Mitsuba Python API

Examples and Exercises

March 22, 2017

1 Python API for Mitsuba

The Mitsuba rendering system exposes many of the C++ API calls to Python access. This notebook includes the examples from the Mitsuba documentation as well as some additional examples for composing and rendering a scene from Python.

Documentation for the Mitsuba Python bindings is available at the Mitsuba website.

Note that this notebook runs on the assumption that there is a local installation of Mitsuba and that it is compiled in the normal RGB (SPECTRUM_SAMPLES = 3) mode. Full integration with *MORTICIA* requires that Mitsuba be compiled with 4 or more spectral channels in order to put Mitusba into the absolute radiometric mode. "Field" integrators are not available when Mitsuba is compiled with SPECTRUM_SAMPLES > 3. The field integrators are illustrated in this notebook, including distance, normals, UV-mapping coordinates are more. These integrators can be accessed using the Mitsuba "multichannel" integrator facility.

The recommended approach is that the local copy of Mitsuba be compiled with SPECTRUM_SAMPLES = 3 for the use of field integrators and that additional compute platforms be available with Mitsuba compiled having SPECTRUM_SAMPLES > 3.

```
In [3]: import os, sys
        import matplotlib as mpl
        import matplotlib.pyplot as plt
        import matplotlib.image as mpimg
        import numpy as np
        # Note that the MORTICIA scene module for Mitsuba is imported as mormit,
        # whereas the Mitsuba Python API is imported as mitsuba
        import morticia.rad.radute as radute
        import morticia.scene.mitsuba as mormit
        font = {'family' : 'normal',
                'weight' : 'bold',
                'size'   : 22}
        mpl.rc('font', **font)
        # Use the following magic to configure the backend for
        # PDF graphic generation if exporting for publication
        backend_figure_format = 'pdf'
        if backend_figure_format:
            %config InlineBackend.figure_format = '$backend_figure_format'
        # Now import the mitsuba Python extension
        # The following applies only to Windows
        # NOTE: remember to specify paths using FORWARD slashes (i.e. '/' instead of
        # '\' to avoid pitfalls with string escaping)
        # Configure the search path for the Python extension module
        my_path_to_mitsuba = 'C:/Users/DGriffith/Downloads/Mitsuba/Mitsuba 0.5.0'
        sys.path.append(my_path_to_mitsuba + '/python/2.7')
        # Ensure that Python will be able to find the Mitsuba core libraries
        os.environ['PATH'] = my_path_to_mitsuba + os.pathsep + os.environ['PATH']
        # On other platforms, measures may also be required to ensure that Python can find the Mitsuba package
        import mitsuba
        # Use auto reload of librad for development purposes
        %load_ext autoreload
        %autoreload 1
        %aimport morticia.scene.mitsuba
        %aimport
        %matplotlib inline
        casetitle = 'Mitsuba Python API'
        subtitle = 'Examples and Exercises'
```

```
Modules to reload:
morticia.scene.mitsuba

Modules to skip:
```

1.1 Accessing Core Funcions

```
In [4]: # A simple 3-vector transformation operation
        from mitsuba.core import *
        # Create a normalized direction vector
        myVector = normalize(mitsuba.core.Vector(1.0, 2.0, 3.0))
        # 90 deg. rotation around the Y axis
        trafo = Transform.rotate(mitsuba.core.Vector(0, 1, 0), 90)
        # Apply the rotation and display the result
        print(trafo * myVector)
```

```
[0.801784, 0.534522, -0.267261]
```

1.2 Loading a Scene

Scenes are loaded using the file resolver to find the .xml scene file and then the SceneHandler to load the scene.

Here, the scene cubi.xml contains a CUBI object used in thermal signatorics. The CUBI is also used as a standard object for field validation.

```
In [5]: from mitsuba.render import SceneHandler
        # Get a reference to the thread's file resolver
        fileResolver = Thread.getThread().getFileResolver()
        # Register any searchs path needed to load scene resources (optional)
        fileResolver.appendPath('./MitsubaScenes/')
        # Optional: supply parameters that can be accessed
        # by the scene (e.g. as $myParameter)
        paramMap = StringMap()
        paramMap['myParameter'] = 'value'
```

```
In [6]: # Load the scene from an XML file
        scene = SceneHandler.loadScene(fileResolver.resolve("./MitsubaScenes/cubi.xml"), paramMap)
```

```
scene.setDestinationFile('./MitsubaScenes/cubiEXR')  # Set the name of the render output file
# Display a textual summary of the scene's contents
print(scene)
```

```
Scene[
  sensor = ref<PerspectiveCameraImpl>[ref=2, ptr=PerspectiveCamera[
    xfov = 40,
    nearClip = 0.01,
    farClip = 10000,
    worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
      -0.707107, -0.235706, -0.666665, 2.12711;
      -0.707107, 0.235706, 0.666665, -2.12711;
      0, 0.942807, -0.333339, 1.06356;
      0, 0, 0, 1
    ]],
    sampler = IndependentSampler[
      sampleCount = 1
    ],
    film = HDRFilm[
      size = [1024, 768],
      fileFormat = 1,
      pixelFormat = rgb, luminance, rgb,
      channelNames = "normal.R", "normal.G", "normal.B", "distance.Y", "uv.R", "uv.G", "uv.B",
      componentFormat = float32,
      cropOffset = [0, 0],
      cropSize = [1024, 768],
      banner = 1,
      filter = GaussianFilter[stddev=0.500000, radius=2.000000]
    ],
    medium = ref<Medium>[null],
    shutterOpen = 0,
    shutterOpenTime = 0
  ]],
  sampler = ref<IndependentSampler>[ref=2, ptr=IndependentSampler[
  sampleCount = 1
]],
integrator = ref<MultiChannelIntegrator>[ref=1, ptr=MultiChannelIntegrator[
  integrators = {
    FieldIntegrator[],
    FieldIntegrator[],
    FieldIntegrator[],
  }
]],
kdtree = ref<ShapeKDTree>[ref=1, ptr=ShapeKDTree[unknown]],
environmentEmitter = ref<EnvironmentMap>[ref=2, ptr=EnvironmentMap[
  filename = "",
  samplingWeight = 1,
  bsphere = BSphere[center = [0, 0, 0], radius = 0],
  worldTransform = ref<AnimatedTransform>[ref=2, ptr=Matrix4x4[
    1, 0, 0, 0;
    0, -4.37114e-008, -1, 0;
    0, 1, -4.37114e-008, 0;
    0, 0, 0, 1
  ]],
  mipmap = TMIPMap[
     pixelFormat = rgb,
     size = 1.0 MiB,
     levels = 10,
     cached = no,
     filterType = ewa,
     bc = [repeat, clamp],
     minimum = [0, 0, 0],
     maximum = [4591.88, 3524.41, 2460.93],
     average = [0.0837834, 0.0815985, 0.082528]
  ],
  medium = ref<Medium>[null]
]],
shapes = {
  Rectangle[
    objectToWorld = Matrix4x4[
      0.25, 0, 0, 0;
      0, -1.09278e-008, -0.25, 0;
      0, 0.25, -1.09278e-008, 0.25;
      0, 0, 0, 1
    ],
    bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
      id = "diffuseWhite",
      reflectance = [1, 1, 1]
    ]],
    emitter = ref<Emitter>[null],
    sensor = ref<Sensor>[null],
    subsurface = ref<Subsurface>[null]
  ],
  Rectangle[
    objectToWorld = Matrix4x4[
      0.25, 0, 0, 0;
      0, 0.25, 0, -0.25;
      0, 0, 0.25, 0;
      0, 0, 0, 1
    ],
    bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
      id = "diffuseWhite",
      reflectance = [1, 1, 1]
    ]],
    emitter = ref<Emitter>[null],
    sensor = ref<Sensor>[null],
    subsurface = ref<Subsurface>[null]
  ],
  Rectangle[
    objectToWorld = Matrix4x4[
      0.25, 0, 0, 0;
      0, 0.25, 0, 0.25;
      0, 0, 0.25, 0.5;
      0, 0, 0, 1
    ],
    bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
      id = "diffuseWhite",
      reflectance = [1, 1, 1]
    ]],
    emitter = ref<Emitter>[null],
    sensor = ref<Sensor>[null],
    subsurface = ref<Subsurface>[null]
  ],
  Rectangle[
    objectToWorld = Matrix4x4[
      0.25, 0, 0, 0;
      0, -1.09278e-008, -0.25, -0.5;
      0, 0.25, -1.09278e-008, -0.25;
      0, 0, 0, 1
    ],
    bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
      id = "diffuseWhite",
      reflectance = [1, 1, 1]
    ]],
    emitter = ref<Emitter>[null],
    sensor = ref<Sensor>[null],
    subsurface = ref<Subsurface>[null]
  ],
  Rectangle[
    objectToWorld = Matrix4x4[
      -1.09278e-008, 0, -0.25, -0.25;
      0, 0.25, 0, -0.25;
      0.25, 0, -1.09278e-008, -0.25;
```

```
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
    ],
    Rectangle[
      objectToWorld = Matrix4x4[
        0.25, 0, 0, 0;
        0, -0.25, 2.18557e-008, -0.25;
        0, -2.18557e-008, -0.25, -0.5;
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
    ],
    Rectangle[
      objectToWorld = Matrix4x4[
        0.25, 0, 0, 0;
        0, -0.25, 2.18557e-008, 0.25;
        0, -2.18557e-008, -0.25, -0.5;
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
    ],
    Rectangle[
      objectToWorld = Matrix4x4[
        -1.09278e-008, 0, -0.25, -0.25;
        0, 0.25, 0, 0.25;
        0.25, 0, -1.09278e-008, -0.25;
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
    ],
    Rectangle[
      objectToWorld = Matrix4x4[
        -1.09278e-008, 0, -0.25, -0.25;
        0, 0.25, 0, 0.25;
        0.25, 0, -1.09278e-008, 0.25;
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
    ],
    Rectangle[
      objectToWorld = Matrix4x4[
        0.25, 0, 0, 0;
        0, -1.09278e-008, 0.25, 0.5;
        0, -0.25, -1.09278e-008, 0.25;
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
    ],
    Rectangle[
      objectToWorld = Matrix4x4[
        0.25, 0, 0, 0;
        0, -1.09278e-008, 0.25, 0.5;
        0, -0.25, -1.09278e-008, -0.25;
        0, 0, 0, 1
      ],
      bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
        id = "diffuseWhite",
        reflectance = [1, 1, 1]
      ]],
      emitter = ref<Emitter>[null],
      sensor = ref<Sensor>[null],
      subsurface = ref<Subsurface>[null]
```

```
],
Rectangle[
  objectToWorld = Matrix4x4[
    -1.09278e-008, 0, 0.25, 0.25;
    0, 0.25, 0, 0.25;
    -0.25, 0, -1.09278e-008, -0.25;
    0, 0, 0, 1
  ],
  bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
    id = "diffuseWhite",
    reflectance = [1, 1, 1]
  ]],
  emitter = ref<Emitter>[null],
  sensor = ref<Sensor>[null],
  subsurface = ref<Subsurface>[null]
],
Rectangle[
  objectToWorld = Matrix4x4[
    -1.09278e-008, 0, 0.25, 0.25;
    0, 0.25, 0, 0.25;
    -0.25, 0, -1.09278e-008, 0.25;
    0, 0, 0, 1
  ],
  bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
    id = "diffuseWhite",
    reflectance = [1, 1, 1]
  ]],
  emitter = ref<Emitter>[null],
  sensor = ref<Sensor>[null],
  subsurface = ref<Subsurface>[null]
],
Rectangle[
  objectToWorld = Matrix4x4[
      -1.09278e-008, 0, 0.25, 0.25;
      0, 0.25, 0, -0.25;
      -0.25, 0, -1.09278e-008, -0.25;
      0, 0, 0, 1
    ],
    bsdf = ref<SmoothDiffuse>[ref=15, ptr=SmoothDiffuse[
      id = "diffuseWhite",
      reflectance = [1, 1, 1]
    ]],
    emitter = ref<Emitter>[null],
    sensor = ref<Sensor>[null],
    subsurface = ref<Subsurface>[null]
  ]
},
emitters = {
  EnvironmentMap[
    filename = "",
    samplingWeight = 1,
    bsphere = BSphere[center = [0, 0, 0], radius = 0],
    worldTransform = ref<AnimatedTransform>[ref=2, ptr=Matrix4x4[
      1, 0, 0, 0;
      0, -4.37114e-008, -1, 0;
      0, 1, -4.37114e-008, 0;
      0, 0, 0, 1
    ]],
    mipmap = TMIPMap[
       pixelFormat = rgb,
       size = 1.0 MiB,
       levels = 10,
       cached = no,
       filterType = ewa,
       bc = [repeat, clamp],
       minimum = [0, 0, 0],
       maximum = [4591.88, 3524.41, 2460.93],
       average = [0.0837834, 0.0815985, 0.082528]
    ],
    medium = ref<Medium>[null]
  ]
},
media = {
},
sensors = {
  PerspectiveCamera[
    xfov = 40,
    nearClip = 0.01,
    farClip = 10000,
    worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
      -0.707107, -0.235706, -0.666665, 2.12711;
      -0.707107, 0.235706, 0.666665, -2.12711;
      0, 0.942807, -0.333339, 1.06356;
      0, 0, 0, 1
    ]],
    sampler = IndependentSampler[
      sampleCount = 1
    ],
    film = HDRFilm[
      size = [1024, 768],
      fileFormat = 1,
      pixelFormat = rgb, luminance, rgb,
      channelNames = "normal.R", "normal.G", "normal.B", "distance.Y", "uv.R", "uv.G", "uv.B",
      componentFormat = float32,
      cropOffset = [0, 0],
      cropSize = [1024, 768],
      banner = 1,
      filter = GaussianFilter[stddev=0.500000, radius=2.000000]
    ],
      medium = ref<Medium>[null],
      shutterOpen = 0,
      shutterOpenTime = 0
    ]
  },
  ssIntegrators = {
  },
  objects = {
    SmoothDiffuse[
      id = "diffuseWhite",
      reflectance = [1, 1, 1]
    ],
    SmoothDiffuse[
      id = "diffuseRed",
      reflectance = [1, 0, 0]
    ]
  }
]
```

1.3 Rendering a Scene

First the scheduler and workers are set up and then the render job is submitted to a job queue. The queue should be set up only once per host. Either execute the next cell for execution on the local host, or the following cell for remote execution.

```
In [7]: # Run this cell only once per session
        from mitsuba.render import RenderQueue, RenderJob
        import multiprocessing
        scheduler = Scheduler.getInstance()

        # Start up the scheduling system with one worker per local core
        for i in range(0, multiprocessing.cpu_count()):
            scheduler.registerWorker(LocalWorker(i, 'wrk%i' % i))
        scheduler.start()
```

The next cell shows how to render via a remote instance of *mtssrv*. Thas can be tested on the local host by specifying the -i 127.0.0.1 option with *mtssrv*.

```
In [5]: # Alternatively set up remote workers
        # Run this cell only once per session

        # Connect to a socket on a named host or IP address
        # 7554 is the default port of 'mtssrv'
        # The IP number 127.0.0.1 usually refers to the local host, but run mtssrv -i 127.0.0.1
        stream = SocketStream('146.64.248.22', 7554)
```

```
In [6]: # Create a remote worker instance that communicates over the stream
        remoteWorker = RemoteWorker('netWorker', stream)
        scheduler = Scheduler.getInstance()
        # Register the remote worker (and any other potential workers)
        scheduler.registerWorker(remoteWorker)
        scheduler.start()
```

```
In [8]: from mitsuba.render import RenderQueue, RenderJob
        # Create a queue for tracking render jobs
        queue = RenderQueue()
```

```
In [9]: # Create a render job and insert it into the queue
        job = RenderJob('myRenderJob', scene, queue)
        job.start()
        # Wait for all jobs to finish and release resources
        queue.waitLeft(0)
        queue.join()
        # Print some statistics about the rendering process
        print(Statistics.getInstance().getStats())
```

```
------------------------------------------------------------
 * Loaded plugins :
    -  plugins\diffuse.dll [Smooth diffuse BRDF]
    -  plugins\envmap.dll [Environment map]
    -  plugins\field.dll [Field extraction integrator]
    -  plugins\gaussian.dll [Gaussian reconstruction filter]
    -  plugins\hdrfilm.dll [High dynamic range film]
    -  plugins\independent.dll [Independent sampler]
    -  plugins\lanczos.dll [Lanczos Sinc filter]
    -  plugins\multichannel.dll [Multi-channel integrator]
    -  plugins\perspective.dll [Perspective camera]
    -  plugins\rectangle.dll [Rectangle intersection primitive]
    -  plugins\sky.dll [Skylight emitter]
    -  plugins\sphere.dll [Sphere intersection primitive]
    -  plugins\sunsky.dll [Sun & sky emitter]

  * General :
    -  Normal rays traced : 786.432 K

  * Texture system :
    -  Cumulative MIP map memory allocations : 1 MiB
-----------------------------------------------------------
```

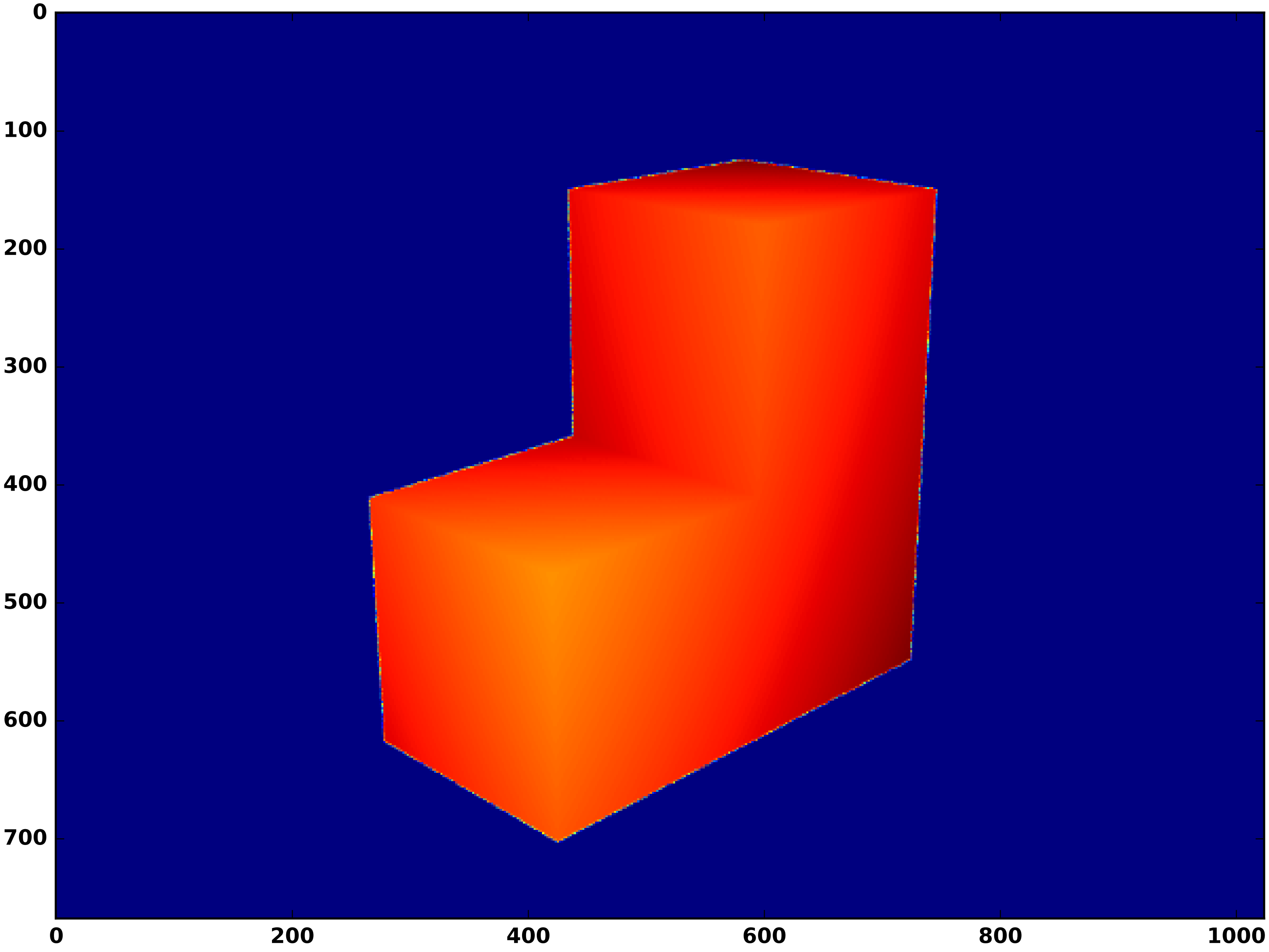
```
In [10]: # Read the data resulting from the Mitsuba run
         channel_names, im_dict, header = radute.readOpenEXR('./MitsubaScenes/cubiEXR.exr')
         # Print keys of what came back in the image dictionary
         print im_dict.keys()
```

```
['normal', 'normal.G', 'uv.R', 'uv', 'distance.Y', 'normal.B', 'uv.B', 'uv.G', 'normal.R']
```

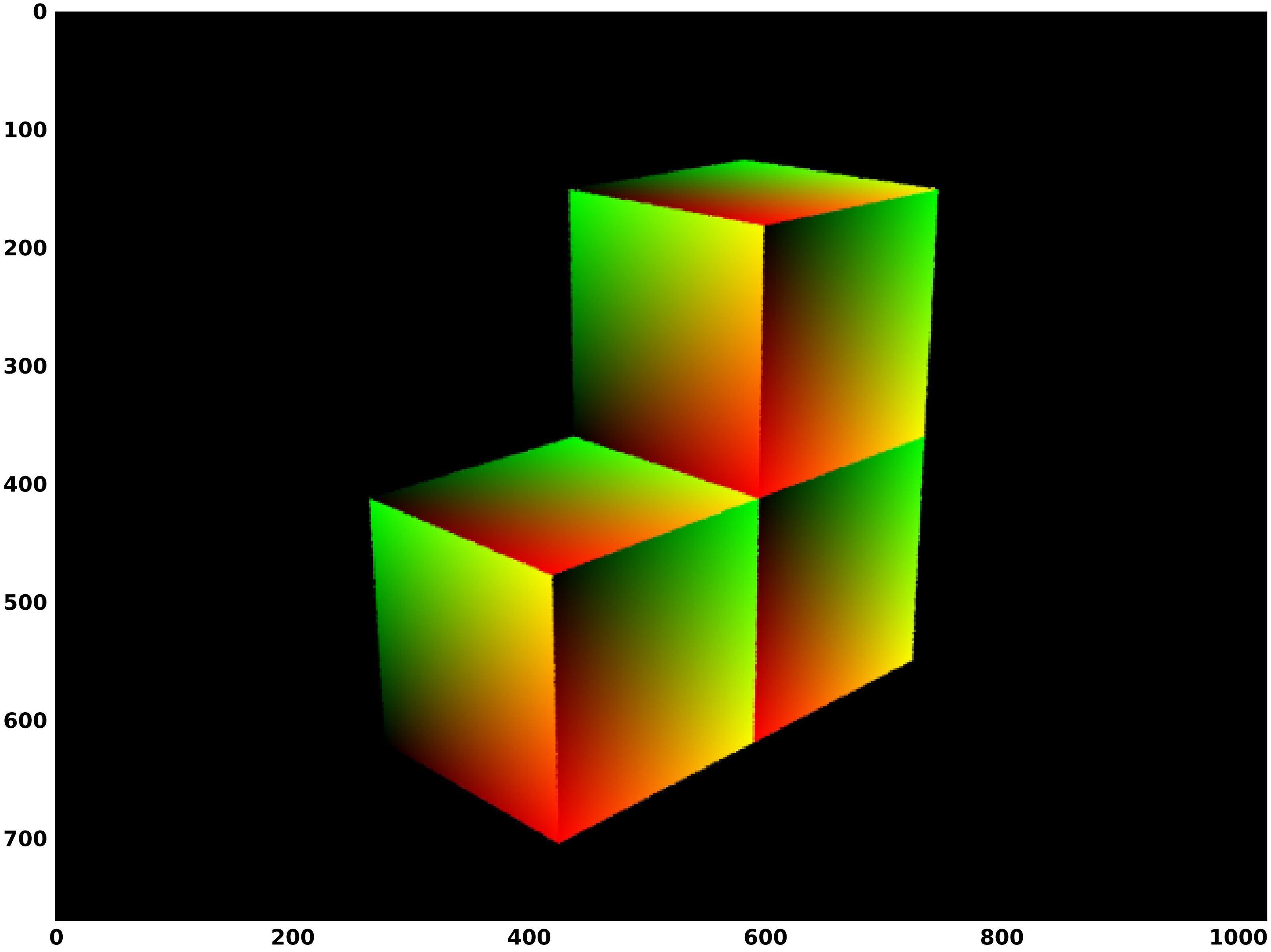
```
In [11]: # Plot the distance data
         plt.figure(figsize=(10.24, 7.68))
         plt.imshow(im_dict['distance.Y'])
```

```
Out[11]: <matplotlib.image.AxesImage at 0xdae6160>
```

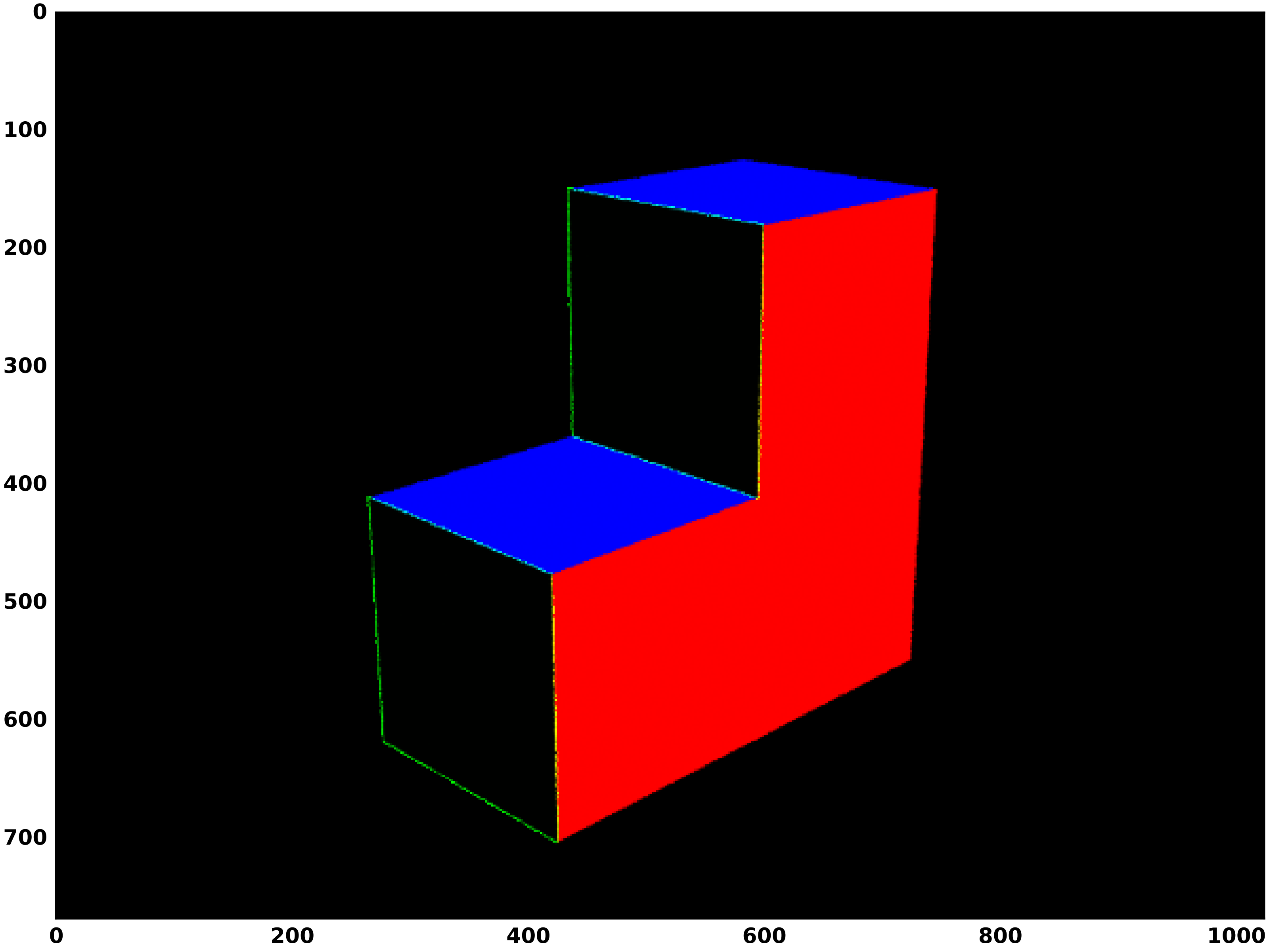
```
C:\Anaconda\envs\mordevpy27\lib\site-packages\matplotlib\font_manager.py:1288: UserWarning: findfont: Font family [u'r
  (prop.get_family(), self.defaultFamily[fontext]))
```


0
100
200
300
400
500
600
700
0
200
400
600
800
1000

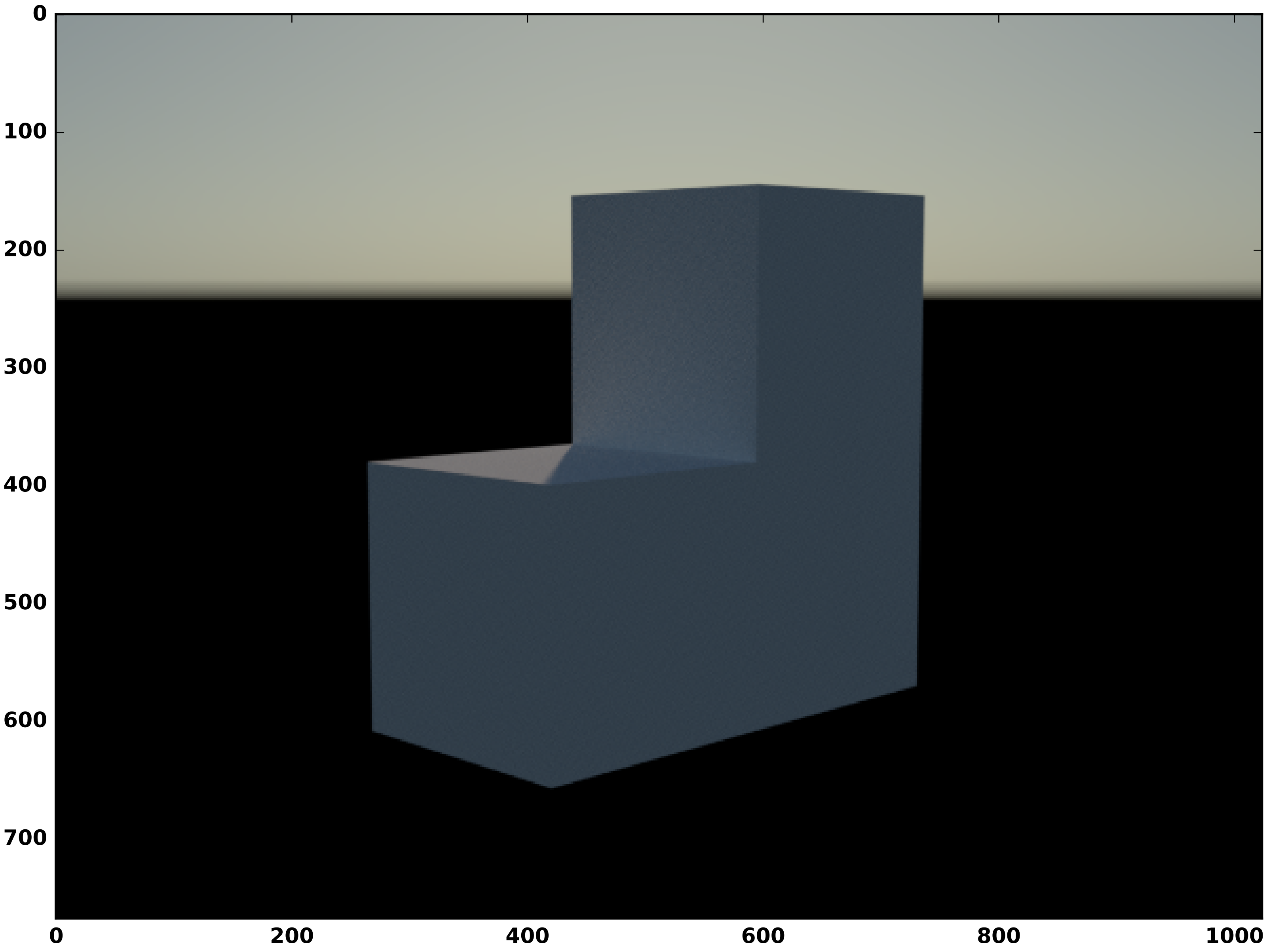
```
In [12]: # Plot the UV data (u, v coordinates on each pixel hit)
         plt.figure(figsize=(10.24, 7.68))
         plt.imshow(im_dict['uv'])

Out[12]: <matplotlib.image.AxesImage at 0xdf7dda0>
```


0
100
200
300
400
500
600
700
0
200
400
600
800
1000

```
In [13]: # Plot the UV data (u, v coordinates on each pixel hit)
         plt.figure(figsize=(10.24, 7.68))
         plt.imshow(im_dict['normal'])

Out[13]: <matplotlib.image.AxesImage at 0xe2ac198>
```


0
100
200
300
400
500
600
700
0
200
400
600
800
1000

```
In [14]: # Load the scene from an XML file for the low dynamic range version
         # Supply parameters that can be accessed
         # by the scene (e.g. as $myParameter)
         paramMap = StringMap()
         paramMap['surfaceAlbedo'] = '0.5 0.5 0.5'
         paramMap['CUBIfaceReflectance'] = '1.0 1.0 1.0'
         scenePNG = SceneHandler.loadScene(fileResolver.resolve("./MitsubaScenes/cubiPNG.xml"), paramMap)
         scenePNG.setDestinationFile('./MitsubaScenes/cubiPNG')  # Set the name of the render output file
         # Create a render job and insert it into the queue
         job = RenderJob('myRenderJob', scenePNG, queue)
         job.start()
         # Wait for all jobs to finish and release resources
         queue.waitLeft(0)
         queue.join()

         # Take a look at the CUBI
         cubi_img = mpimg.imread('./MitsubaScenes/cubiPNG.png')
         plt.figure(figsize=(10.24, 7.68))
         plt.imshow(cubi_img)

Out[14]: <matplotlib.image.AxesImage at 0xe37d7b8>
```


0
100
200
300
400
500
600
700
0
200
400
600
800
1000

```
In [15]: # Load the material preview scene from an XML file
         mat_scene = SceneHandler.loadScene(fileResolver.resolve("./MitsubaScenes/matpreview.xml"))
         mat_scene.setDestinationFile('./MitsubaScenes/mat_ball')  # Set the name of the render output file
         # Display a textual summary of the scene's contents
         print(mat_scene)
```

```
Scene[
  sensor = ref<PerspectiveCameraImpl>[ref=2, ptr=PerspectiveCamera[
    xfov = 37.8664,
    nearClip = 0.01,
    farClip = 10000,
    worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
      -0.685884, -0.317366, -0.654861, 3.69558;
      -0.727631, 0.312466, 0.610671, -3.46243;
      0.0108156, 0.895346, -0.44524, 3.25463;
      0, 0, 0, 1
    ]],
    sampler = LowDiscrepancySampler[
      sampleCount = 64,
      dimension = 4
    ],
    film = LDRFilm[
      size = [683, 512],
      fileFormat = 0,
      pixelFormat = rgb,
      gamma = -1,
      cropOffset = [0, 0],
      cropSize = [683, 512],
      banner = 0,
      method = gamma,
      exposure = 0,
    reinhardKey = 0.18,
    reinhardBurn = 0,
    filter = GaussianFilter[stddev=0.500000, radius=2.000000]
  ],
  medium = ref<Medium>[null],
  shutterOpen = 0,
  shutterOpenTime = 0
]],
sampler = ref<LowDiscrepancySampler>[ref=2, ptr=LowDiscrepancySampler[
  sampleCount = 64,
  dimension = 4
]],
integrator = ref<MIPathTracer>[ref=1, ptr=MIPathTracer[
  maxDepth = -1,
  rrDepth = 5,
  strictNormals = 0
]],
kdtree = ref<ShapeKDTree>[ref=1, ptr=ShapeKDTree[unknown]],
environmentEmitter = ref<EnvironmentMap>[ref=2, ptr=EnvironmentMap[
  filename = "./MitsubaScenes/envmap.exr",
  samplingWeight = 1,
  bsphere = BSphere[center = [0, 0, 0], radius = 0],
  worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
    0.224951, -1e-006, 0.97437, 0;
    0.97437, 0, -0.224951, 0;
    8.74228e-014, 1, 1e-006, 8.87;
    0, 0, 0, 1
  ]],
  mipmap = TMIPMap[
     pixelFormat = rgb,
     size = 1.0 MiB,
     levels = 10,
     cached = no,
     filterType = ewa,
     bc = [repeat, clamp],
     minimum = [8.19564e-005, 0.000175357, 4.86374e-005],
     maximum = [19.2813, 10.7656, 8.82031],
     average = [0.39696, 0.316207, 0.278359]
  ],
  medium = ref<Medium>[null]
]],
shapes = {
  SerializedMesh[
    name = "matpreview@2",
    triangleCount = 57152,
    vertexCount = 29439,
    faceNormals = false,
    hasNormals = true,
    hasTexcoords = true,
    hasTangents = false,
    hasColors = false,
    surfaceArea = -1,
    aabb = AABB3[min=[-1.05939, -1.08033, 0.01403], max=[1.08033, 1.05939, 1.91551]],
    bsdf = ref<SmoothPlastic>[ref=1, ptr=SmoothPlastic[
      id = "unnamed",
      specularReflectance = [1, 1, 1],
      diffuseReflectance = [0.00913406, 0.0595112, 0.107023],
      specularSamplingWeight = 0.950366,
      diffuseSamplingWeight = 0.0496341,
      nonlinear = 0,
      eta = 1.89947,
      fdrInt = 0.763693,
      fdrExt = 0.147406
    ]],
    subsurface = ref<Subsurface>[null],
    emitter = ref<Emitter>[null]
```

```
],
SerializedMesh[
  name = "Interior-mesh_0",
  triangleCount = 3936,
  vertexCount = 2078,
  faceNormals = false,
  hasNormals = true,
  hasTexcoords = true,
  hasTangents = false,
  hasColors = false,
  surfaceArea = -1,
  aabb = AABB3[min=[-0.927272, -0.927272, -0.0058961], max=[0.927272, 0.927272, 1.71208]],
  bsdf = ref<SmoothDiffuse>[ref=2, ptr=SmoothDiffuse[
    id = "__diffmat",
    reflectance = [0.18, 0.18, 0.18]
  ]],
  subsurface = ref<Subsurface>[null],
  emitter = ref<Emitter>[null]
],
SerializedMesh[
  name = "Plane-mesh_0",
  triangleCount = 512,
  vertexCount = 289,
  faceNormals = false,
  hasNormals = true,
  hasTexcoords = true,
  hasTangents = false,
  hasColors = false,
  surfaceArea = -1,
  aabb = AABB3[min=[-7.19786, -5.46007, -0.0120714], max=[5.14732, 7.94973, 6.84708]],
  bsdf = ref<SmoothDiffuse>[ref=2, ptr=SmoothDiffuse[
    id = "__planemat",
    reflectance = Checkerboard[
          color1 = [0.2, 0.2, 0.2],
          color0 = [0.4, 0.4, 0.4]
        ]
      ]],
      subsurface = ref<Subsurface>[null],
      emitter = ref<Emitter>[null]
    ]
  },
  emitters = {
    EnvironmentMap[
      filename = "./MitsubaScenes/envmap.exr",
      samplingWeight = 1,
      bsphere = BSphere[center = [0, 0, 0], radius = 0],
      worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
        0.224951, -1e-006, 0.97437, 0;
        0.97437, 0, -0.224951, 0;
        8.74228e-014, 1, 1e-006, 8.87;
        0, 0, 0, 1
      ]],
      mipmap = TMIPMap[
         pixelFormat = rgb,
         size = 1.0 MiB,
         levels = 10,
         cached = no,
         filterType = ewa,
         bc = [repeat, clamp],
         minimum = [8.19564e-005, 0.000175357, 4.86374e-005],
         maximum = [19.2813, 10.7656, 8.82031],
         average = [0.39696, 0.316207, 0.278359]
      ],
      medium = ref<Medium>[null]
    ]
  },
media = {
},
sensors = {
  PerspectiveCamera[
    xfov = 37.8664,
    nearClip = 0.01,
    farClip = 10000,
    worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
      -0.685884, -0.317366, -0.654861, 3.69558;
      -0.727631, 0.312466, 0.610671, -3.46243;
      0.0108156, 0.895346, -0.44524, 3.25463;
      0, 0, 0, 1
    ]],
    sampler = LowDiscrepancySampler[
      sampleCount = 64,
      dimension = 4
    ],
    film = LDRFilm[
      size = [683, 512],
      fileFormat = 0,
      pixelFormat = rgb,
      gamma = -1,
      cropOffset = [0, 0],
      cropSize = [683, 512],
      banner = 0,
      method = gamma,
      exposure = 0,
      reinhardKey = 0.18,
      reinhardBurn = 0,
      filter = GaussianFilter[stddev=0.500000, radius=2.000000]
    ],
    medium = ref<Medium>[null],
    shutterOpen = 0,
   shutterOpenTime = 0
  ]
 },
 ssIntegrators = {
 },
 objects = {
  SmoothDiffuse[
   id = "__diffmat",
   reflectance = [0.18, 0.18, 0.18]
  ],
  Checkerboard[
    color1 = [0.2, 0.2, 0.2],
    color0 = [0.4, 0.4, 0.4]
  ],
  SmoothDiffuse[
   id = "__planemat",
   reflectance = Checkerboard[
     color1 = [0.2, 0.2, 0.2],
     color0 = [0.4, 0.4, 0.4]
   ]
  ]
 }
]
```

```
In [16]: # Create a render job and insert it into the queue
         job = RenderJob('myRenderJob', mat_scene, queue)
         job.start()
         # Wait for all jobs to finish and release resources
         queue.waitLeft(0)
         queue.join()
```

```
In [ ]: # Perform the animation run
        mat_sensor = mat_scene.getSensor()
```

```
mat_sensor.setShutterOpen(0)
mat_sensor.setShutterOpenTime(1)
stepSize = 5
for i in range(0,360 / stepSize):
    rotationCur = Transform.rotate(Vector(0, 0, 1), i*stepSize)
    rotationNext = Transform.rotate(Vector(0, 0, 1), (i+1)*stepSize)
    trafoCur = Transform.lookAt(rotationCur * Point(0,-6,4),
        Point(0, 0, .5), rotationCur * Vector(0, 1, 0))
    trafoNext = Transform.lookAt(rotationNext * Point(0,-6,4),
        Point(0, 0, .5), rotationNext * Vector(0, 1, 0))
    atrafo = AnimatedTransform()
    atrafo.appendTransform(0, trafoCur)
    atrafo.appendTransform(1, trafoNext)
    atrafo.sortAndSimplify()
    mat_sensor.setWorldTransform(atrafo)
    mat_scene.setDestinationFile('./MitsubaScenes/frame_%03i' % i)
    job = RenderJob('job_%i' % i, mat_scene, queue)
    job.start()
    queue.waitLeft(0)
```

```
In [ ]: # Release resources
        queue.join()
```

2 Creating a Scene

The first example from the Mitsuba manual on scene construction shows how to build a sensor with a film.

First a generic plugin manager is created and then a plugin instance of specific type is assigned, in this case a perspective camera with HD film.

```
In [17]: from mitsuba.render import Scene
         pmgr = PluginManager.getInstance()  # Get generic plugin manager instance
         # Encodes parameters on how to instantiate the 'perspective' plugin
         sensorProps = Properties('perspective')
         sensorProps['toWorld'] = Transform.lookAt(
             Point(0, 0, -10), # Camera origin
             Point(0, 0, 0), # Camera target
             Vector(0, 1, 0) # 'up' vector
             )
         sensorProps['fov'] = 45.0
         # Encodes parameters on how to instantiate the 'ldrfilm' plugin
         filmProps = Properties('ldrfilm')
         filmProps['width'] = 1920
         filmProps['height'] = 1080
         # Load and instantiate the plugins
         sensor = pmgr.createObject(sensorProps)
         film = pmgr.createObject(filmProps)
         # First configure the film and then add it to the sensor
         film.configure()
         sensor.addChild('film', film)
         # Now, the sensor can be configured
         sensor.configure()
         # Print the sensor
         sensor

Out[17]: PerspectiveCamera[
           xfov = 45,
           nearClip = 0.01,
           farClip = 10000,
           worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
             1, 0, 0, 0;
             0, 1, 0, 0;
             0, 0, 1, -10;
             0, 0, 0, 1
           ]],
           sampler = IndependentSampler[
             sampleCount = 4
           ],
           film = LDRFilm[
             size = [1920, 1080],
             fileFormat = 0,
             pixelFormat = rgb,
             gamma = -1,
             cropOffset = [0, 0],
             cropSize = [1920, 1080],
             banner = 1,
             method = gamma,
             exposure = 0,
             reinhardKey = 0.18,
             reinhardBurn = 0,
             filter = GaussianFilter[stddev=0.500000, radius=2.000000]
           ],
           medium = ref<Medium>[null],
           shutterOpen = 0,
           shutterOpenTime = 0
         ]
```

2.1 Creating a Scene using Dictionaries

The following cell shows how to do the same sensor/film creation using dictionaries instead. This sensor/film has the same properties as that created in the previous cell.

```
In [18]: pmgr = PluginManager.getInstance()
         sensor = pmgr.create({
             'type' : 'perspective',
             'toWorld' : Transform.lookAt(
                 Point(0, 0, -10),
                 Point(0, 0, 0),
                 Vector(0, 1, 0)
             ),
             'film' : {
                 'type' : 'ldrfilm',
                 'width' : 1920,
                 'height' : 1080
             }
         })
         # Now, the sensor can be configured
         sensor.configure()
```

```
In [19]: # Print out the sensor plugin instance
         # Note how there are considerably more properties that has been given default values
         sensor
```

```
Out[19]: PerspectiveCamera[
           xfov = 41.323,
           nearClip = 0.01,
           farClip = 10000,
           worldTransform = ref<AnimatedTransform>[ref=1, ptr=Matrix4x4[
             1, 0, 0, 0;
             0, 1, 0, 0;
             0, 0, 1, -10;
             0, 0, 0, 1
           ]],
           sampler = IndependentSampler[
             sampleCount = 4
           ],
           film = LDRFilm[
             size = [1920, 1080],
             fileFormat = 0,
             pixelFormat = rgb,
             gamma = -1,
             cropOffset = [0, 0],
             cropSize = [1920, 1080],
             banner = 1,
             method = gamma,
             exposure = 0,
             reinhardKey = 0.18,
             reinhardBurn = 0,
             filter = GaussianFilter[stddev=0.500000, radius=2.000000]
           ],
           medium = ref<Medium>[null],
           shutterOpen = 0,
           shutterOpenTime = 0
         ]
```

2.2 Full Scene Creation

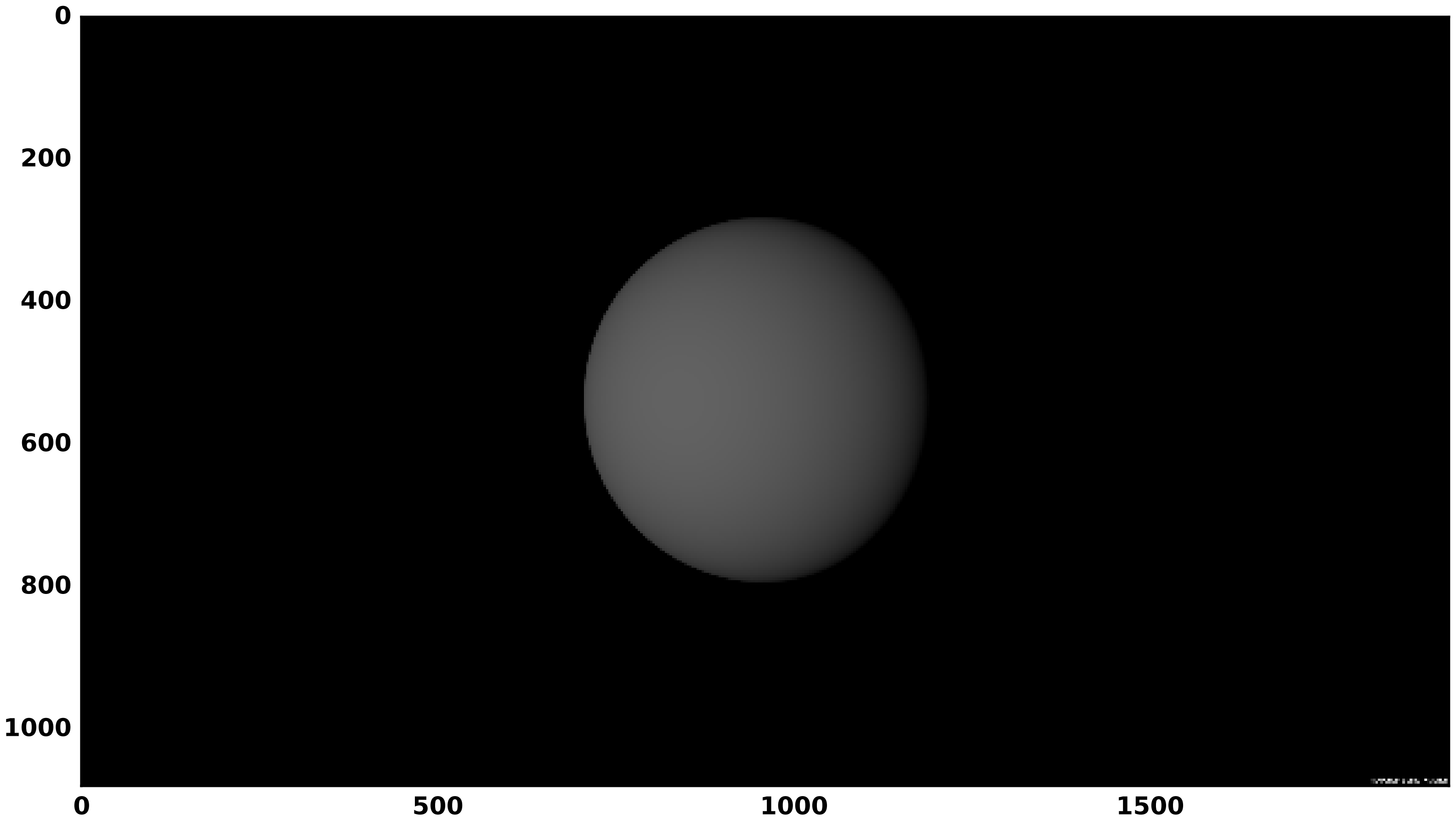
The previous examples only provided snippets of a scene. The following is a full scene creation example from the Mitsuba manual.

```
In [20]: full_scene = Scene()
         # Create a sensor, film & sample generator
         full_scene.addChild(pmgr.create({
             'type' : 'perspective',
             'toWorld' : Transform.lookAt(
                 Point(0, 0, -10),
                 Point(0, 0, 0),
                 Vector(0, 1, 0)
             ),
             'film' : {
                 'type' : 'ldrfilm',
                         'width' : 1920,
                         'height' : 1080
             },
             'sampler' : {
                 'type' : 'ldsampler',
                 'sampleCount' : 2
             }
         }))
         # Set the integrator
         full_scene.addChild(pmgr.create({
             'type' : 'path'
         }))
         # Add a light source
         full_scene.addChild(pmgr.create({
             'type' : 'point',
             'position' : Point(5, 0, -10),
             'intensity' : Spectrum(100)
         }))
         # Add a shape
         full_scene.addChild(pmgr.create({
             'type' : 'sphere',
             'center' : Point(0, 0, 0),
             'radius' : 1.0,
             'bsdf' : {
                 'type' : 'diffuse',
                 'reflectance' : Spectrum(0.4)
             }
         }))
         full_scene.setDestinationFile('ball')  # Set the name of the render output file
         # By default, the output file will be a .png
         full_scene.configure()
```

```
In [21]: # Render the full scene just created using the existing job queus
         job = RenderJob('myRenderJob', full_scene, queue)
         job.start()
         # Wait for all jobs to finish and release resources
         queue.waitLeft(0)
         queue.join()
         # Print some statistics about the rendering process
         print(Statistics.getInstance().getStats())
```

```
------------------------------------------------------------
 * Loaded plugins :
    -  plugins\checkerboard.dll [Checkerboard texture]
    -  plugins\diffuse.dll [Smooth diffuse BRDF]
    -  plugins\envmap.dll [Environment map]
    -  plugins\field.dll [Field extraction integrator]
    -  plugins\gaussian.dll [Gaussian reconstruction filter]
    -  plugins\halton.dll [Halton QMC sampler]
    -  plugins\hdrfilm.dll [High dynamic range film]
    -  plugins\independent.dll [Independent sampler]
    -  plugins\lanczos.dll [Lanczos Sinc filter]
    -  plugins\ldrfilm.dll [Low dynamic range film]
    -  plugins\ldsampler.dll [Low discrepancy sampler]
    -  plugins\multichannel.dll [Multi-channel integrator]
    -  plugins\path.dll [MI path tracer]
    -  plugins\perspective.dll [Perspective camera]
    -  plugins\plastic.dll [Smooth plastic BRDF]
    -  plugins\point.dll [Point emitter]
    -  plugins\rectangle.dll [Rectangle intersection primitive]
    -  plugins\serialized.dll [Serialized mesh loader]
    -  plugins\sky.dll [Skylight emitter]
    -  plugins\sphere.dll [Sphere intersection primitive]
    -  plugins\sunsky.dll [Sun & sky emitter]

  * General :
    -  Normal rays traced : 94.495 M
    -  Shadow rays traced : 42.069 M

  * Path tracer :
    -  Average path length : 1.28 (65.94 M / 51.69 M)

  * Texture system :
    -  Cumulative MIP map memory allocations : 3.001 MiB
    -  Filtered texture lookups : 17.12 % (19.37 M of 113.14 M)
    -  Lookups with clamped anisotropy : 0.00 % (0.00 of 19.37 M)
-----------------------------------------------------------
```

```
In [22]: # Show the result
         ball_img = mpimg.imread('ball.png')
         plt.figure(figsize=(10, 5.625))
         plt.imshow(ball_img)

Out[22]: <matplotlib.image.AxesImage at 0x1f4817b8>
```



```
In [25]: import datetime
         now = datetime.datetime.now()
         print 'Completed Run at ', str(now)
         # After executing this cell, save the notebook before running the
         # publish cells below
         # To run the complete notebook, select this cell
         # and then choose Cell->Run All Above from the menu
```

```
Completed Run at  2017-03-22 14:13:16.257000
```

```
In [24]: %%javascript
         var kernel = IPython.notebook.kernel;
         var thename = window.document.getElementById("notebook_name").innerHTML;
         var command = "theNotebook = " + "'"+thename+"'";
         kernel.execute(command);
```

```
<IPython.core.display.Javascript object>
```

```
In [ ]: result_folder = './MitsubaScenes'
        # Run this cell to publish, but save the notebook beforehand
        # The contents of this cell strictly for publishing the notebook.
        if publish:
            notebook_name = theNotebook + '.ipynb'
            # Run nbconvert to create a tex file as well as pdf graphic files
            !jupyter nbconvert --to latex $notebook_name
            # Do touchups
            def touchup_build_tex(tex_file, touchups):
                # Read the LaTeX file
                f = open(tex_file,'r')
```

```
    filedata = f.read()
    f.close()
    # Perform touchups
    for src, target in touchups.iteritems():
            filedata = filedata.replace(src, target)
    # Write file again
    f = open(tex_file,'w')
    f.write(filedata)
    f.close()
    # Build PDF using LaTeX
    !pdflatex $tex_file > pdflatex.out

touchups = {'[11pt]{article}': '[11pt, a4paper, landscape]{scrartcl}',
            'title{' + theNotebook + '}':
            'title{' + casetitle + '}' +
            '\subtitle{' + subtitle + '}'}
touchup_build_tex(theNotebook + '.tex', touchups)
# Move the compiled pdf to the results folder
import os
publication = result_folder + os.sep + casename + '.pdf'
if os.path.exists(publication):
    os.remove(publication)
os.rename(theNotebook + '.pdf', publication)
```