LABORATORIO DI REALTÀ AUMENTATA

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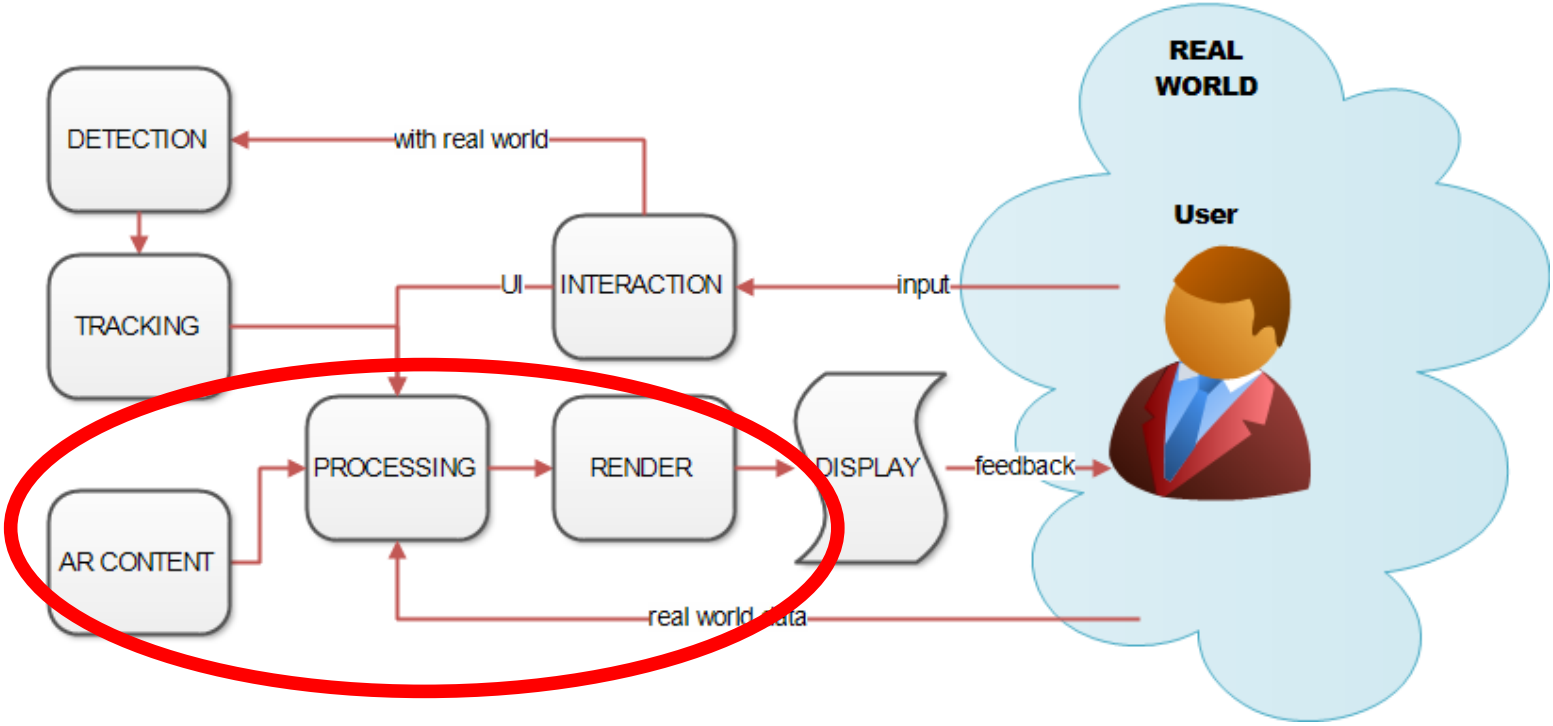
Project: 3D graphics

Architecture of an AR system



Canvas and 3D

- We already know HTML5's canvas has a 2D graphics context (`canvas.getContext("2d")`)
- There is also a 3d context, which is accessible only through the WebGL API. It allows to display interactive 3d graphics without the use of external plugins
- Check for support: **`http://get.webgl.org/`**

WebGL

3D graphics contents directly rendered in web pages. Initially based on…

API for mobile devices. Based on…

cross-platform API initially developed by SGI since 1991

WebGL: pros

- Extremely powerful
- Extremely fast, since it can directly access the graphics hardware

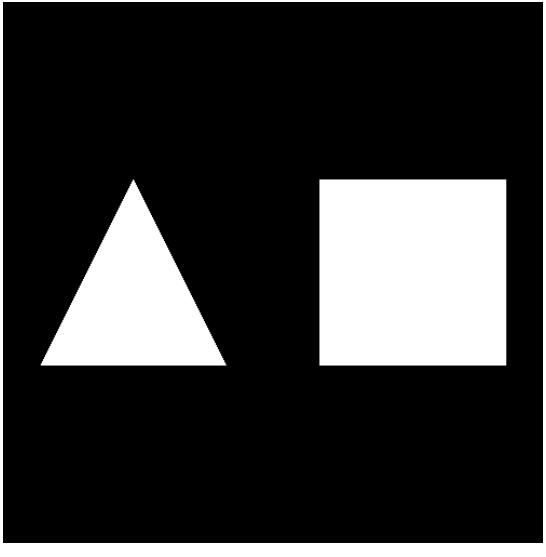
ha funzioni a BASSO LIVELLO : es. disegna / sposta un vertice / linee / triangoli e il resto si costruisce da essi

sono sempre definiti in uno spazio 3d dati 3 punti

sfruttano a pieno l'hardware della GPU → molto veloce

WebGL: cons

- Extremely COMPLEX (da programmare)



- Check the tutorial for drawing these shapes:

http://dzeek.net/dzeek/molythio/webgl/tutorial/lesson1.html

WebGL made easy: Three.js

- How can we use the powerful features of WebGL, avoiding the hassle of a complex API?
- By using an high-level 3D graphics library which hides all the WebGL complexity to the user

- **Three.js**

- http://threejs.org/

Three.js resources

- A very nice introduction to Three.js

http://davidscottlyons.com/threejs/presentations/frontporch14/index.html#slide-0

- Examples for almost every Three.js function

http://stemkoski.github.io/Three.js/

- Three.js website has many examples too

http://threejs.org/

Preparing for the lesson

- First of all, download three.js from the original website (warning: ~300 MB download!) or take the basic library file from the elearning website
- We will use the compact version named three.min.js
- Copy this file in the same folder of your web pages
- Current version: r127

Preparing for the lesson

- Create a basic HTML page with a canvas

```
<!doctype html>
<html>
<head>
    <meta charset="UTF-8">
    <title>Three.js test</title>
    <script src="three.min.js"></script>
</head>
<body>
    <canvas width="640" height="480" id="mycanvas"></canvas>
</body>
</html>
```

Setting up three.js

```
<script>
window.onload = function(){
        // setup three.js
        var mycnv = document.getElementById("mycanvas");
        var renderer = new THREE.WebGLRenderer({canvas: mycnv});
        var scene = new THREE.Scene();
        var camera = new THREE.PerspectiveCamera( 75, mycnv.width
                                        / mycnv.height, 0.1, 1000 );
        scene.add(camera);
}
</script>
```

Renderer

```
var renderer = new THREE.WebGLRenderer({canvas: mycnv});
```

- The renderer creates a 2D image (visible on the screen) of the 3D world, as seen from the camera
- `{canvas: mycnv}` – the optional input is an object with a single property called “canvas”. It’s the canvas where to draw
- Alternative solution (does not require the onload event):

```
var renderer = new THREE.WebGLRenderer();
renderer.setSize( window.innerWidth, window.innerHeight );
document.body.appendChild( renderer.domElement );
```

Scene

```
var scene = new THREE.Scene();
```

- The `scene` is a container for the objects to be visualized
- It also contains the two other fundamental elements for an object to be visible
  - Cameras
  - lights

Camera

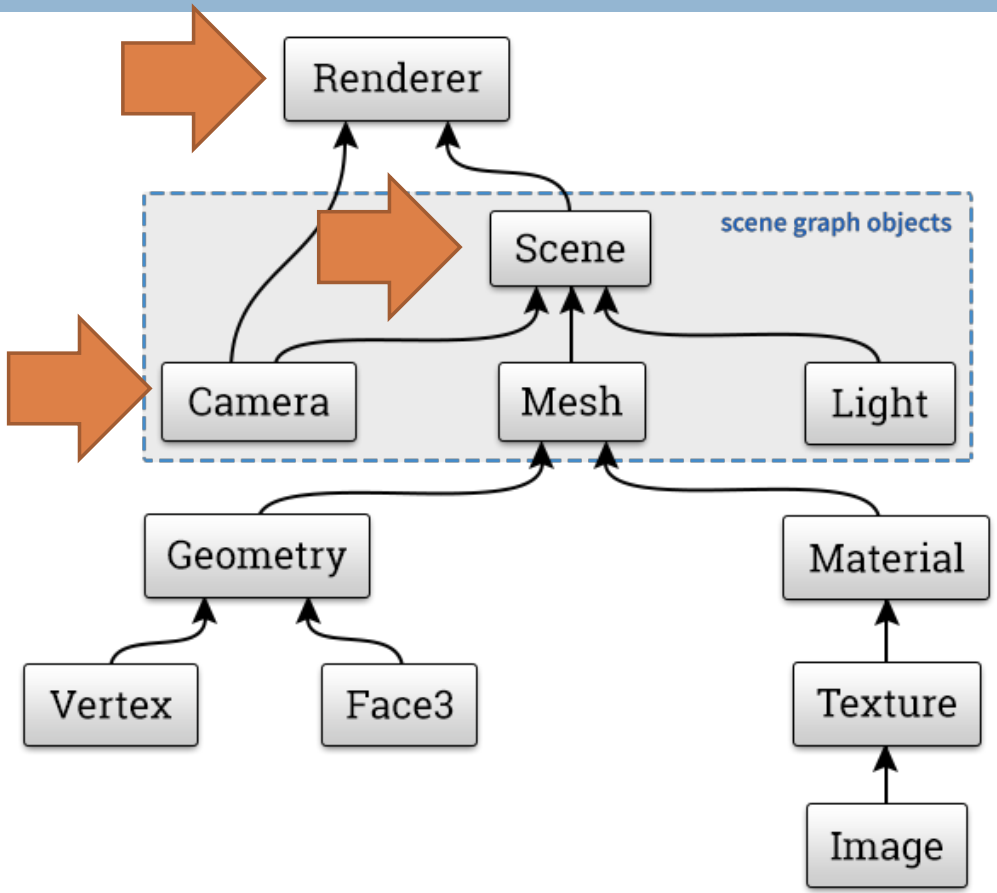
```
var camera = new THREE.PerspectiveCamera( 75, mycnv.width
                                / mycnv.height, 0.1, 1000 );
scene.add(camera);
```

- The camera it's the point of view from which you observe the 3D world
- We use a perspective camera (orthographic cameras are available too!)
- We specify the field-of-view (75°, common for many cameras), and the image ratio
- The last two parameters are the near and far clipping planes

Camera – side note

- Note that the camera is added to the scene
- You'll notice that this is not the case for some examples on the web
- In the past, adding the camera to the scene was not mandatory, however this omission is now deprecated

Scene structure



Img from: http://davidscottlyons.com/threejs/presentations/frontporch14/index.html#slide-0

Adding an object

```
// create a cube
var geometry = new THREE.BoxGeometry( 1, 1, 1 );
var material = new THREE.MeshBasicMaterial({ color: 0x00ff00 });
var cube = new THREE.Mesh( geometry, material );
scene.add( cube );
```

Geometry

- A geometry describes the 3D **shape** of an object

```
var geometry = new THREE.BoxGeometry( 1, 1, 1 );
```

- This creates a cube (actually, a polyhedron made of triangles)

Material

- A material defines the **appearance** of an object

```
var material = new THREE.MeshBasicMaterial({ color: 0x00ff00 });
```

- This creates a basic green material
- Are you familiar with hexadecimal RGB color notation?

Mesh

- A **mesh** is a 3D object: it is composed of a geometry and a material

```
var cube = new THREE.Mesh( geometry, material );
scene.add( cube );
```

- A mesh is what you add to the scene if you want to see your object

Render loop

```
// render loop
function renderloop() {
	requestAnimationFrame( renderloop );
	renderer.render( scene, camera );
}
renderloop();
```

- The render loop is a function that is repeatedly called each time a frame needs to be drawn

Render

```
requestAnimationFrame( renderloop );
```

- With this line, the render() function sets itself as the function to be called to render the next frame
- This creates an endless rendering loop

Render

```
renderer.render( scene, camera );
```

- The second line tells the renderer object to render the scene “scene”, as seen from camera “camera”
- The output will be drawn in the canvas associated to the renderer

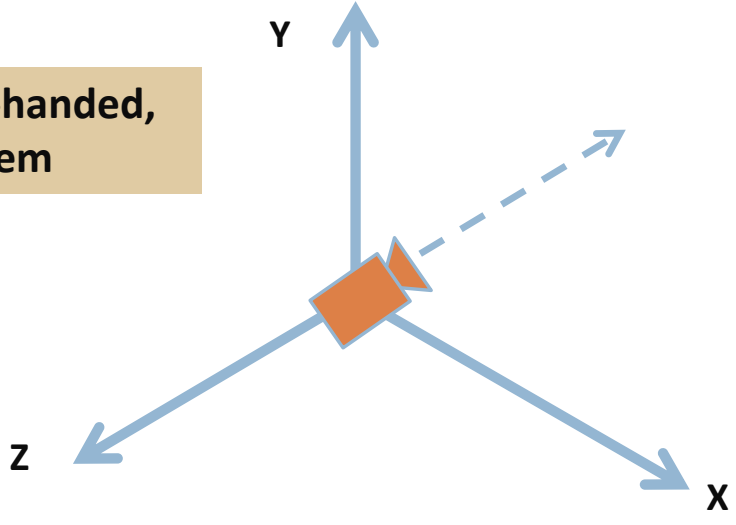
Let’s try it!

- Ops…

Object positions

- Problem: the box and cameras are created at the origin (0,0,0). The camera lies inside the box!
- By default cameras looks toward –Z direction

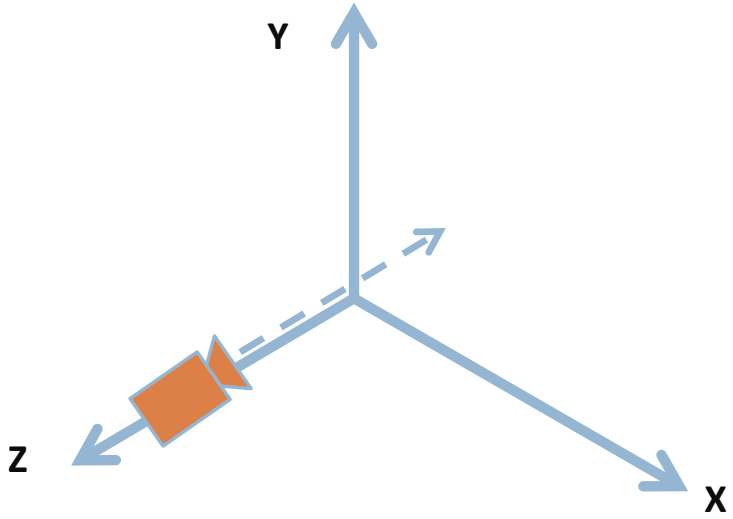
Three.js uses a right-handed, Y-up coordinate system



Object positions

- Solution: move the camera along the positive Z axis

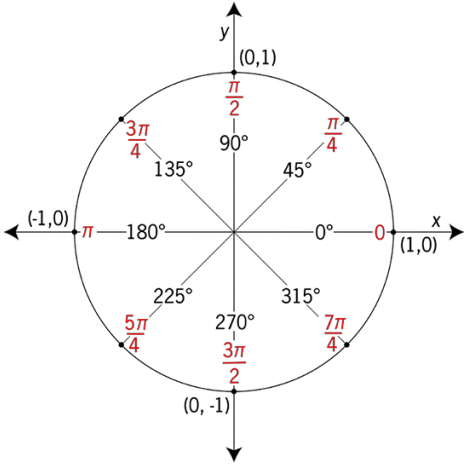
```
camera.position.z = 3;
```



Apply transformations

- Objects can be translated, rotated and scaled
- What's the effect of these transformations?
  - `Cube.position.x = 10;`
  - `Cube.rotation.z += 0.1;`
  - `Cube.scale.set(2,2,2);`

These are properties of the Object3D object. Anything that can be inserted in a scene derives from it



Angles are expressed in **radians**
Three.Math.degToRad() converts degrees to radians

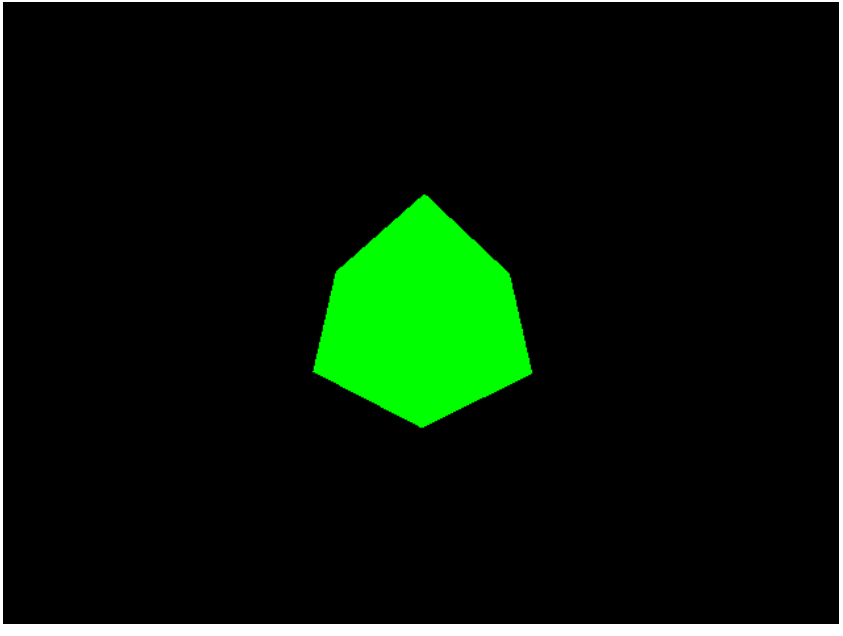
Moving the object

- Try this render loop:

```
// render loop
function render() {
	requestAnimationFrame( render );
	cube.rotation.z += 0.01;
	cube.rotation.x += 0.01;
	renderer.render( scene, camera );
}
render();
```

Output

- Maybe not what we expected

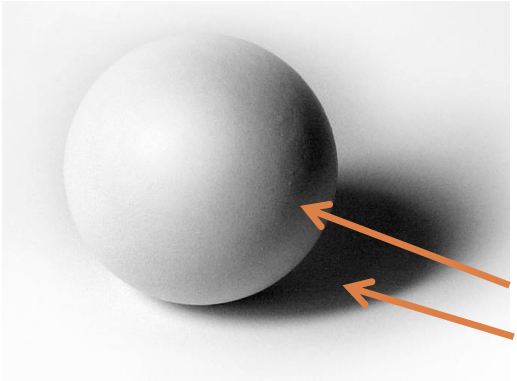


Use a Lambert material

- Change the material to a MeshLambertMaterial, which can handle core shadows

```
var material = new THREE.MeshLambertMaterial({color: 0x00ff00});
```

- Everything dark again…

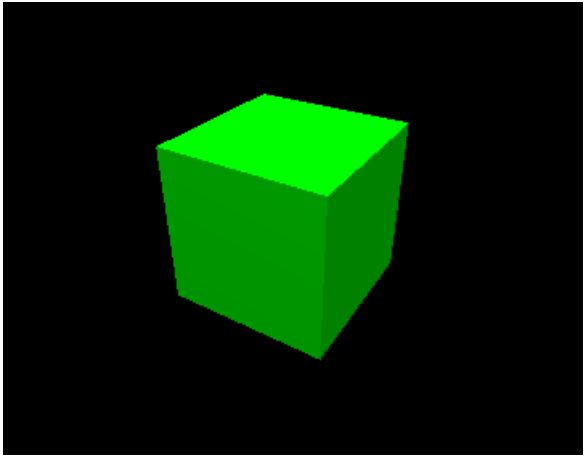


Lights

- To see anything (except objects with BasicMaterial) you need a light
- Several types
  - Ambient light
  - Directional light → 
  - Hemisphere light → 
  - Point light → 
  - Spot light → classico faro
- Let's use a point light and an ambient light

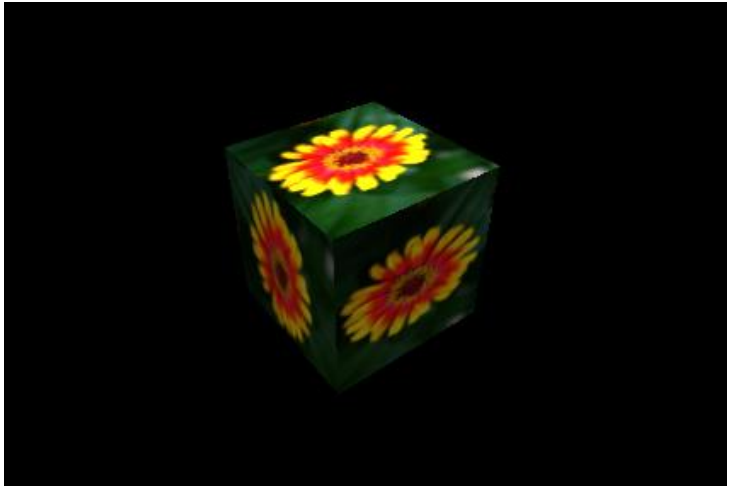
Adding lights

```
// adding lights
var plight = new THREE.PointLight(0xffffff);
plight.position.set(0,3,3);
scene.add(plight);
var alight = new THREE.AmbientLight(0x808080);
scene.add(alight);
```



Textures

```
// create the cube
var geometry = new THREE.BoxGeometry( 1, 1, 1 );
var texture = new THREE.TextureLoader().load("flower.jpg");
var material = new THREE.MeshLambertMaterial( { map: texture } );
var cube = new THREE.Mesh( geometry, material );
scene.add( cube );
```



Warning: won't work locally (see next slide)

Textures

- If you get the warning “image is not power of two”, either
  - Resize the image to power-of-two sides (e.g. 512x512)
  - Or add `texture.minFilter = THREE.LinearFilter;`
- More on texture mapping
  - https://solutiondesign.com/blog/-/sdg/webgl-and-three-js-texture-mappi-1/19147

How to work locally

- Solution 1: use a local web server
  - https://threejs.org/docs/index.html#manual/en/introduction/How-to-run-things-locally
- Solution 2: force your browser to allow local file loading. Warning: potential security issues! Use it **only** for local development!
  - Chrome: https://stackoverflow.com/questions/18586921/how-to-launch-html-using-chrome-at-allow-file-access-from-files-mode
  - Firefox: https://discourse.mozilla.org/t/firefox-68-local-files-now-treated-as-cross-origin-1558299/42493

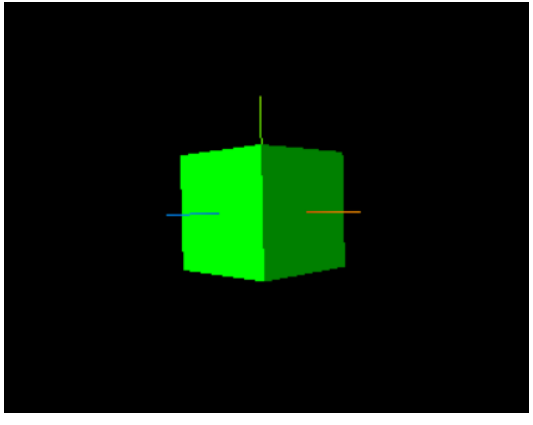
Back to transformations

- Now that the object is clearly visible, let's go back to transformations
- **Rule n. 1**: rotations are referred to a **local axis system**!

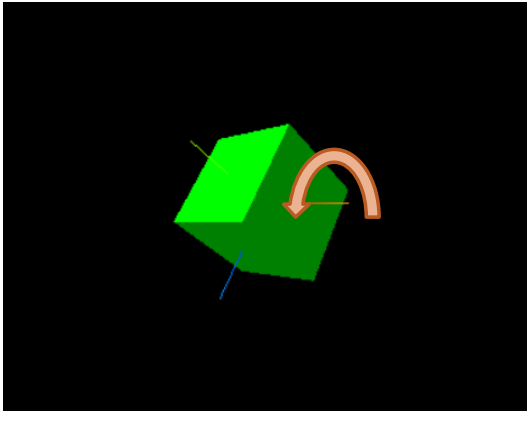
```
cube.rotation.x = Math.PI/4;
// render loop
function renderloop() {
        requestAnimationFrame( renderloop );
        cube.rotation.z += 0.01;
        renderer.render( scene, camera );
}
renderloop();
```

After the rotation around x axis, the second rotation will NOT be around *world* z axis. The x rotation also rotated the *local* z axis

Local rotations

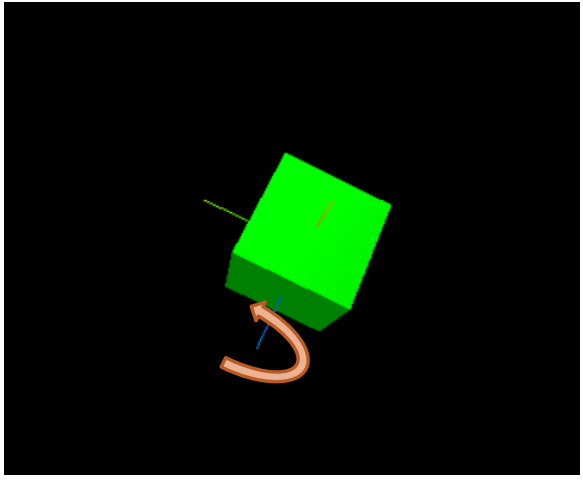


Starting position
(camera not in front of the object)



Rotation around x axis
also rotates the local
coordinate system

Rotation around the
local z axis



Order of rotations

- Now try this

```
cube.rotation.z = Math.PI/4;
// render loop
function renderloop() {
        requestAnimationFrame( renderloop );
        cube.rotation.x += 0.01;
        renderer.render( scene, camera );
}
renderloop();
```

- Seems to contradict what we just said. It appears to rotate around world x axis
- The problem lies in the **rotation order**

Order of rotations

- **Rule n. 2:**
- When you specify values in the .rotation vector, they are not applied immediately
- Rather, they are applied at render time in a specific order
- By default, x rotations are applied first. Then y rotations, finally z rotations

Order of rotations

```
cube.rotation.z = Math.PI/4;
// render loop
function render() {
        requestAnimationFrame( render );
        cube.rotation.x += 0.01;
        renderer.render( scene, camera );
}
```

- Thus, even if we wrote the z rotation first, Three.js first rotates the cube around the x axis, and then around the z axis.
- Order of rotations is important!

Order of rotations

- You can change the rotation order
- In the previous example, see the difference if you add the following line:

```
cube.rotation.order = 'ZXY';
```

Loading external meshes

- There are several loaders to load 3D models in different formats (e.g. .OBJ files)
- Best choice: GLTF/GLB format, optimized for web apps
- How to get GLTF files:
  - Download them, e.g. from **`https://sketchfab.com`**
  - Convert from other formats (online converters available)
  - Use GLTF exporter plugins for 3D modeling software (Maya, Blender, 3DSMax, c4d, etc.)
  - Windows 10 users: use the 3d paint app
- Warning: same local file issues already seen for textures…

Loading a GLTF mesh

- First we must import the loader, which is distributed as an external file:

```
<script src="GLTFLoader.js"></script>
```

- And we must change the output color space encoding, or the GLTF objects will look too dark:

```
renderer.outputEncoding = THREE.sRGBEncoding;
```

Loading a GLTF mesh

- You can now use the loader:

```
// load the model
var loader = new THREE.GLTFLoader();
var car;
loader.load('./car.gltf', function(gltf_model){
        car = gltf_model.scene
        scene.add(car);
});
```

(Car model from https://sketchfab.com)

(the loaded object is big – roughly 800 units wide. To see it you will need to move the camera and lights outside it)