Robot Operating System) to describe robots and other objects, it was created by the WillowGarage and the Open Source Robotics Foundation (OSRF). Many robots have public URDF files, you can find a description and tutorial here: http://wiki.ros.org/urdf/Tutorials

Important note: most joints (slider, revolute, continuous) have motors enabled by default that prevent free motion. This is similar to a robot joint with a very high-friction harmonic drive. You should set the joint motor control mode and target settings using pybullet.setJointMotorControl2. See the setJointMotorControl2 API for more information.

The loadURDF arguments are:

| | | | |
|---|---|---|---|
| required | fileName | string | a relative or absolute path to the URDF file on the file system of the physics server. |
| optional | basePosition | vec3 | create the base of the object at the specified position in world space coordinates [X,Y,Z] |

| | | | |
|---|---|---|---|
| optional | baseOrientation | vec4 | create the base of the object at the specified orientation as world space quaternion [X,Y,Z,W] |
| optional | useMaximalCoordinates | int | Experimental. By default, the joints in the URDF file are created using the reduced coordinate method: the joints are simulated using the Featherstone Articulated Body algorithm (btMultiBody in Bullet 2.x). The useMaximalCoordinates option will create a 6 degree of freedom rigid body for each link, and constraints between those rigid bodies are used to model joints. |
| optional | useFixedBase | int | force the base of the loaded object to be static |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

loadURDF returns a body unique id, a non-negative integer value. If the URDF file cannot be loaded, this integer will be negative and not a valid body unique id.

## loadBullet, loadSDF, loadMJCF

You can also load objects from other file formats, such as .bullet, .sdf and .mjcf. Those file formats support multiple objects, so the return value is a list of object unique ids. The SDF format is explained in detail at http://sdformat.org. The loadSDF command only extracts some essential parts of the SDF related to the robot models and geometry, and ignores many elements related to cameras, lights and so on. The loadMJCF command performs basic import of MuJoCo MJCF xml files, used in OpenAI Gym. See also the Important note under loadURDF related to default joint motor settings, and make sure to use setJointMotorControl2.

| | | | |
|---|---|---|---|
| required | fileName | string | a relative or absolute path to the URDF file on the file system of the physics server. |
| optional | useMaximalCoordinates | int | Experimental. See loadURDF for more details. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## saveWorld

You can create a snapshot of the current world as a pybullet Python file, stored on the server. saveWorld can be useful as a basic editing feature, setting up the robot, joint angles, object positions and environment for example in VR. Later you can just load the pybullet Python file to re-create the world. Note that not all settings are stored in the world file at the moment.

The input arguments are:

| | | | |
|---|---|---|---|
| required | fileName | string | filename of the pybullet file. |
| optional | clientServerId | int | if you connected to multiple servers, you can pick one |

## getQuaternionFromEuler and getEulerFromQuaternion

The pybullet API uses quaternions to represent orientations. Since quaternions are not very intuitive for people, there are two APIs to convert between quaternions and Euler angles.
The getQuaternionFromEuler input arguments are:

| | | | |
|---|---|---|---|
| required | eulerAngle | vec3: list of 3 floats | The X,Y,Z Euler angles are in radians, accumulating 3 rotations around the X, Y and Z axis. |

getQuaternionFromEuler returns a list of 3 floating point values, a vec3.

The getEulerFromQuaternion input arguments are:

| | | | |
|---|---|---|---|
| required | quaternion | vec4: list of 4 floats | The quaternion format is [x,y,z,w] |

getEulerFromQuaternion returns a quaternion, vec4 list of 4 floating point values [X,Y,Z,W]

## getMatrixFromQuaternion

getMatrixFromQuaternion is a utility API to create a 3x3 matrix from a quaternion. The input is a quaternion and output a list of 9 floats, representing the matrix.

## stepSimulation

stepSimulation will perform all the actions in a single forward dynamics simulation step such as collision detection, constraint solving and integration.

stepSimulation input arguments are optional:

| | | | |
|---|---|---|---|
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

stepSimulation has no return values.

See also setRealTimeSimulation to automatically let the physics server run forward dynamics simulation based on its real-time clock.

## setRealTimeSimulation

By default, the physics server will not step the simulation, unless you explicitly send a 'stepSimulation' command. This way you can maintain control determinism of the simulation. It is possible to run the simulation in real-time by letting the physics server automatically step the simulation according to its real-time-clock (RTC) using the setRealTimeSimulation command. If you enable the real-time simulation, you don't need to call 'stepSimulation'.

The input parameters are:

| | | | |
|---|---|---|---|
| required | enableRealTimeSimulation | int | 0 to disable real-time simulation, 1 to enable |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## getBasePositionAndOrientation

getBasePositionAndOrientation reports the current position and orientation of the base (or root link) of the body in Cartesian world coordinates. The orientation is a quaternion in [x,y,z,w] format.

The getBasePositionAndOrientation input parameters are:

| | | | |
|---|---|---|---|
| required | objectUniqueId | int | object unique id, as returned from loadURDF. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getBasePositionAndOrientation returns the position list of 3 floats and orientation as list of 4 floats in [x,y,z,w] order. Use getEulerFromQuaternion to convert the quaternion to Euler if needed.

See also resetBasePositionAndOrientation to reset the position and orientation of the object.

This completes the first pybullet script. Bullet ships with several URDF files in the Bullet/data folder.

# resetBasePositionAndOrientation

You can reset the position and orientation of the base (root) of each object. It is best only to do this at the start, and not during a running simulation, since the command will override the effect of all physics simulation.

The input arguments to resetBasePositionAndOrientation are:

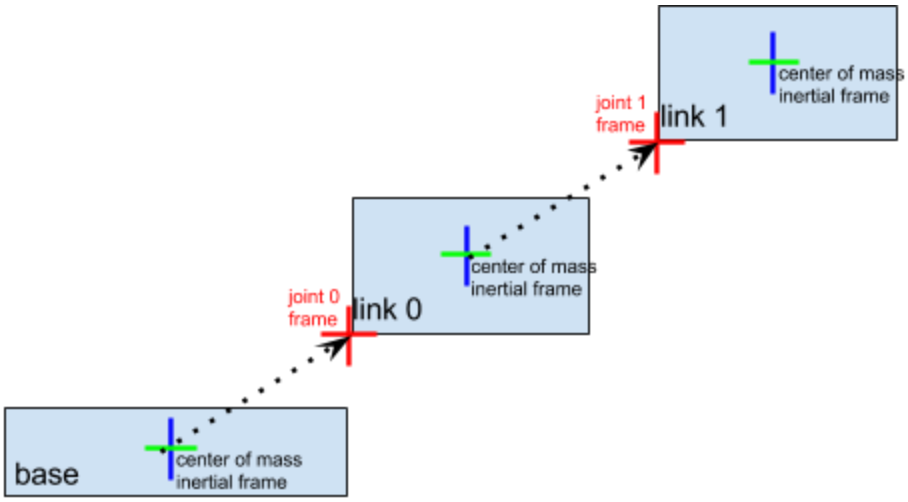
| | | | |
|---|---|---|---|
| required | objectUniqueId | int | object unique id, as returned from loadURDF. |
| required | basePosition | vec3 | reset the base of the object at the specified position in world space coordinates [X,Y,Z] |
| required | baseOrientation | vec4 | reset the base of the object at the specified orientation as world space quaternion [X,Y,Z,W] |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

There are no return arguments.

# Controlling a robot

In the Introduction we already showed how to initialize pybullet and load some objects. If you replace the file name in the loadURDF command with "r2d2.urdf" you can simulate a R2D2 robot from the ROS tutorial. Let's control this R2D2 robot to move, look around and control the gripper. For this we need to know how to access its joint motors.

## Base, Joints, Links




A simulated robot as described in a URDF file has a base, and optionally links connected by joints. Each joint connects one parent link to a child link. At the root of the hierarchy there is a single root parent that we call base. The base can be either fully fixed, 0 degrees of freedom, or fully free, with 6 degrees of freedom. Since each link is connected to a parent with a single joint, the number of joints is equal to the number of links. Regular links have link indices in the range [0..getNumJoints()] Since the base is not a regular 'link', we use the convention of -1 as its link index. We use the convention that joint frames are expressed relative to the parents center of mass inertial frame, which is aligned with the principle axis of inertia.

## getNumJoints, getJointInfo

After you load a robot you can query the number of joints using the getNumJoints API. For the r2d2.urdf this should return 15.

getNumJoints input parameters:

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | the body unique id, as returned by loadURDF etc. |

| | | | |
|---|---|---|---|
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getNumJoints returns an integer value representing the number of joints.

## getJointInfo

For each joint we can query some information, such as its name and type.

getJointInfo input parameters

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | the body unique id, as returned by loadURDF etc. |
| required | jointIndex | int | an index in the range [0 .. getNumJoints(bodyUniqueId)] |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getJointInfo returns a list of information:

| | | |
|---|---|---|
| jointIndex | int | the same joint index as the input parameter |
| jointName | string | the name of the joint, as specified in the URDF (or SDF etc) file |
| jointType | int | type of the joint, this also implies the number of position and velocity variables. JOINT_REVOLUTE, JOINT_PRISMATIC, JOINT_SPHERICAL, JOINT_PLANAR, JOINT_FIXED. See the section on Base, Joint and Links for more details. |
| qIndex | int | the first position index in the positional state variables for this body |
| uIndex | int | the first velocity index in the velocity state variables for this body |
| flags | int | reserved |
| jointDamping | float | the joint damping value, as specified in the URDF file |
| jointFriction | float | the joint friction value, as specified in the URDF file |

## setJointMotorControl2

Note: setJointMotorControl is obsolete and replaced by setJointMotorControl2 API.

We can control a robot by setting a desired control mode for one or more joint motors. During the stepSimulation the physics engine will simulate the motors to reach the given target value that can be reached within the maximum motor forces and other constraints. Each revolute joint and prismatic joint is motorized by default. There are 3 different motor control modes: position control, velocity control and torque control.

You can effectively disable the motor by using a force of 0, for example:

```
maxForce = 0
mode = p.VELOCITY_CONTROL
p.setJointMotorControl2(objUid, linkIndex, controlMode=mode, force=maxForce)
```

If you want a wheel to maintain a constant velocity, with a max force you can use:

```
maxForce = 500
p.setJointMotorControl2(bodyUniqueId=objUid,
                        linkIndex=0,
                        controlMode=p.VELOCITY_CONTROL,
                        targetVelocity = targetVel,
                        force = maxForce)
```

The input arguments to setJointMotorControl2 are:

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id as returned from loadURDF etc. |
| required | linkIndex | int | link index in range [0..getNumJoints(bodyUniqueId) |
| required | controlMode | int | POSITION_CONTROL, VELOCITY_CONTROL, TORQUE_CONTROL |
| optional | targetPosition | float | in POSITION_CONTROL the targetValue is target position of the joint |
| optional | targetVelocity | float | in VELOCITY_CONTROL and POSITION_CONTROL the targetValue is target velocity of the joint, see implementation note below. |
| optional | force | float | in POSITION_CONTROL and VELOCITY_CONTROL this is the maximum motor force used to reach the target value. In TORQUE_CONTROL this is the force/torque to be applied each simulation step. |
| optional | positionGain | float | See implementation note below |
| optional | velocityGain | float | See implementation note below |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

Note: the actual implementation of the joint motor controller is as a constraint for POSITION_CONTROL and VELOCITY_CONTROL, and as an external force for TORQUE_CONTROL:

| method | implementation | component | constraint error to be minimized |
|---|---|---|---|
| POSITION_CONTROL | constraint | velocity and position constraint | error = position_gain*(desired_position-actual_position)+velocity_gain*(de |

| | | | |
|---|---|---|---|
| | | | sired_velocity-actual_velocity) |
| VELOCITY_CONTROL | constraint | pure velocity constraint | error = desired_velocity - actual_velocity |
| TORQUE_CONTROL | external force | | |

## getJointState, resetJointState

We can query several state variables from the joint using getJointState, such as the joint position, velocity, joint reaction forces and joint motor torque.

getJointState input parameters

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id as returned by loadURDF etc |
| required | jointIndex | int | link index in range [0..getNumJoints(bodyUniqueId)] |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getJointState output

| | | |
|---|---|---|
| jointPosition | float | The position value of this joint. |
| jointVelocity | float | The velocity value of this joint. |
| jointReactionForces | list of 6 floats | There are the joint reaction forces, if a torque sensor is enabled for this joint. Without torque sensor, it is [0,0,0,0,0,0]. |
| appliedJointMotorTorque | float | This is the motor torque applied during the last stepSimulation |

## resetJointState

You can reset the state of the joint. It is best only to do this at the start, while not running the simulation: resetJointState overrides all physics simulation.

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id as returned by loadURDF etc |
| required | jointIndex | int | link index in range [0..getNumJoints(bodyUniqueId)] |
| required | targetValue | float | the joint position (angle in radians) |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## enableJointForceTorqueSensor

You can enable or disable a joint force/torque sensor in each joint. Once enabled, if you perform a stepSimulation, the 'getJointState' will report the joint reaction forces in the fixed degrees of freedom: a fixed joint will measure all 6DOF joint forces/torques. A revolute/hinge joint force/torque sensor will measure 5DOF reaction forces along all axis except the hinge axis. The applied force by a joint motor is available in the appliedJointMotorTorque of getJointState.

The input arguments to enableJointForceTorqueSensor are:

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id as returned by loadURDF etc |
| required | jointIndex | int | join index in range [0..getNumJoints(bodyUniqueId)] |
| optional | enableSensor | int | 1/True to enable, 0/False to disable the force/torque sensor |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## getLinkState

You can also query the Cartesian world position and orientation for the center of mass of each link using getLinkState. It will also report the local inertial frame of the center of mass to the URDF link frame, to make it easier to compute the graphics/visualization frame.

getLinkState input parameters

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | |
| required | linkIndex | int | |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getLinkState return values

| | | |
|---|---|---|
| linkWorldPosition | vec3, list of 3 floats | Cartesian position of center of mass |
| linkWorldOrientation | vec4, list of 4 floats | Cartesian orientation of center of mass, in quaternion [x,y,z,w] |
| localInertialFramePosition | vec3, list of 3 floats | local position offset of inertial frame (center of mass) to URDF link frame |
| localInertialFrameOrientation | vec4, list of 4 floats | local orientation (quaternion [x,y,z,w]) offset of |

| | | |
|---|---|---|
| | | the inertial frame to the URDF link frame. |

Example scripts (could be out-of-date, check actual examples/pybullet folder.)

| | |
|---|---|
| examples/pybullet/quadruped.py | load a quadruped from URDF file, step the simulation, control the motors for a simple hopping gait based on sine waves. |
| examples/pybullet/testrender.py | load a URDF file and render an image, get the pixels (RGB, depth, segmentation mask) and display the image using MatPlotLib. |
| examples/pybullet/testrender_np.py | Similar to testrender.py, but speed up the pixel transfer using NumPy arrays. Also includes simple benchmark/timings. |
| examples/pybullet/saveWorld.py | Save the state (position, orientation) of objects into a pybullet Python scripts. This is mainly useful to setup a scene in VR and save the initial stte. Not all state is serialized. |
| examples/pybullet/inverse_kinematics.py | Show how to use the calculateInverseKinematics command, creating a Kuka ARM clock |

## getBaseVelocity, resetBaseVelocity

You get access to the linear and angular velocity of the base of a body using getBaseVelocity. The input parameters are:

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id, as returned from the load* methods. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

This returns a list of two vector3 values (3 floats in a list) representing the linear velocity [x,y,z] and angular velocity [wx,wy,wz] in Cartesian worldspace coordinates.

You can reset the linear and/or angular velocity of the base of a body using resetBaseVelocity. The input parameters are:

| | | | |
|---|---|---|---|
| required | objectUniqueId | int | body unique id, as returned from the load* methods. |

| | | | |
|---|---|---|---|
| optional | linearVelocity | vec3, list of 3 floats | linear velocity [x,y,z] in Cartesian world coordinates. |
| optional | angularVelocity | vec3, list of 3 floats | angular velocity [wx,wy,wz] in Cartesian world coordinates. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## applyExternalForce, applyExternalTorque

You can apply a force or torque to a body using applyExternalForce and applyExternalForce. Note that this method will only work when explicitly stepping the simulation using stepSimulation, in other words: setRealTimeSimulation(0). After each simulation step, the external forces are cleared to zero. If you are using 'setRealTimeSimulation(1), applyExternalForce/Torque will have undefined behavior (either 0, 1 or multiple force/torque applications).

The input parameters are:

| | | | |
|---|---|---|---|
| required | objectUniqueId | int | object unique id as returned by load methods. |
| required | linkIndex | int | link index or -1 for the base. |
| required | forceObj | vec3, list of 3 floats | force vector to be applied [x,y,z]. See flags for coordinate system. |
| required | posObj | vec3, list of 3 floats | position on the link where the force is applied. See flags for coordinate system. |
| required | flags | int | Specify the coordinate system of force/position: either WORLD_FRAME for Cartesian world coordinates or or LINK_FRAME for local link coordinates. |
| optional | physicsClientId | int | |

## getNumBodies, getBodyInfo, getBodyUniqueId

getNumBodies will return the total number of bodies in the physics server.
If you used 'getNumBodies' you can query the body unique ids using 'getBodyUniqueId'. Note that all APIs already return body unique ids, so you typically never need to use getBodyUniqueId if you keep track of them.

getBodyInfo will return the base name, as extracted from the URDF, SDF, MJCF or other file.

# createConstraint, removeConstraint, changeConstraint

URDF, SDF and MJCF specify articulated bodies as a tree-structures without loops. The 'createConstraint' allows you to connect specific links of bodies to close those loops. See Bullet/examples/pybullet/quadruped.py how to connect the legs of a quadruped 5-bar closed loop linkage. In addition, you can create arbitrary constraints between objects, and between an object and a specific world frame. See Bullet/examples/pybullet/constraint.py for an example. It can also be used to control the motion of physics objects, driven by animated frames, such as a VR controller. It is better to use constraints, instead of setting the position or velocity directly for such purpose, since those constraints are solved together with other dynamics constraints.

createConstraint has the following input parameters:

| | | | |
|---|---|---|---|
| required | parentBodyUniqueId | int | parent body unique id |
| required | parentLinkIndex | int | parent link index (or -1 for the base) |
| required | childBodyUniqueId | int | child body unique id, or -1 for no body (specify a non-dynamic child frame in world coordinates) |
| required | childLinkIndex | int | child link index, or -1 for the base |
| required | jointType | int | joint type: JOINT_REVOLUTE, JOINT_PRISMATIC, JOINT_FIXED, JOINT_POINT2POINT |
| required | jointAxis | vec3, list of 3 floats | joint axis, in child link frame |
| required | parentFramePosition | vec3, list of 3 floats | position of the joint frame relative to parent center of mass frame. |
| required | childFramePosition | vec3, list of 3 floats | position of the joint frame relative to a given child center of mass frame (or world origin if no child specified) |
| optional | parentFrameOrientation | vec4, list of 4 floats | the orientation of the joint frame relative to parent center of mass coordinate frame |
| optional | childFrameOrientation | vec4, list of 4 floats | the orientation of the joint frame relative to the child center of mass coordinate frame (or world origin frame if no child specified) |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

createConstraint will return an integer unique id, that can be used to change or remove the constraint.

changeConstraint allows you to change parameters of an existing constraint. The input parameters are:

| | | | |
|---|---|---|---|
| required | userConstraintUniqueId | int | unique id returned by createConstraint |
| optional | jointChildPivot | vec3, list of 3 floats | updated child pivot, see 'createConstraint' |
| optional | jointChildFrameOrientation | vec4, list of 4 floats | updated child frame orientation as quaternion |
| optional | maxForce | float | maximum force that constraint can apply |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

See also Bullet/examples/pybullet/constraint.py

removeConstraint will remove a constraint, given by its unique id. Its input parameters are:

| | | | |
|---|---|---|---|
| required | userConstraintUniqueId | int | unique id as returned by createConstraint |
| optional | physicsClientId | int | unique id as returned by 'connect' |

## getNumConstraints

You can query for the total number of constraints, created using 'createConstraint'. Optional parameter is the int physicsClientId.

## getConstraintInfo

You can query the constraint info give a constraint unique id.
The input parameters are

| | | | |
|---|---|---|---|
| required | constraintUniqueId | int | unique id as returned by createConstraint |
| optional | physicsClientId | int | unique id as returned by 'connect' |

The output list is:

| | | |
|---|---|---|
| parentBodyIndex | int | See createConstraint |
| parentJointIndex | int | See createConstraint |
| childBodyIndex | int | See createConstraint |

| | | |
|---|---|---|
| childLinkIndex | int | See createConstraint |
| constraintType | int | See createConstraint |
| jointAxis | vec3, list of 3 floats | See createConstraint |
| jointPivotInParent | vec3, list of 3 floats | See createConstraint |
| jointPivotInChild | vec3, list of 3 floats | See createConstraint |
| jointFrameOrientationParemt | vec4, list of 4 floats | See createConstraint |
| jointFrameOrientationChild | vec4, list of 4 floats | See createConstraint |
| maxAppliedForce | float | See createConstraint |

## setTimeStep

You can set the physics engine timestep that is used when calling 'stepSimulation'. It is best to only call this method at the start of a simulation. Don't change this time step regularly. setTimeStep can also be achieved using the new setPhysicsEngineParameter API.

The input parameters are:

| | | | |
|---|---|---|---|
| required | timeStep | float | Each time you call 'stepSimulation' the timeStep will proceed with 'timeStep'. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## setPhysicsEngineParameter

You can set physics engine parameters using the setPhysicsEngineParameter API. The following input parameters are exposed:

| | | | |
|---|---|---|---|
| optional | fixedTimeStep | float | physics engine timestep in fraction of seconds, each time you call 'stepSimulation'. Same as 'setTimeStep' |
| optional | numSolverIterations | int | Choose the number of constraint solver iterations. |
| optional | useSplitImpulse | int | Advanced feature, only when using maximial coordinates: split the positional constraint solving and velocity constraint solving in two stages, to prevent huge penetration recovery forces. |

| | | | |
|---|---|---|---|
| optional | splitImpulsePenetrationThreshold | float | Related to 'useSplitImpulse': if the penetration for a particular contact constraint is less than this specified threshold, no split impulse will happen for that contact. |
| optional | numSubSteps | int | Subdivide the physics simulation step further by 'numSubSteps'. This will trade performance over accuracy. |
| optional | collisionFilterMode | int | Use 0 for default collision filter: (group A&maskB) AND (groupB&maskA). Use 1 to switch to the OR collision filter: (group A&maskB) OR (groupB&maskA) |
| optional | contactBreakingThreshold | float | Contact points with distance exceeding this threshold are not processed by the LCP solver. In addition, AABBs are extended by this number. Defaults to 0.02 in Bullet 2.x. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

## resetSimulation

resetSimulation will remove all objects from the world and reset the world to initial conditions. It takes one optional parameter: the physics client Id (in case you created multiple physics server connections).

## startStateLogging/stopStateLogging

The saveWorld command lets you store the current state of the world in a pybullet file. State logging lets you the state of one or more objects after each simulation step (call to stepSimulation or automatically when setRealTimeSimulation is enabled). This allows you to record trajectories of objects. We plan to implement various types of logging, including logging the state of VR controllers, and all common state of bodies such as base position and orientation, joint positions (angles) and joint motor forces. As a starting point we implemented the logging of the Minitaur robot. The log file from pybullet simulation is identical to the real Minitaur quadruped log file.

See Bullet/examples/pybullet/logMinitaur.py for an example.

| | | | |
|---|---|---|---|
| required | loggingType | int | At the moment, STATE_LOGGING_MINITAUR is implemented. This will require to load the quadruped/quadruped.urdf and object unique id from the quadruped. It logs the timestamp, IMU roll/pitch/yaw, 8 leg motor positions (q0-q7), 8 leg motor torques |

| | | | |
|---|---|---|---|
| | | | (u0-u7), the forward speed of the torso and mode (unused in simulation).<br><br>Todo: STATE_LOGGING_VR_CONTROLLERS, STATE_LOGGING_GENERIC_ROBOT_DATA etc. |
| required | fileName | string | file name (absolute or relative path) to store the log file data. |
| optional | objectUniqueIds | list of int | If left empty, the logger may log every object, otherwise the logger just logs the objects in the objectUniqueIds list. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

The command will return a non-negative int loggingUniqueId, that can be used with stopStateLogging.

## stopStateLogging

You can stop a logger using its loggingUniqueId.

# Synthetic Camera Rendering

pybullet has a build-in CPU renderer based on TinyRenderer. This makes it very easy to render images from an arbitrary camera position.

The synthetic camera is specified by two 4 by 4 matrices: the view matrix and the projection matrix. Since those are not very intuitive, there are some helper methods to compute the view and projection matrix from understandable parameters.

## computeViewMatrix

The computeViewMatrix input parameters are

| | | | |
|---|---|---|---|
| required | cameraEyePosition | vec3, list of 3 floats | eye position in Cartesian world coordinates |
| required | cameraTargetPosition | vec3, list of 3 floats | position of the target (focus) point, in Cartesian world coordinates |
| required | cameraUpVector | vec3, list of 3 floats | up vector of the camera, in Cartesian world coordinates |

Output is the 4x4 view matrix, stored as a list of 16 floats.

## computeViewMatrixFromYawPitchRoll

The input parameters are

| | | | |
|---|---|---|---|
| required | cameraTargetPosition | list of 3 floats | target focus point in Cartesian world coordinates |
| required | distance | float | distance from eye to focus point |
| required | yaw | float | yaw angle in degrees, up and down |
| required | pitch | float | pitch in degrees around up vector |
| required | roll | float | roll in degrees around forward vector |
| required | upAxisIndex | int | either 1 for Y or 2 for Z axis up. |

Output is the 4x4 view matrix, stored as a list of 16 floats.

## computeProjectionMatrix

The input parameters are

| | | | |
|---|---|---|---|
| required | left | float | left screen (canvas) coordinate |
| required | right | float | right screen (canvas) coordinate |
| required | bottom | float | bottom screen (canvas) coordinate |
| required | top | float | top screen (canvas) coordinate |
| required | near | float | near plane distance |
| required | far | float | far plane distance |

Output is the 4x4 projection matrix, stored as a list of 16 floats.

## computeProjectionMatrixFOV

This command also will return a 4x4 projection matrix, using different parameters. You can check out OpenGL documentation for the meaning of the parameters.
The input parameters are:

| | | | |
|---|---|---|---|
| required | fov | float | field of view |
| required | aspect | float | aspect ratio |
| required | nearVal | float | near plane distance |
| required | farVal | float | far plane distance |

# getCameraImage

The getCameraImage API will return a RGB image, a depth buffer and a segmentation mask buffer with body unique ids of visible objects for each pixel. Note that pybullet can be compiled using the numpy option: using numpy will improve the performance of copying the camera pixels from C to Python. Note: the old renderImage API is obsolete and replaced by getCameraImage.

getCameraImage input parameters:

| | | | |
|---|---|---|---|
| required | width | int | horizontal image resolution in pixels |
| required | height | int | vertical image resolution in pixels |
| optional | viewMatrix | 16 floats | 4x4 view matrix, see computeViewMatrix* |
| optional | projectionMatrix | 16 floats | 4x4 projection matrix, see computeProjection* |
| optional | lightDirection | vec3, list of 3 floats | light direction |
| optional | lightColor | vec3, list of 3 floats | light color in [RED,GREEN,BLUE] in range 0..1 |
| optional | lightDistance | float | distance of the light |
| optional | shadow | int | 1 for shadows, 0 for no shadows |
| optional | lightAmbientCoeff | float | light ambient coefficient |
| optional | lightDiffuseCoeff | float | light diffuse coefficient |
| optional | lightSpecularCoeff | float | light specular coefficient |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getCameraImage  returns a list of parameters:

| | | |
|---|---|---|
| width | int | width image resolution in pixels (horizontal) |
| height | int | height image resolution in pixels (vertical) |

| | | |
|---|---|---|
| rgbPixels | list of [char RED,char GREEN,char BLUE] [0..width*height] | list of pixel colors in R,G,B format, in range [0..255] for each color |
| depthPixels | list of float [0..width*height] | depth buffer |
| segmentationMaskBuffer | list of int [0..width*height] | for each pixels the visible object index |

## getVisualShapeData

You can access visual shape information using getVisualShapeData. You could use this to bridge your own rendering method with pybullet simulation, and synchronize the world transforms manually after each simulation step.

The input parameters are:

| | | | |
|---|---|---|---|
| required | objectUniqueId | int | object unique id, as returned by a load method. |
| optional | physicsClientId | int | physics client id as returned by 'connect' |

The output is a list of visual shape data, each visual shape is in the following format:

| | | |
|---|---|---|
| objectUniqueId | int | object unique id, same as the input |
| linkIndex | int | link index or -1 for the base |
| visualGeometryType | int | visual geometry type (TBD) |
| dimensions | vec3, list of 3 floats | dimensions (size, local scale) of the geometry |
| meshAssetFileName | string, list of chars | path to the triangle mesh, if any. Typically relative to the URDF, SDF or MJCF file location, but could be absolute. |
| localVisualFrame position | vec3, list of 3 floats | position of local visual frame, relative to link/joint frame |
| localVisualFrame orientation | vec4, list of 4 floats | orientation of local visual frame relative to link/joint frame |
| rgbaColor | vec4, list of 4 floats | URDF color (if any specified) in red/green/blue/alpha |

The physics simulation uses center of mass as a reference for the Cartesian world transforms, in getBasePositionAndOrientation and in getLinkState. If you implement your own rendering, you need to transform the local visual transform to world space, making use of the center of mass world transform and the (inverse) localInertialFrame. You can access the localInertialFrame using the getLinkState API.

## resetVisualShapeData

You can use resetVisualShapeData to change the texture of a shape. This texture will currently only affect the software renderer (see getCameraImage), not the OpenGL visualization window (yet).

| | | | |
|---|---|---|---|
| required | objectUniqueId | int | object unique id, as returned by load method. |
| required | jointIndex | int | link index |
| required | shapeIndex | int | shape index, within range. See getVisualShapeData. |
| required | textureUniqueId | int | texture unique id, as returned by 'loadTexture' method |
| required | physicsClientId | int | physics client id as returned by 'connect' |

## loadTexture

Load a texture from file and return a non-negative texture unique id if the loading succeeds. This unique id can be used with resetVisualShapeData.

# Collision Detection Queries

You can query the contact point information that existed during the last 'stepSimulation'. To get the contact points you can use the 'getContactPoints' API. Note that the 'getContactPoints' will not recompute any contact point information.

## getOverlappingObjects

This query will return all the unique ids of objects that have axis aligned bounding box overlap with a given axis aligned bounding box.

The getOverlappingObjects input parameters are:

| | | | |
|---|---|---|---|
| required | aabbMin | vec3, list of 3 floats | minimum coordinates of the aabb |
| required | aabbMax | vec3, list of 3 floats | minimum coordinates of the aabb |
| optional | physicsClientId | int | if you connected to |

| | | | |
|---|---|---|---|
| | | | multiple servers, you can pick one. |

The getOverlappingObjects will return a list of object unique ids.

## getContactPoints

The getContactPoints input parameters are as follows:

| | | | |
|---|---|---|---|
| optional | filterBodyUniqueIdA | int | only report contact points that involve body A |
| optional | filterBodyUniqueIdB | int | only report contact points that involve body B |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getContactPoints will return a list of contact points. Each contact point has the following fields:

| | | |
|---|---|---|
| contactFlag | int | reserved |
| bodyUniqueIdA | int | body unique id of body A |
| bodyUniqueIdB | int | body unique id of body B |
| linkIndexA | int | link index of body A, -1 for base |
| linkIndexB | int | link index of body B, -1 for base |
| positionOnA | vec3, list of 3 floats | contact position on A, in Cartesian world coordinates |
| positionOnB | vec3, list of 3 floats | contact position on B, in Cartesian world coordinates |
| contactNormalOnB | vec3, list of 3 floats | contact normal on B, pointing towards A |
| contactDistance | float | contact distance, positive for separation, negative for penetration |
| normalForce | float | normal force applied during the last 'stepSimulation' |

## getClosestPoints

It is also possible to compute the closest points, independent from stepSimulation. This also lets you compute closest points of objects with an arbitrary separating distance. In this query there will be no normal forces reported.

getClosestPoints input parameters:

| | | | |
|---|---|---|---|
| required | objectUniqueIdA | int | object unique id for first object (A) |
| required | objectUniqueIdB | int | object unique id for second object (B) |
| required | maxDistance | float | If the distance between objects exceeds this maximum distance, no points may be returned. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

getClosestPoints returns a list of closest points in the same format as getContactPoints (but normalForce is always zero in this case)

## rayTest

You can perform a single raycast to find the intersection information of the first object hit.

The rayTest input parameters are:

| | | | |
|---|---|---|---|
| required | rayFromPosition | vec3, list of 3 floats | start of the ray in world coordinates |
| required | rayToPosition | vec3, list of 3 floats | end of the ray in world coordinates |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

The raytest query will return the following information in case of an intersection:

| | | |
|---|---|---|
| objectUniqueId | int | object unique id of the hit object |
| linkIndex | int | link index of the hit object, or -1 if none/parent. |
| hit fraction | float | hit fraction along the ray in range [0,1] along the ray. |
| hit position | vec3, list of 3 floats | hit position in Cartesian world coordinates |
| hit normal | vec3, list of 3 floats | hit normal in Cartesian world coordinates |

# Inverse Dynamics, Kinematics

## calculateInverseDynamics

calculateInverseDynamics will compute the forces needed to reach the given joint accelerations, starting from specified joint positions and velocities.

The calculateInverseDynamics input parameters are:

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id, as returned by loadURDF etc. |
| required | jointPositions | list of float | joint positions (angles) |
| required | jointVelocities | list of float | joint velocities |
| required | jointAccelerations | list of float | desired joint accelerations |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

calculateInverseDynamics returns a list of joint forces.

# Inverse Kinematics

You can compute the joint angles that makes the end-effector reach a given target position in Cartesian world space. Internally, Bullet uses an improved version of Samuel Buss Inverse Kinematics library. At the moment only the Damped Least Squared method with or without Null Space control is exposed, with a single end-effector target. Optionally you can also specify the target orientation of the end effector. In addition, there is an option to use the null-space to specify joint limits and rest poses. This optional null-space support requires all 4 lists (lowerLimits, upperLimits, jointRanges, restPoses), otherwise regular IK will be used. See also inverse_kinematics.py example in Bullet/examples/pybullet folder for details.

## calculateInverseKinematics

calculateInverseKinematics input parameters are:

| | | | |
|---|---|---|---|
| required | bodyUniqueId | int | body unique id, as returned by loadURDF |
| required | endEffectorLinkIndex | int | end effector link index |
| required | targetPosition | vec3, list of 3 floats | target position in Cartesian world space |
| optional | targetOrientation | vec3, list of 4 floats | target orientation in Cartesian world space, quaternion [x,y,w,z]. If not specified, pure position IK will be used. |
| optional | lowerLimits | list of floats [0..nDof] | Optional null-space IK requires all 4 lists (lowerLimits, upperLimits, jointRanges, restPoses). Otherwise regular IK will be used. |
| optional | upperLimits | list of floats [0..nDof] | |
| optional | jointRanges | list of floats [0..nDof] | |
| optional | restPoses | list of floats [0..nDof] | |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

calculateInverseKinematics returns a list of joint positions. See Bullet/examples/pybullet/inverse_kinematics.py for an example.

# Virtual Reality

When pybullet is connected to a virtual reality physics server, you can get access to the VR controller state. The VR physics server uses the OpenVR API for HTC Vive and Oculus Rift Touch controller support. OpenVR is currently working on Windows, Valve is also working on a Linux version.

See also https://www.youtube.com/watch?v=VMJyZtHQL50 for an example video of the VR example, part of Bullet, that can be fully controlled using pybullet over shared memory, UDP or TCP connection.

## getVREvents

getVREvents will return a list of controllers that changed state since the last call to getVREvents. getVREvents has one optional input parameter, physicsClientId.

The output parameters are:

| | | |
|---|---|---|
| controllerId | int | controller index (0..MAX_VR_CONTROLLERS) |
| controllerPosition | vec3, list of 3 floats | controller position, in world space Cartesian coordinates |
| controllerOrientation | vec4, list of 4 floats | controller orientation quaternion [x,y,z,w] in world space |
| controllerAnalogueAxis | float | analogue axis value |
| numButtonEvents | int | number of button events since last call to getVREvents |
| numMoveEvents | int | number of move events since last call to getVREvents |
| buttons | int[8], list of 8 integers | flags for each button: VR_BUTTON_IS_DOWN (currently held down), VR_BUTTON_WAS_TRIGGERED (went down at least once since last cal to getVREvents, VR_BUTTON_WAS_RELEASED (was released at least once since last call to getVREvents). Note that only VR_BUTTON_IS_DOWN reports actual current state. For example if the button went down and up, you can tell from the RELEASE/TRIGGERED flags, even though IS_DOWN is still false. |

See Bullet/examples/pybullet/vrEvents.py for an example of VR drawing.

## setVRCameraState

setVRCameraState allows to set the camera root transform offset position and orientation. This allows to control the position of the VR camera in the virtual world. It is also possible to let the VR Camera track an object, such as a vehicle.

setVRCameraState has the following arguments (there are no return values):

| | | | |
|---|---|---|---|
| optional | rootPosition | vec3, vector of 3 floats | camera root position |
| optional | rootOrientation | vec3, vector of 3 floats | camera root orientation |
| optional | trackObject | vec3, vector of 3 floats | the object unique id to track |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one. |

# Debug GUI, Lines, Text, Parameters

pybullet has some functionality to make it easier to debug, visualize and tune the simulation. This feature is only useful if there is some 3D visualization window, such as GUI mode or when connected to a separate physics server (such as Example Browser in 'Physics Server' mode or standalone Physics Server with OpenGL GUI).

## addUserDebugLine

You can add a 3d line specified by a 3d starting point (from) and end point (to), a color [red,green,blue], a line width and a duration in seconds. The arguments to addUserDebugline are:

| | | | |
|---|---|---|---|
| required | lineFromXYZ | vec3, list of 3 floats | starting point of the line in Cartesian world coordinates |
| required | lineToXYZ | vec3, list of 3 floats | end point of the line in Cartesian world coordinates |
| optional | lineColorRGB | vec3, list of 3 floats | RGB color [Red, Green, Blue] each component in range [0..1] |
| optional | lineWidth | float | line width (limited by OpenGL implementation) |
| optional | lifeTime | float | use 0 for permanent line, or positive time in seconds (afterwards the line with be removed automatically) |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

addUserDebugLine will return a non-negative unique id, that lets you remove the line using removeUserDebugItem.

## addUserDebugText

You can add some 3d text at a specific location using a color and size. The input arguments are:

| | | | |
|---|---|---|---|
| required | text | text | text represented as a string (array of characters) |
| required | textPosition | vec3, list of 3 floats | 3d position of the text in Cartesian world coordinates [x,y,z] |
| optional | textColorRGB | vec3, list of 3 floats | RGB color [Red, Green, Blue] each component in range [0..1] |
| optional | textSize | float | Text size |
| optional | lifeTime | float | use 0 for permanent text, or positive time in seconds (afterwards the text with be removed automatically) |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

addUserDebugText  will return a non-negative unique id, that lets you remove the line using removeUserDebugItem.

## addUserDebugParameter, readUserDebugParameter

addUserDebugParameter lets you add custom sliders to tune parameters. It will return a unique id. This lets you read the value of the parameter using readUserDebugParameter. The input parameters of addUserDebugParameter are:

| | | | |
|---|---|---|---|
| required | paramName | string | name of the parameter |
| required | rangeMin | float | minimum value |
| required | rangeMax | float | maximum value |
| required | startValue | float | starting value |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

The input parameters of readUserDebugParameter are:

| | | | |
|---|---|---|---|
| required | itemUniqueId | int | the unique id returned by 'addUserDebugParameter) |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

Return value is the most up-to-date reading of the parameter.

## removeUserDebugItem

The functions to add user debug lines, text or parameters will return a non-negative unique id if it succeeded. You can remove the debug item using this unique id using the removeUserDebugItem method.The input parameters are:

| | | | |
|---|---|---|---|
| required | itemUniqueId | int | unique id of the debug item to be removed (line, text etc) |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

## setDebugObjectColor

The built-in OpenGL visualizers have a wireframe debug rendering feature: press 'w' to toggle. The wireframe has some default colors. You can override the color of a specific object and link using setDebugObjectColor. The input parameters are:

| | | | |
|---|---|---|---|
| required | objectUniqueId | int | unique id of the object |
| required | linkIndex | int | link index |
| optional | objectDebugColorRGB | vec3, list of 3 floats | debug color in [Red,Green,Blue]. If not provided, the custom color will be removed. |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

## configureDebugVisualizer

You can configure some settings of the built-in OpenGL visualizer, such as enabling or disabling wireframe, shadows and GUI rendering. This is useful since some laptops or Desktop GUIs have performance issues with our OpenGL 3 visualizer.

| | | | |
|---|---|---|---|
| required | flag | int | The feature to enable or disable, such as |

| | | | |
|---|---|---|---|
| | | | COV_ENABLE_WIREFRAME, COV_ENABLE_SHADOW,COV_ENABLE_GUI |
| required | enable | int | 0 or 1 |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

Example:
pybullet.configureDebugVisualizer(pybullet.COV_ENABLE_WIREFRAME,1)

## resetDebugVisualizerCamera

You can set the 3D OpenGL debug visualizer camera distance (between eye and camera target position), camera yaw and pitch and camera target position.

| | | | |
|---|---|---|---|
| required | cameraDistance | float | distance from eye to camera target position |
| required | cameraYaw | float | camera yaw angle (in degrees) up/down |
| required | cameraPitch | float | camera pitch angle (in degrees) left/right |
| required | cameraTargetPosition | vec3, list of 3 floats | cameraTargetPosition is the camera focus point |
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

Example: pybullet.resetDebugVisualizerCamera( cameraDistance=3, cameraYaw=30, cameraPitch=52, cameraTargetPosition=[0,0,0])

## getKeyboardEvents

You can receive all keyboard events that happened since the last time you called 'getKeyboardEvents'. Each event has a keycode and a state. The state is a bit flag combination of KEY_DOWN, KEY_WAS_TRIGGED and KEY_WAS_RELEASED. If a key is going from 'up' to 'down' state, you receive the KEY_WAS_TRIGGED state, as well as the 'KEY_DOWN' state. If a key was pressed and released, the state will be KEY_WAS_TRIGGED and KEY_WAS_RELEASED.

Some special keys are defined: B3G_F1 … B3G_F12, B3G_LEFT_ARROW, B3G_RIGHT_ARROW, B3G_UP_ARROW, B3G_DOWN_ARROW, B3G_PAGE_UP, B3G_PAGE_DOWN, B3G_PAGE_END, B3G_HOME, B3G_DELETE, B3G_INSERT.

The input of getKeyBoardEvents is an optional physicsClientId:

| | | | |
|---|---|---|---|
| optional | physicsClientId | int | if you connected to multiple servers, you can pick one |

The output is a dictionary of keycode 'key' and keyboard state 'value'.

# Build and install pybullet

There are a few different ways to install pybullet on Windows, Mac OSX and Linux. We use Python 2.7 and Python 3.5.2, but expect most Python 2.x and Python 3.x versions should work. First get the source code from github, using

git clone https://github.com/bulletphysics/bullet3

## Using cmake on Linux and Mac OSX

1) Download and install cmake
2) Run the shell script in the root of Bullet:
   build_and_run_cmake_pybullet_double.sh
3) On Mac OSX, create symbolic link:
   ln -s pybullet.dylib pybullet.so
4) Make sure Python finds our pybullet.so module:
   export PYTHONPATH = /your_path_to_bullet/build_cmake/examples/pybullet

That's it. Test pybullet by running a python interpreter and enter 'import pybullet' to see if the module loads. If so, you can play with the pybullet scripts in Bullet/examples/pybullet.

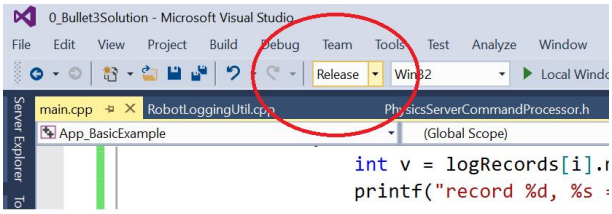
## Possible Linux Issues

- Make sure OpenGL is installed
- When using Anaconda as Python distribution, conda install libgcc so that 'GLIBCXX' is found (see http://askubuntu.com/questions/575505/glibcxx-3-4-20-not-found-how-to-fix-this-error)
- It is possible that cmake cannot find the python libs when using Anaconda as Python distribution. You can add them manually by going to the ../build_cmake/CMakeCache.txt file and changing following line:
  'PYTHON_LIBRARY:FILEPATH=/usr/lib/python2.7/config-x86_64-linux-gnu/libpython2.7.so'

## Using premake for Window

Make sure some Python version is installed in c:\python-3.5.2 (or other version folder name)

Click on build_visual_studio_vr_pybullet_double.bat and open the 0_Bullet3Solution.sln project in Visual Studio, convert projects if needed.
Switch to Release mode, and compile the 'pybullet' project.




Then there are a few options to import pybullet in a Python interpreter:

1) Rename pybullet_vs2010..dll to pybullet.pyd and start the Python.exe interpreter using bullet/bin as the current working directory. Optionally for debugging: rename bullet/bin/pybullet_vs2010_debug.dll to pybullet_d.pyd and start python_d.exe)
2) Rename bullet/bin/pybullet_vs2010..dll to pybullet.pyd and use command prompt: export PYTHONPATH=c:\develop\bullet3\bin (replace with actual folder where Bullet is located) or create this PYTHONPATH environment variable using Windows GUI
3) create an administrator prompt (cmd.exe) and create a symbolic link as follows

cd c:\python-3.5.2\dlls

mklink pybullet.pyd c:\develop\bullet3\bin\pybullet_vs2010.dll

Then run python.exe and import pybullet should work.

TODO: Using setup.py and pip easier installation of pybullet.

# FAQ and Tips

Question: What happens to Bullet 2.x and the Bullet 3 OpenCL implementation?
Answer: pybullet is wrapping the Bullet C-API. We will put the Bullet 3 OpenCL GPU API (and future Bullet 4.x API) behind this C-API. So if you use pybullet or the C-API you are future-proof. Not to be confused with the Bullet 2.x C++ API.

Question: How can I improve the performance and stability of the collision detection?
Answer: There are many ways to optimize, for example:
shape type

1) Choose one or multiple primitive collision shape types such as box, sphere, capsule, cylinder to approximate an object, instead of using convex or concave triangle meshes.
2) If you really need to use triangle meshes, create a convex decomposition using Hierarchical Approximate Convex Decomposition (v-HACD). The test_hacd utility converts convex triangle mesh in an OBJ file into a new OBJ file with multiple convex

hull objects. See for example Bullet/data/teddy_vhacd.urdf pointing to Bullet/data/teddy2_VHACD_CHs.obj, or duck_vhacd.urdf pointing to duck_vhacd.obj.

3) Reduce the number of vertices in a triangle mesh. For example Blender 3D has a great mesh decimation modifier that interactively lets you see the result of the mesh simplification.
4) Use rolling friction and spinning friction for round objects such as sphere and capsules and robotic grippers using the <rolling_friction> and <spinning_friction> nodes inside <link><contact> nodes. See for example Bullet/data/sphere2.urdf
5) Use a small amount of compliance for wheels using the <stiffness value="30000"/> <damping value="1000"/> inside the URDF <link><contact> xml node. See for example the Bullet/data/husky/husky.urdf vehicle.
6) Use the double precision build of Bullet, this is good both for contact stability and collision accuracy. Choose some good constraint solver setting and time step.
7) Decouple the physics simulation from the graphics. pybullet already does this for the GUI and various physics servers: the OpenGL graphics visualization runs in its own thread, independent of the physics simulation.

Question: What are the options for friction handling?

Answer: by default, Bullet and pybullet uses a pyramidal approximation of the Coulomb friction model. You can enable rolling and spinning friction by adding a <rolling_friction> and <spinning_friction> node inside the <link><contact> node, see the Bullet/data/sphere2.urdf for example. Instead of the pyramid approximation, we will enable the option for Coulomb friction using an actual implicit cone.

Question: What kind of constant or threshold inside Bullet, that makes high speeds impossible?

Answer: By default, Bullet relies on discrete collision detection in combination with penetration recovery. Relying purely on discrete collision detection means that an object should not travel faster than its own radius within one timestep. Bullet has is an option for continuous collision detection to catch collisions for objects that move faster than their own radius within one timestep. This will be enabled in pybullet.