DeepRob

Discussion 8
Prelude to Rigid Body Objects
University of Michigan and University of Minnesota

Next Time: Rigid Body Objects

- Seminar 3: Object Pose, Geometry, SDF, Implicit Surfaces
  1. SUM: Sequential scene understanding and manipulation, Sui et al., 2017
  2. DeepSDF: Learning Continuous Signed Distance Functions for Shape Representation, Park et al., 2019
  3. Implicit surface representations as layers in neural networks, Michalkiewicz et al., 2019
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- Seminar 4: Dense Descriptors, Category-level Representations
  1. Dense Object Nets: Learning Dense Visual Object Descriptors By and For Robotic Manipulation, Florence et al., 2018
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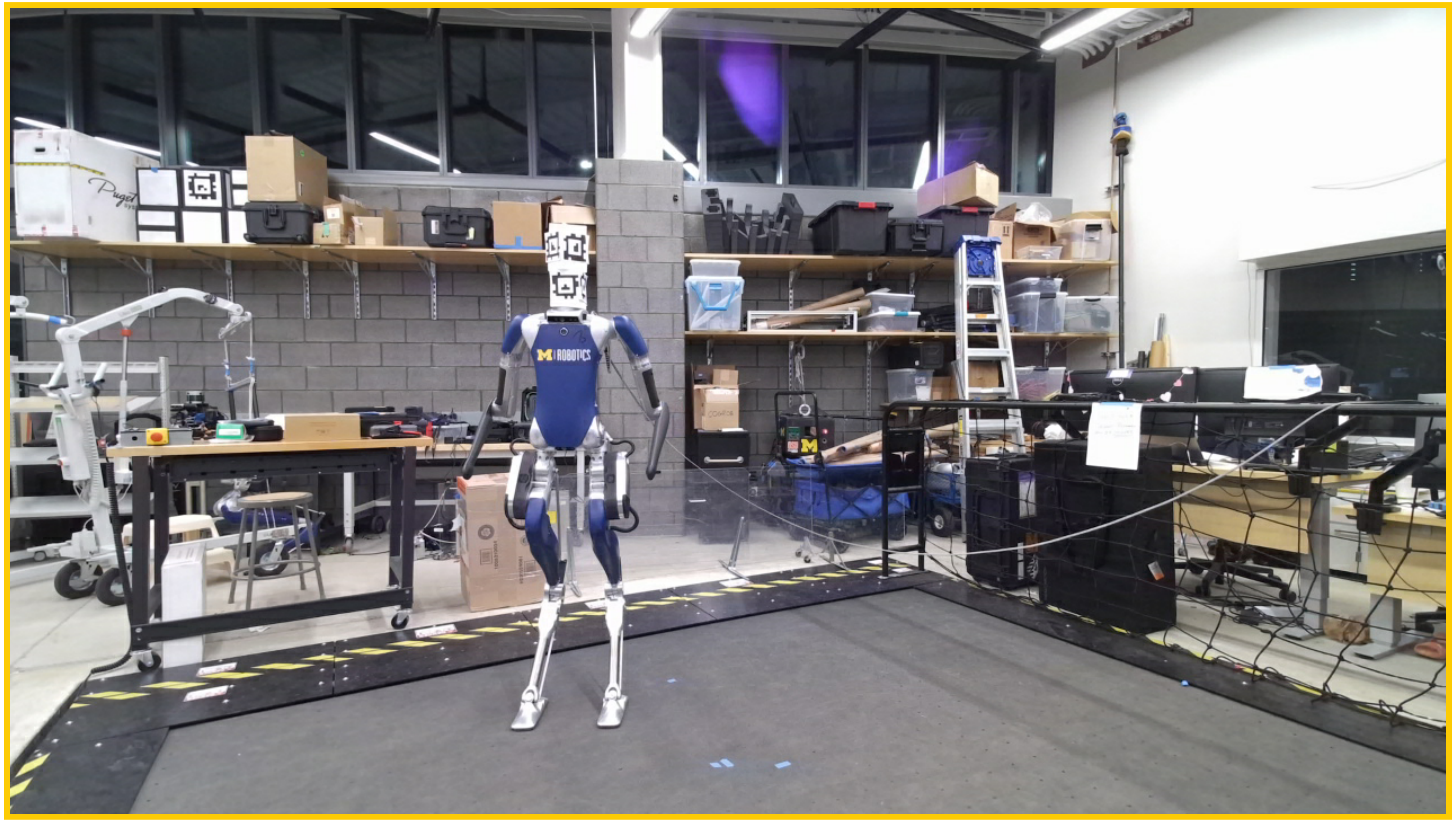
Last Time: 3D Perception



Data courtesy of [Anthony Opipari](), [Liz Olson](), [Grant Gibson](), and [Arden Knoll]()

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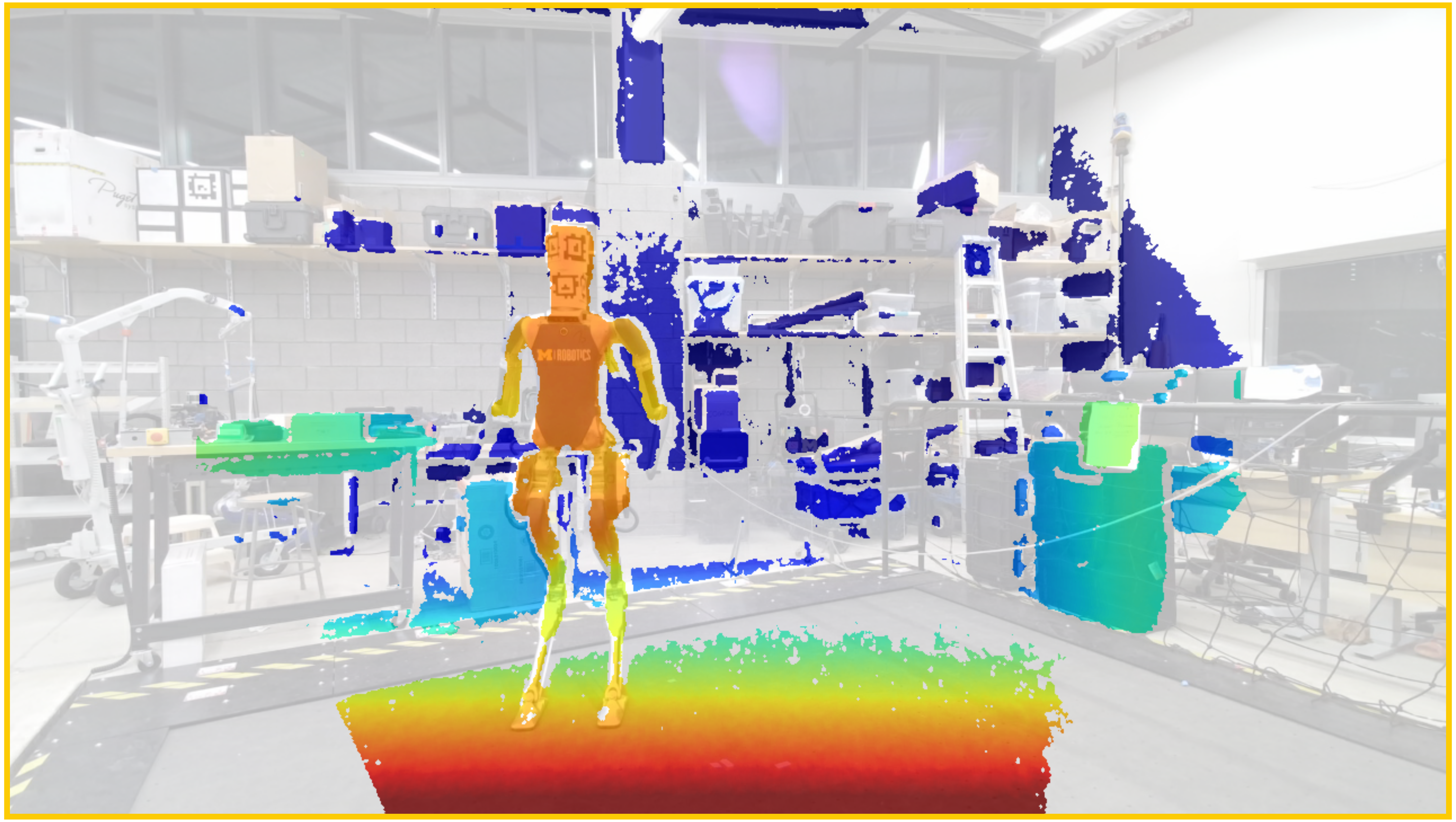

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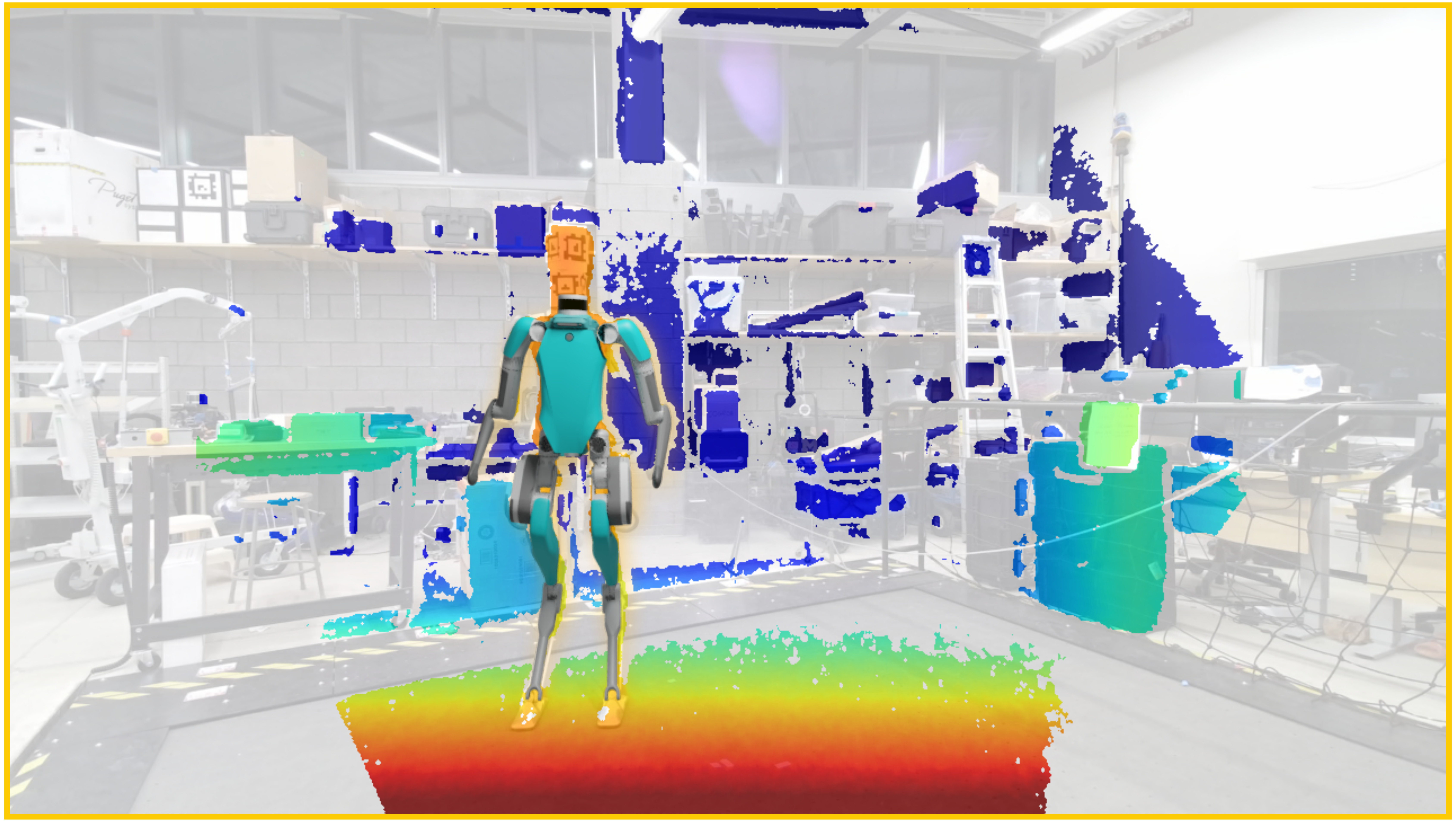
This Time: Rigid Body Objects



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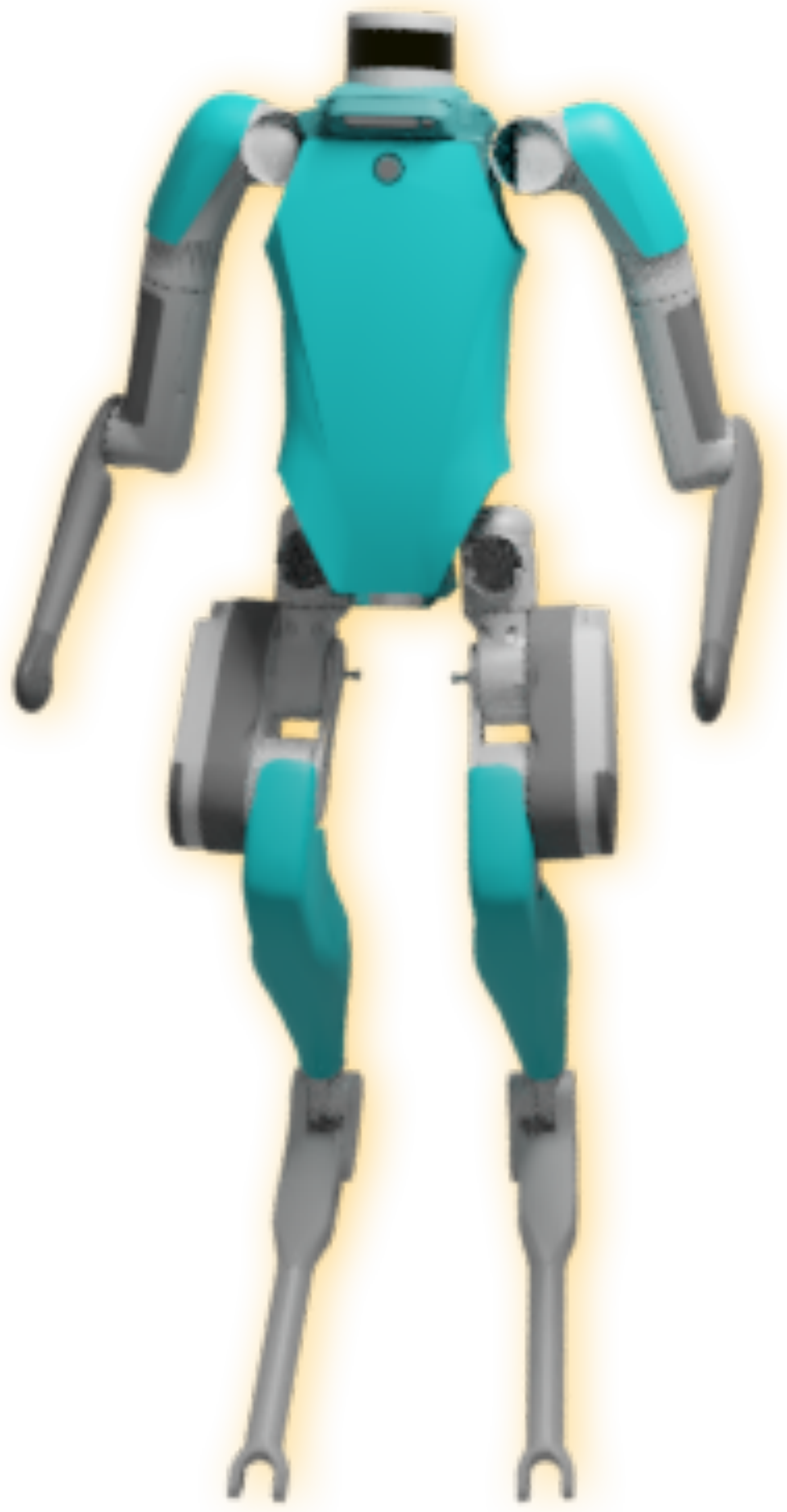
Example Rigid Body Object

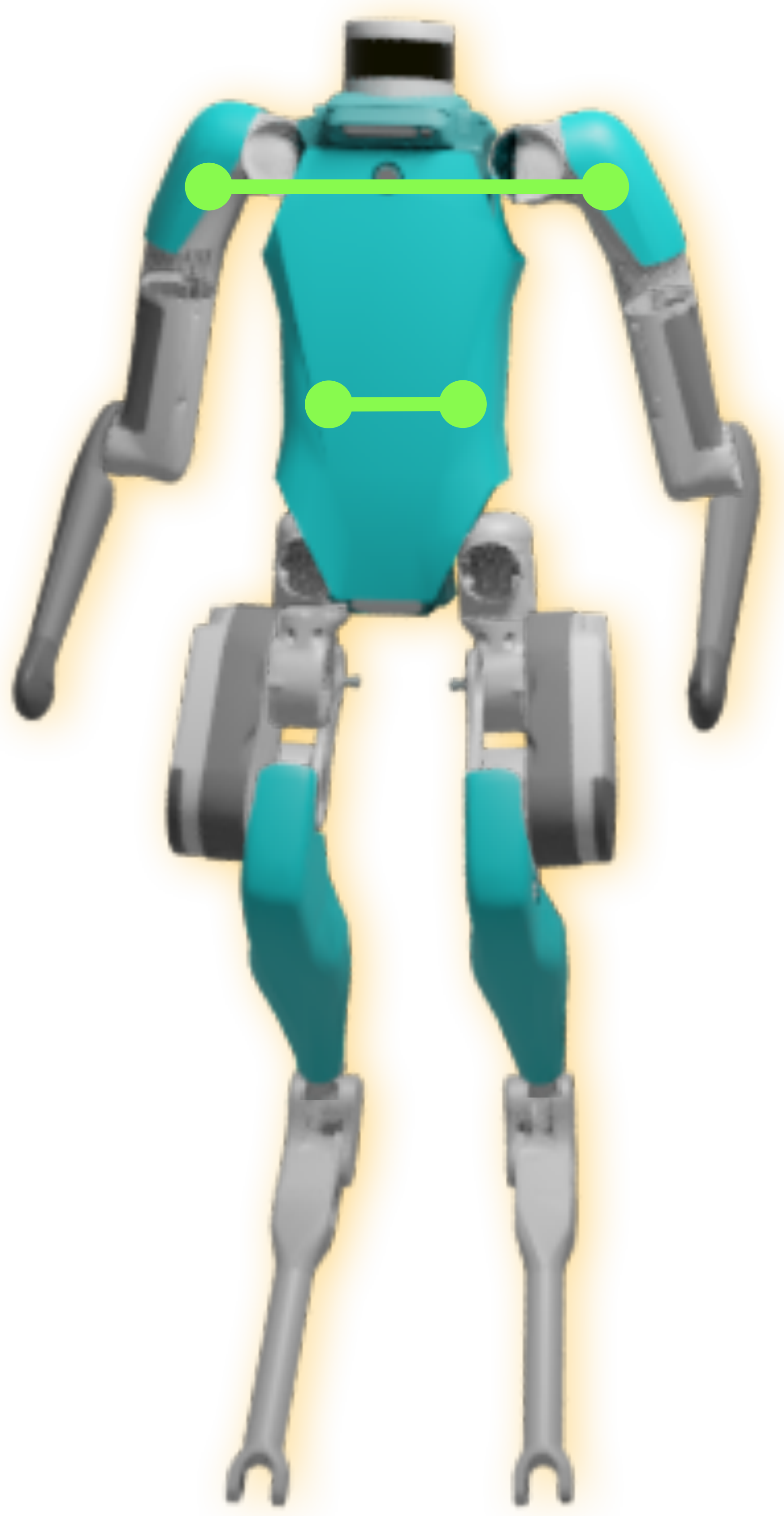


Example Rigid Body Object

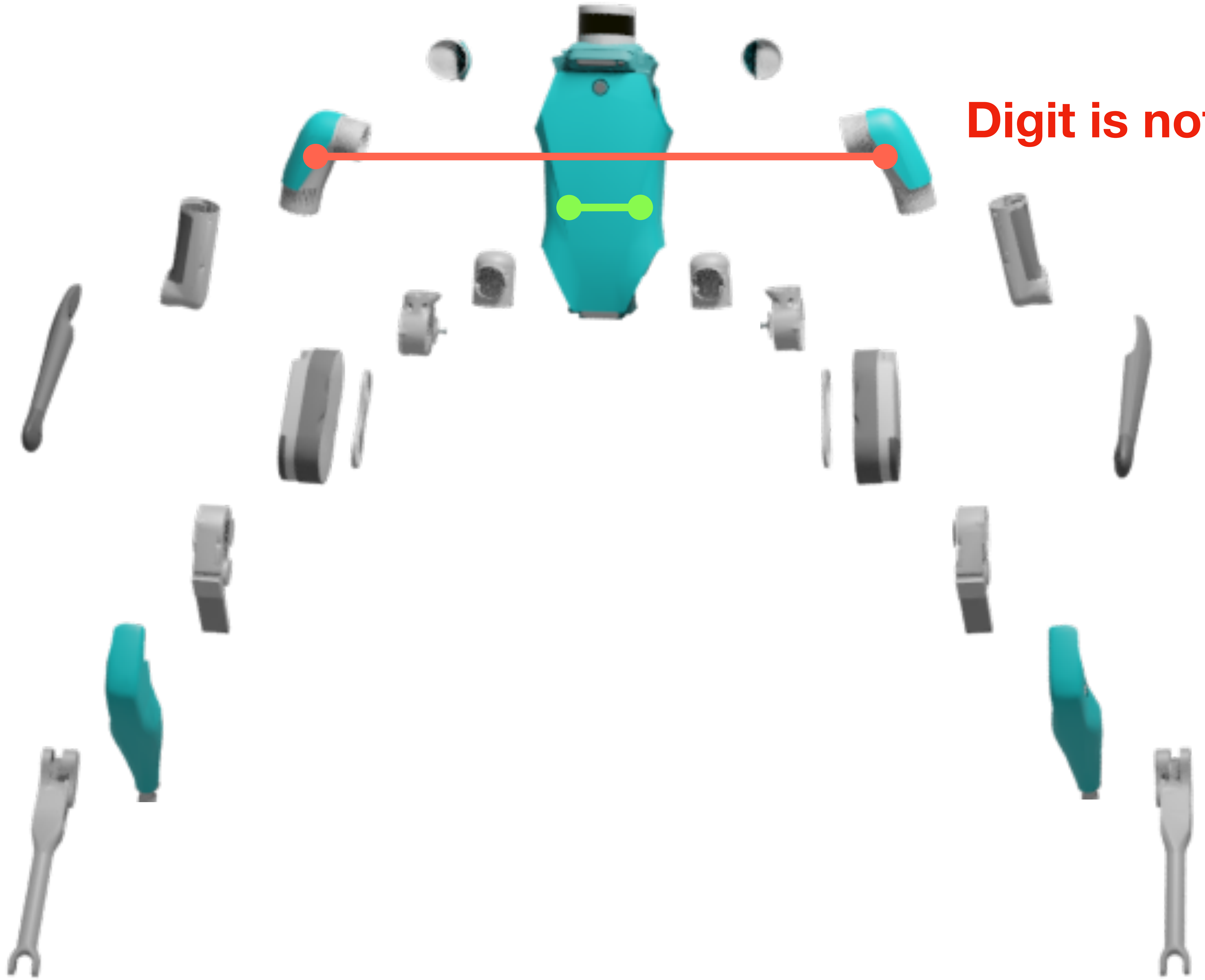
Rigid body:

Model of an object that assumes no deformation is possible

I.e. Every pair of points on the object remain at constant distance



Aside: Digit is an Articulated Object



Digit is not a rigid body object!

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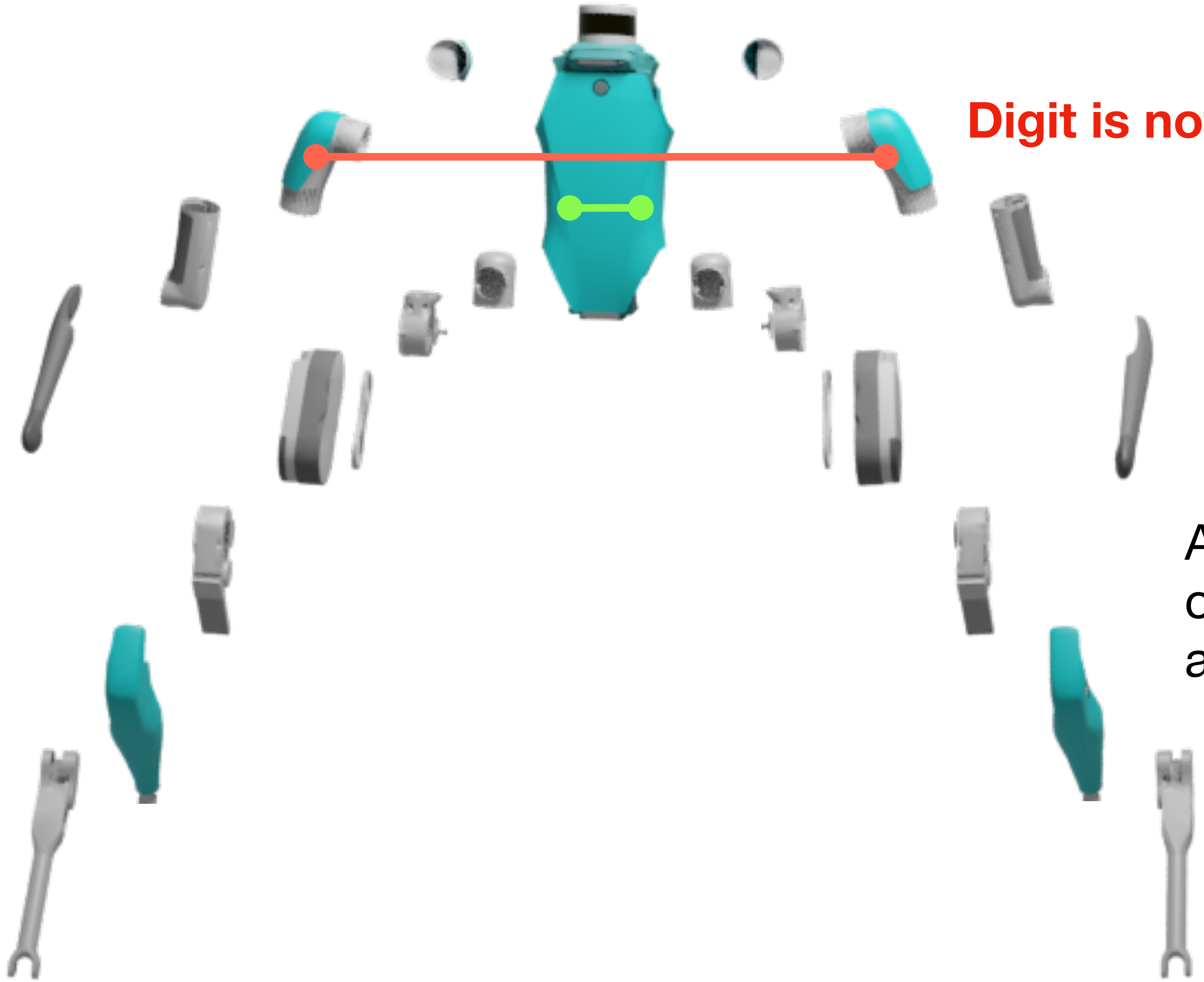

Digit is not a rigid body object!

Articulated objects are composed of rigid bodies and connecting joints

Rigid Body Objects

Rigid Body Objects

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Model of an object that assumes no deformation is possible

I.e. Every pair of points on the object remain at constant distance

How to represent the 3D geometry of objects?

What roles can deep learning play?

Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

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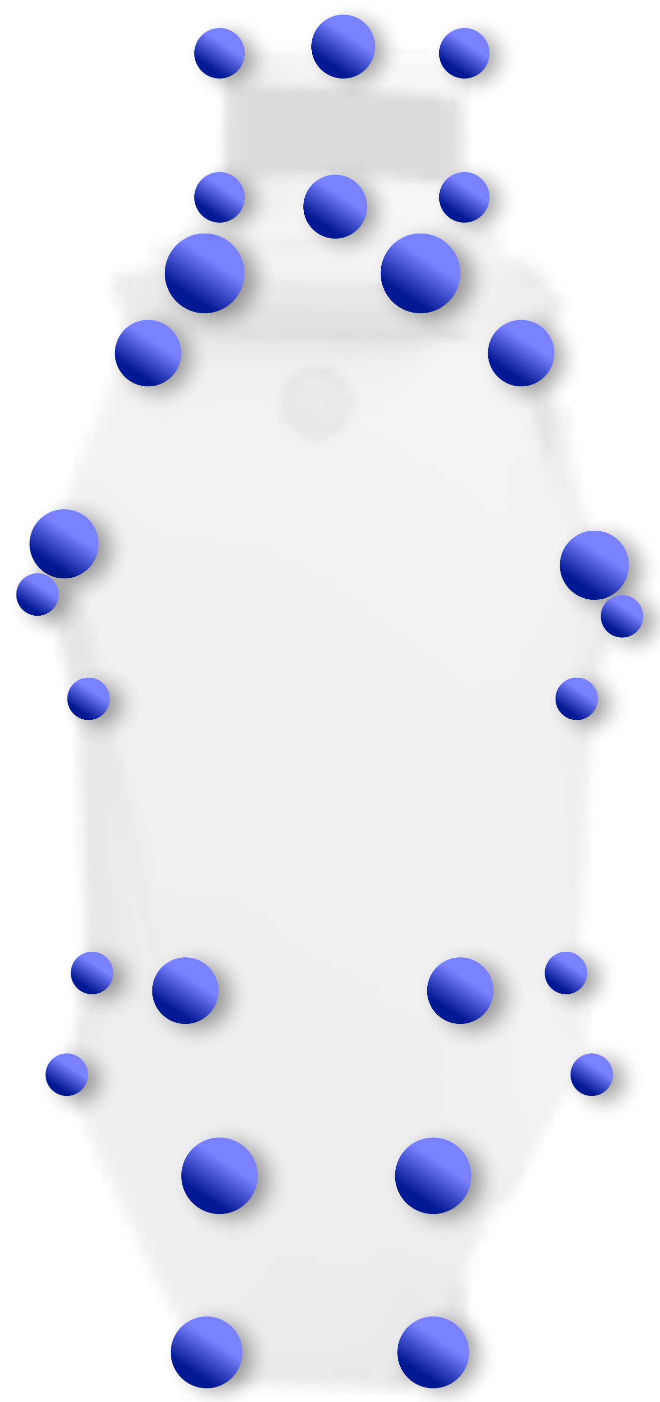

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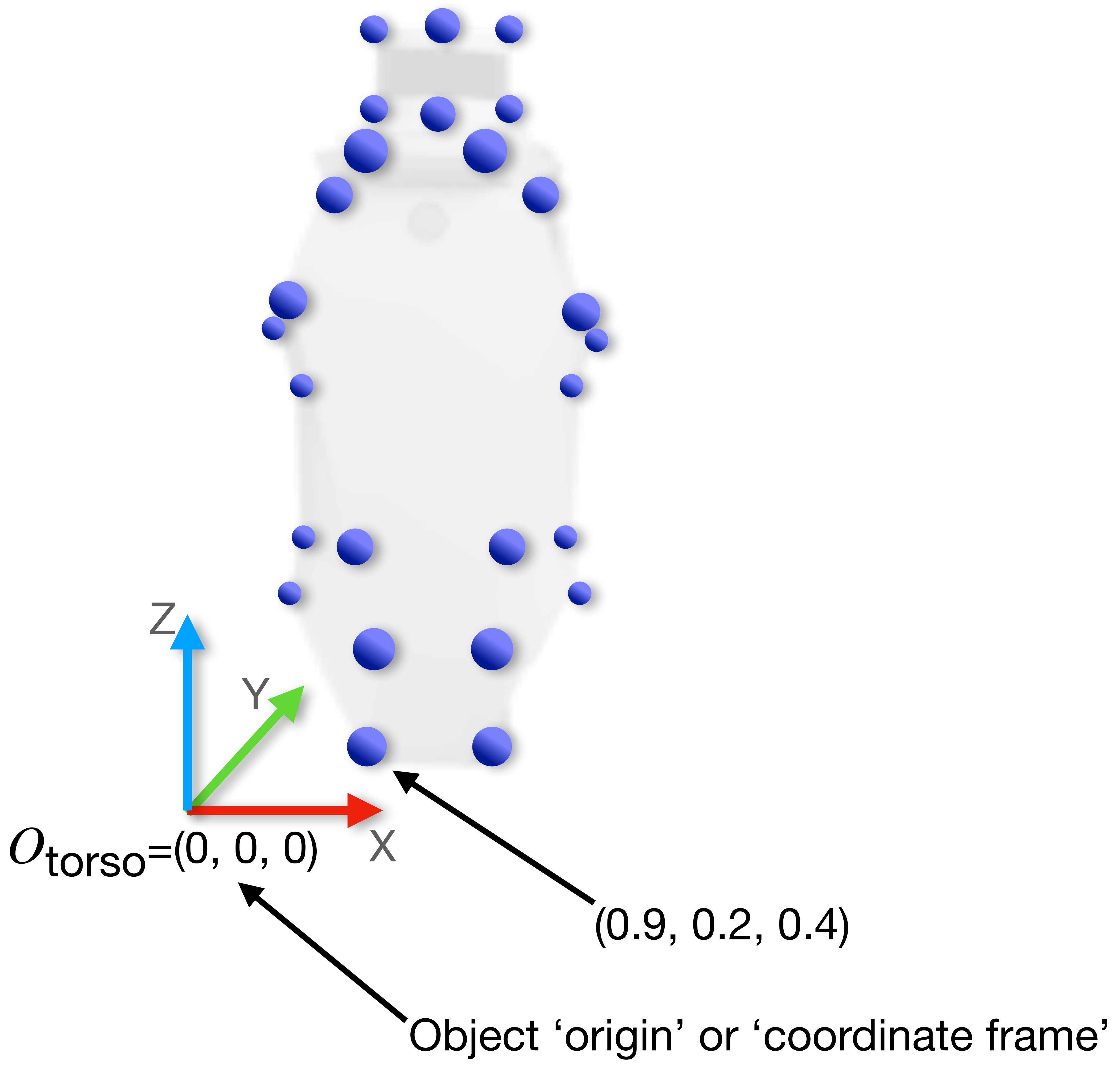
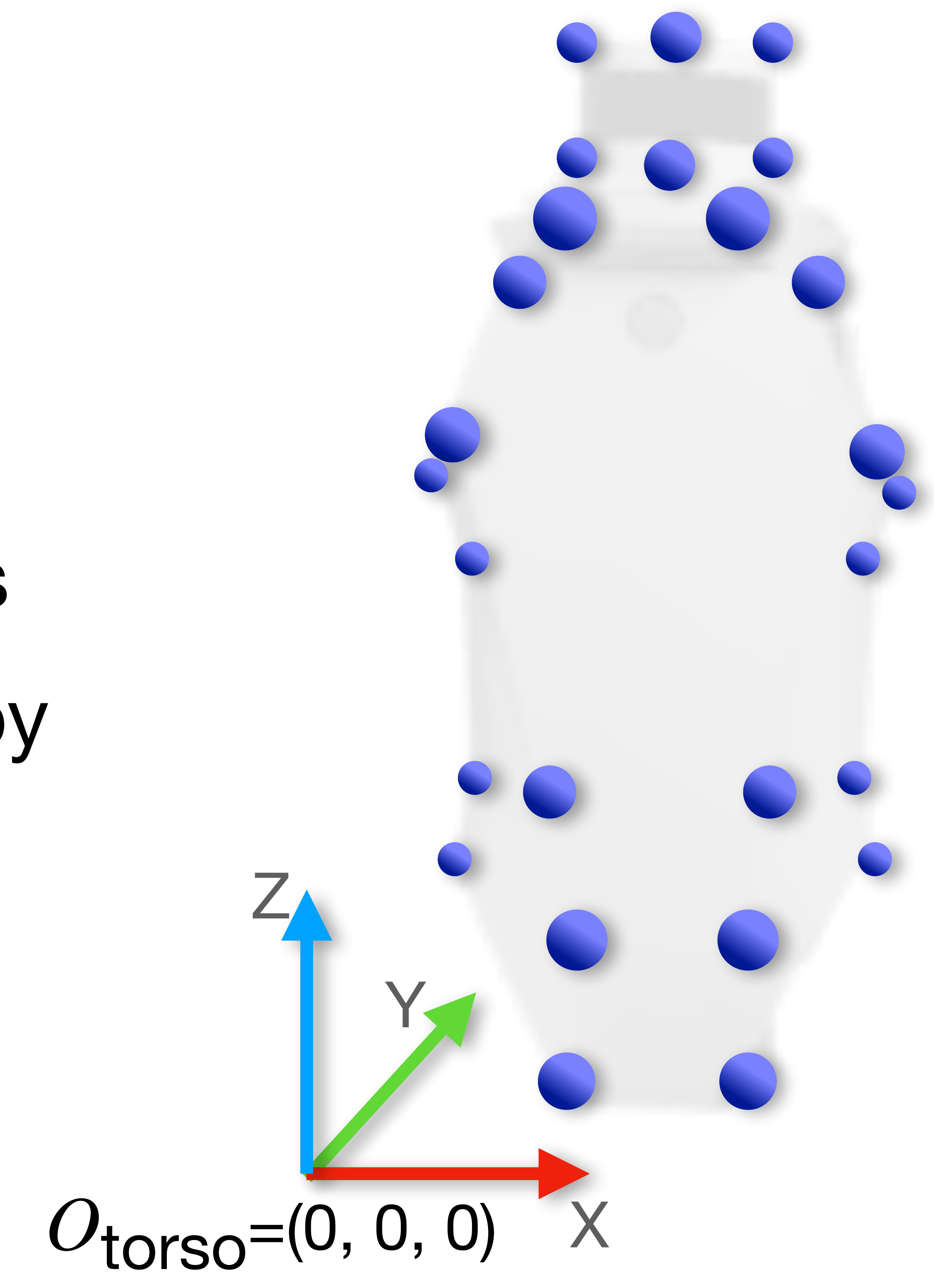


Rigid Body Objects: Explicit Representation

How to represent the 3D geometry of objects?

Vertices: set of 3D coordinates

Faces: set of polygons made by connecting subset of vertices



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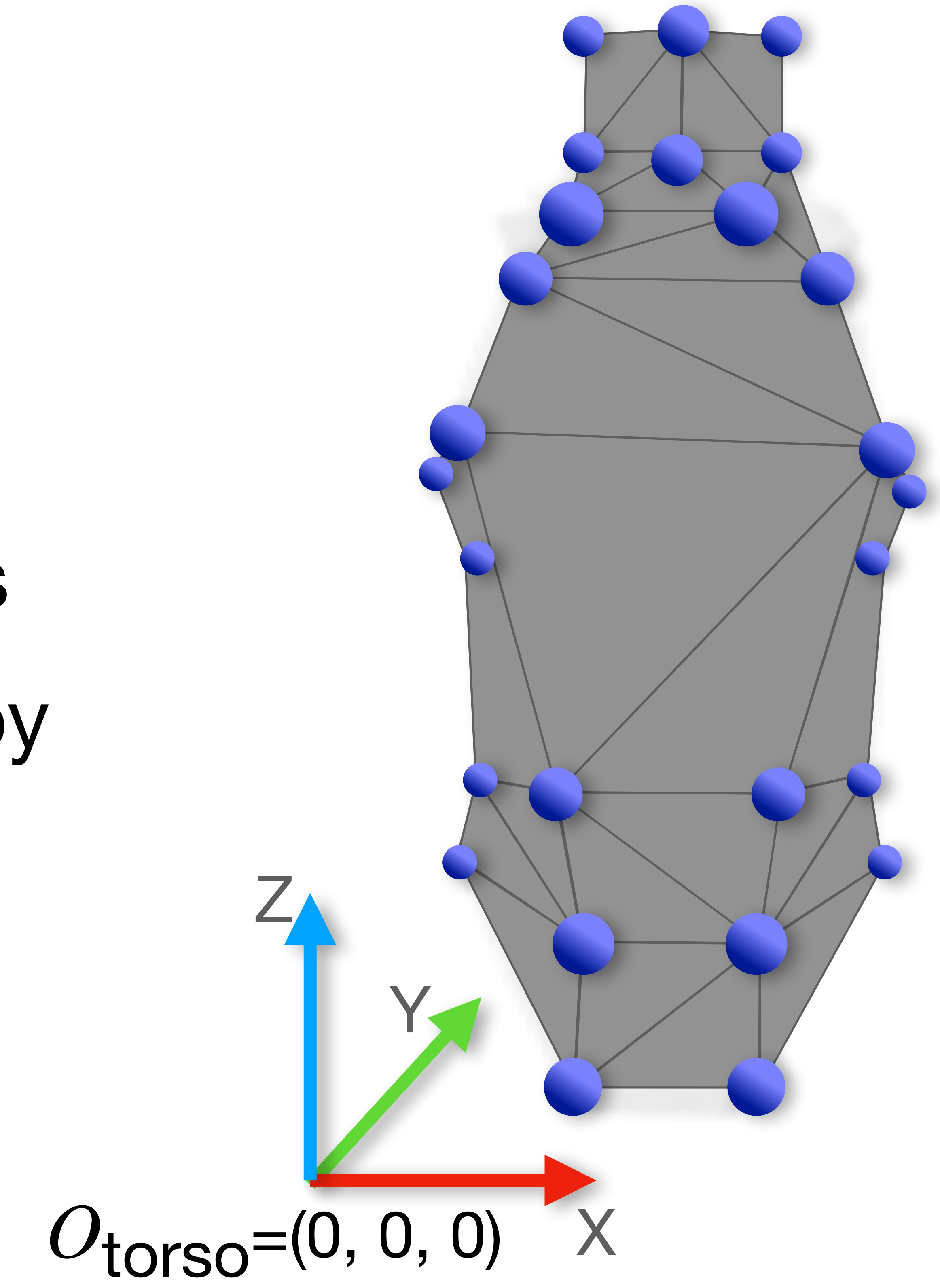

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Texture

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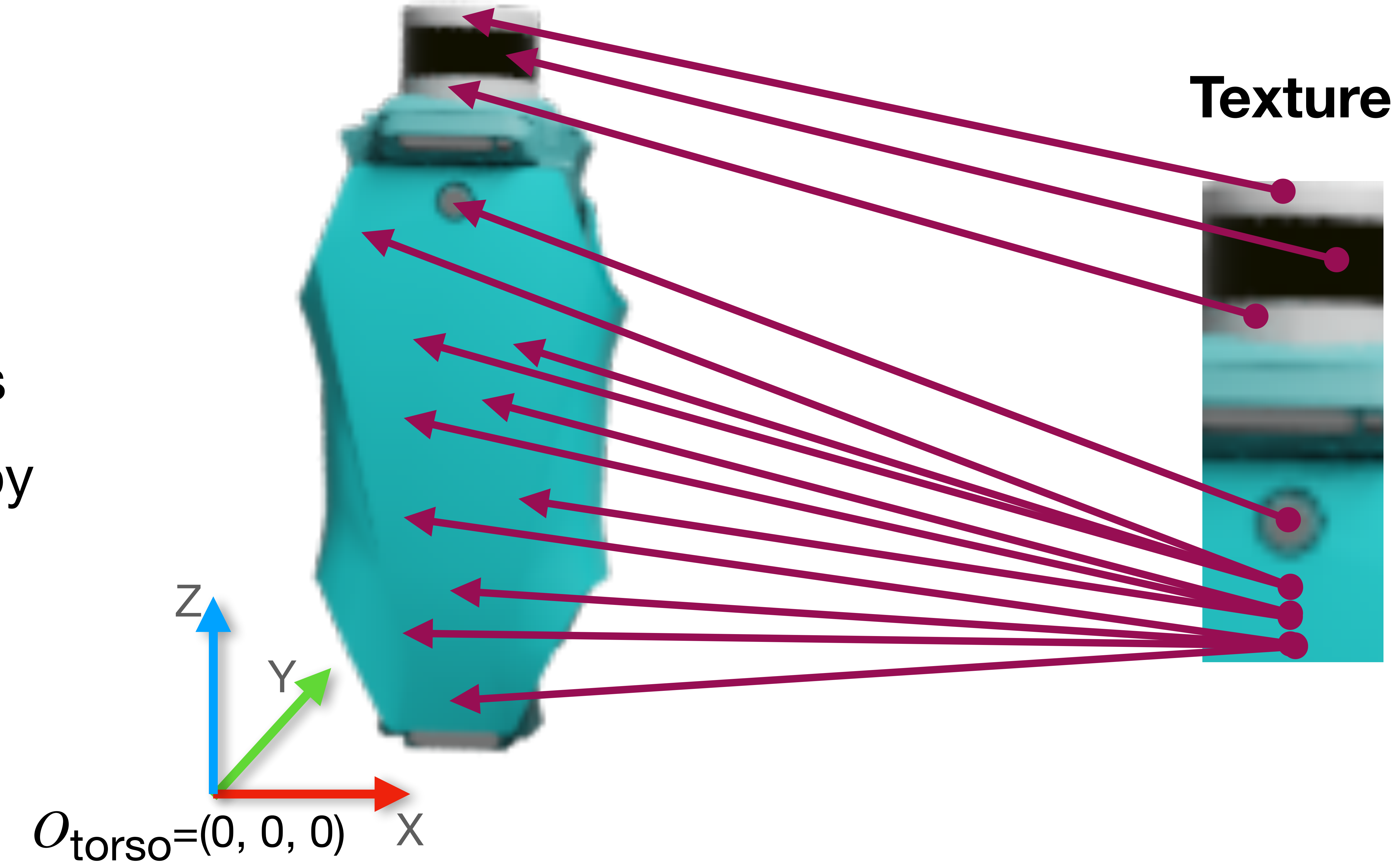

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Common Geometry File Formats

.obj (wavefront)

.ply (polygon file format)

.stl (standard tessellation language)

.dae (collaborative design activity)

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torso.obj

```
# Blender v2.92.0 OBJ File: ''
# www.blender.org
mtllib torso.mtl
o __TMPOBJ____TMPMESH__.002
v -0.008115 0.069371 0.399356
v -0.007999 0.062997 0.404000
v -0.007999 0.070006 0.400481
v -0.083020 0.080245 0.186004
⋮
f 1//1 2//1 3//1
f 4//2 5//2 6//2
f 561//3 562//3 563//3
f 727//4 728//4 729//4
f 730//4 731//4 732//4
f 733//4 734//4 735//4
```

Texture file

Vertices

Faces

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Where are geometry definitions from?

Human artists (e.g. [Sketchfab](), [cgtrader]())

Photogrammetry algorithms (e.g. [Matterport]())

Rigid Body Objects: Pose

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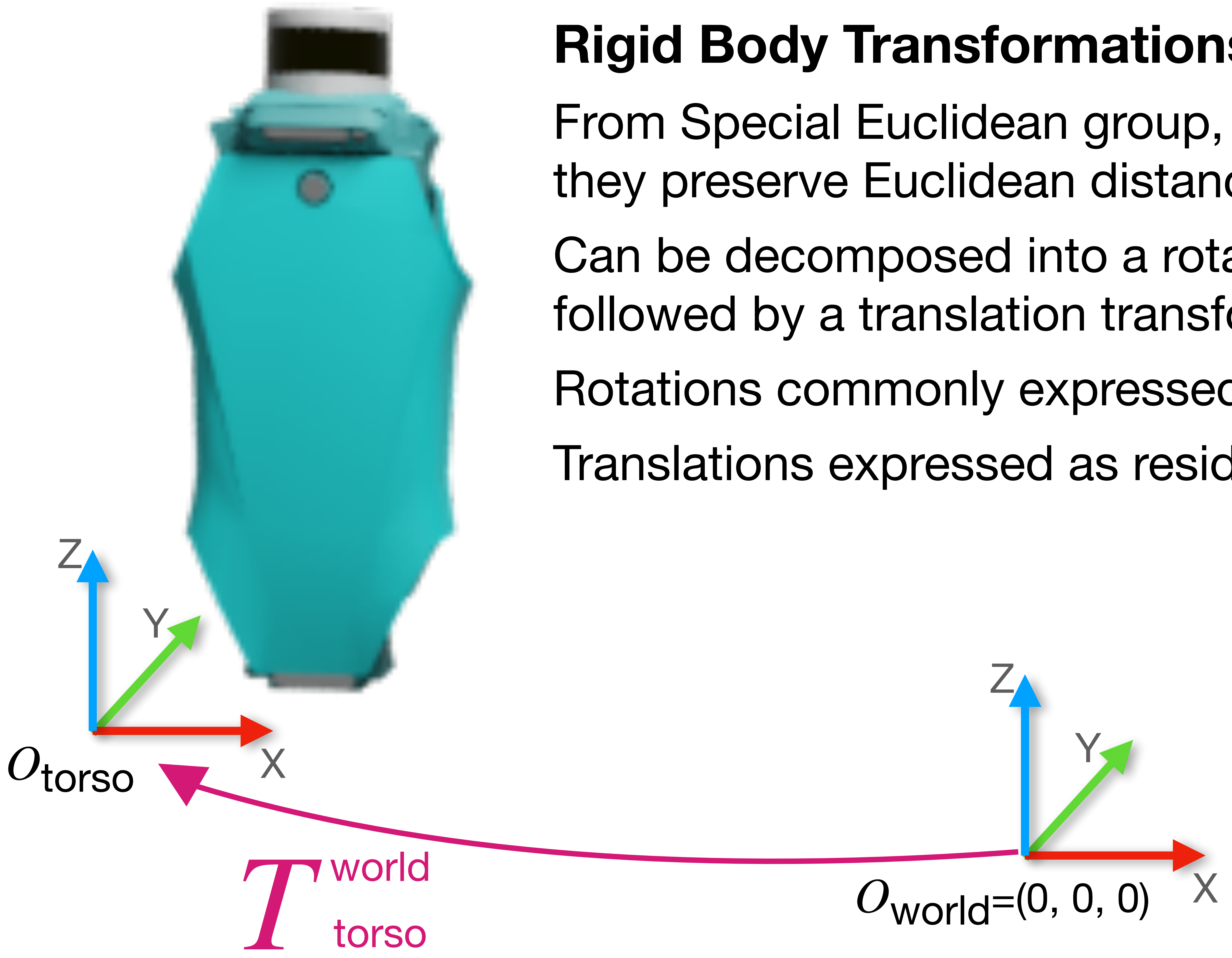


Rigid Body Transformations

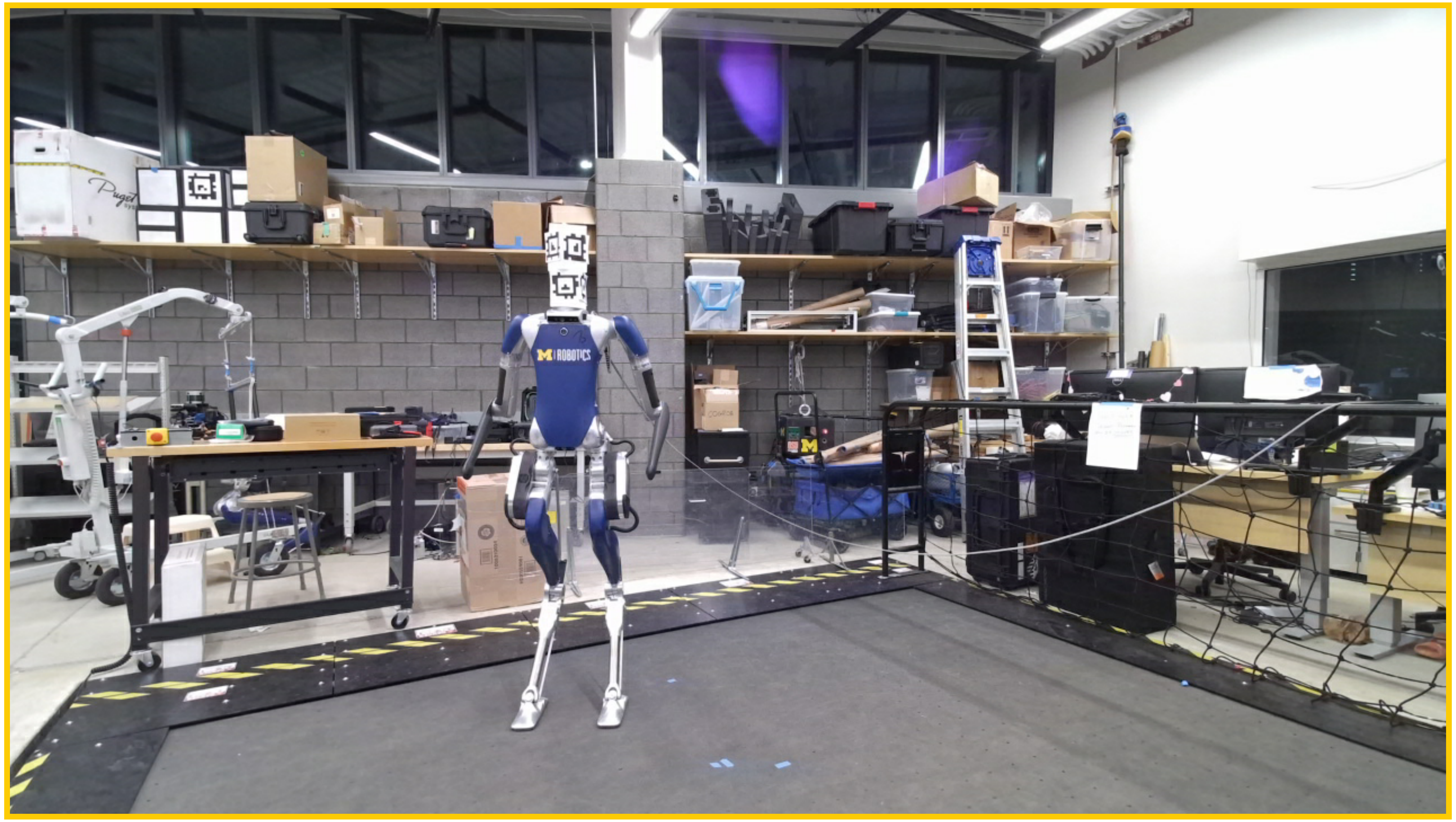
From Special Euclidean group, SE(3), meaning they preserve Euclidean distance

Can be decomposed into a rotation (3DoF) followed by a translation transform (3DoF)

Rotations commonly expressed as [quaternions]

Translations expressed as residuals (deltas)

Collections of Rigid Body Objects



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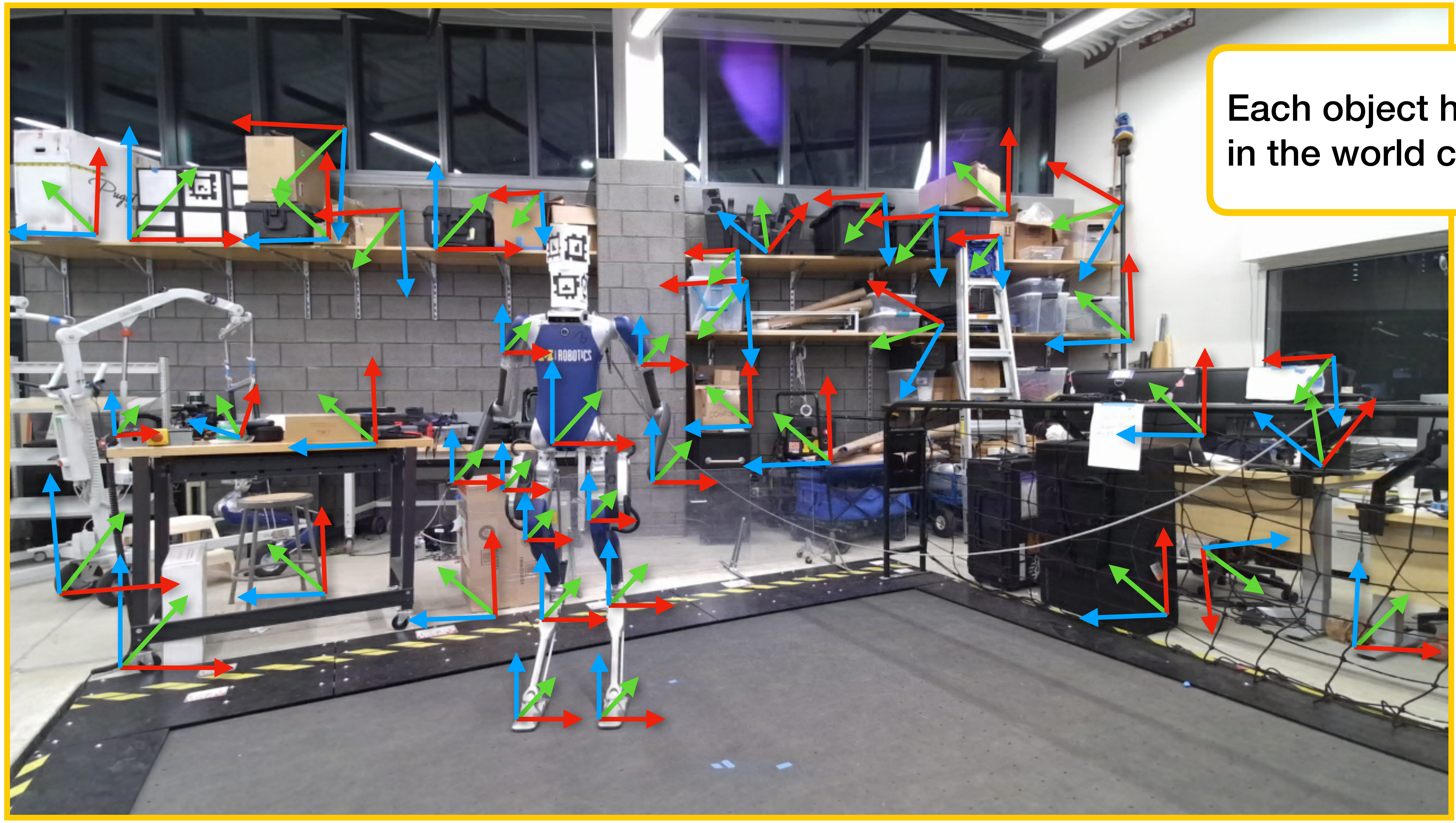

Each object has its own pose in the world coordinate frame

Data courtesy of Anthony Opipari, Liz Olson, Grant Gibson, and Arden Knoll

Explicit Object Representations are Useful for Model-Driven Robotics

Knowing object geometry and pose enables

- Collision-free motion planning
- Path planning and obstacle avoidance
- Task planning
- Goal-directed manipulation

Rigid Body Objects: Roles for Deep Learning

- 6DoF pose estimation
  - How to perceive from vision or tactile sensors?
- Implicit surfaces and signed distance functions
  - How to model an object's surface *implicitly* by a learned network?
- Dense object descriptors
  - How to extract features from a learned network that describe local and global object properties?
- Category-level representations
  - How to model geometry and pose for objects of varying shape but same semantic category?

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