Weston Robot

RSE2107A – Lecture 4

Gazebo and Mapping (GMapping)

Agenda

01
Simulators

02
Gazebo

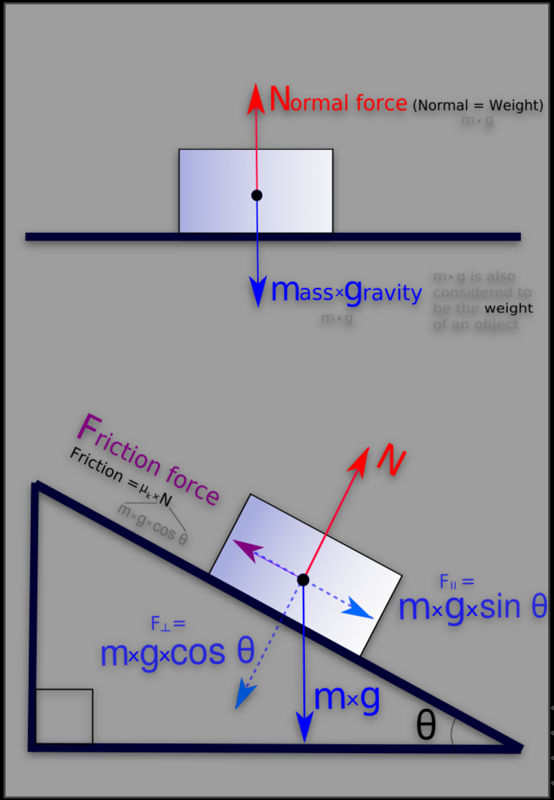
03
3D Printing

04
ROS Navigation

Simulators

What?

- Simulators aim to represent the *dynamic* responses/behaviour of real world processes (or systems) with the use of models.
- This mathematical model represents the key characteristics, relationships and behaviours within the target system.



How?

- The simulated system's state can be calculated using it's mathematical model, given a set of inputs/constraints.
- The model results in the mathematical dynamics that form an analog of the behaviour of the modelled system. (i.e. solving and processing the mathematical equations represents expected behaviour data)
- Simulators use this result to create a visual "mock-up" for easier visualisation.

Why?

- Simulation can be used
  - Evaluate a proposed change to a system.
  - Evaluate performance of an existing system.
  - Alternative to potentially costly real world testing/training.
  - Offer insights rapidly and otherwise difficult to obtained using other methods.

When?

- Any system/process that has a flow of events can be simulated, though more effective on systems with changes over time and variable/random factors/inputs.
- Generally can be categories to 3 types:
  - Systems that progress through time (*Discrete Event*)
  - Systems that progress through space (*Dynamic*)
  - Interactions between multiple systems (*Process*)

Gazebo

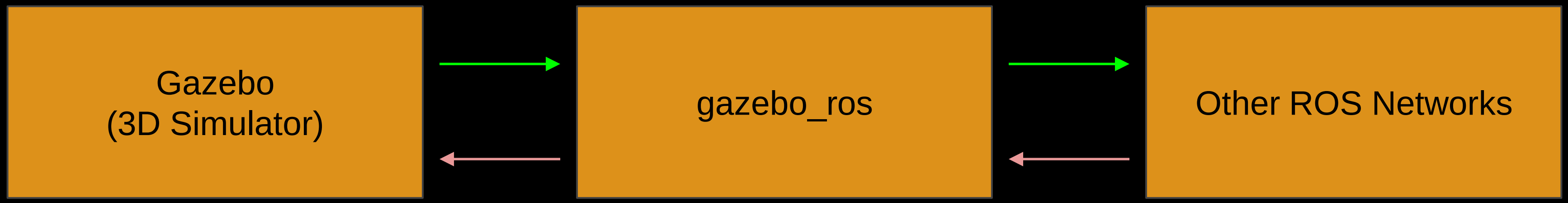
Robots In Gazebo

- Gazebo is a 3d *dynamic* simulator with the ability to accurately simulate robots/sensors in various environments.
- It has access to models to simulate
  - Rigid body control/movement
  - Collisions
  - 3D virtual worlds
  - Sensors

Robots In Gazebo

- Generally, ordinary differential equations (ODEs) are used to describe our robots. By solving the system's state from the set of ODEs at discrete time intervals, we are able to get the simulated behaviour of the robot during the simulated time periods.

Gazebo with ROS



- Gazebo by itself is a 3D Simulator, whereas gazebo_ros is a node to translate information between ROS and Gazebo

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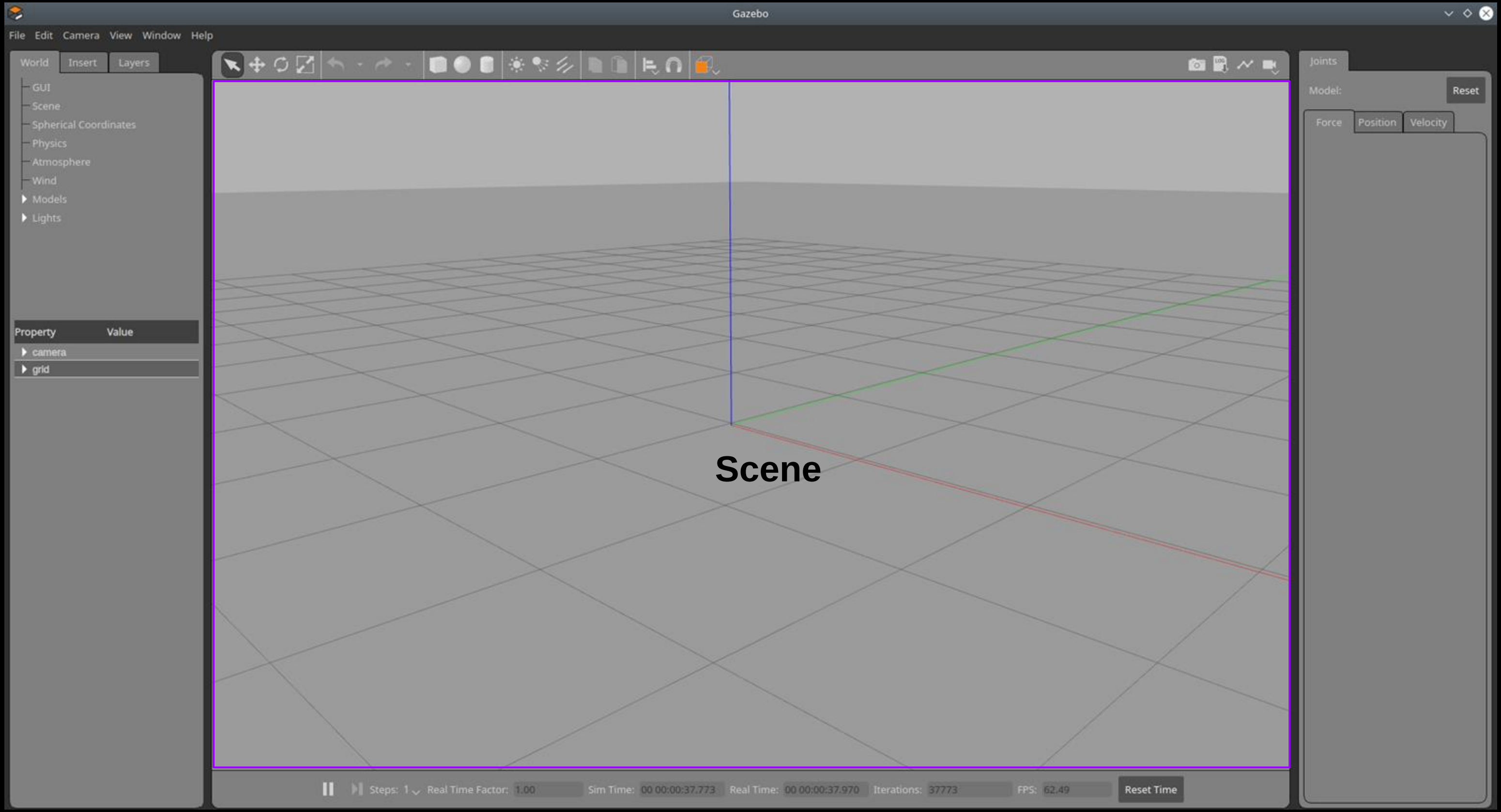

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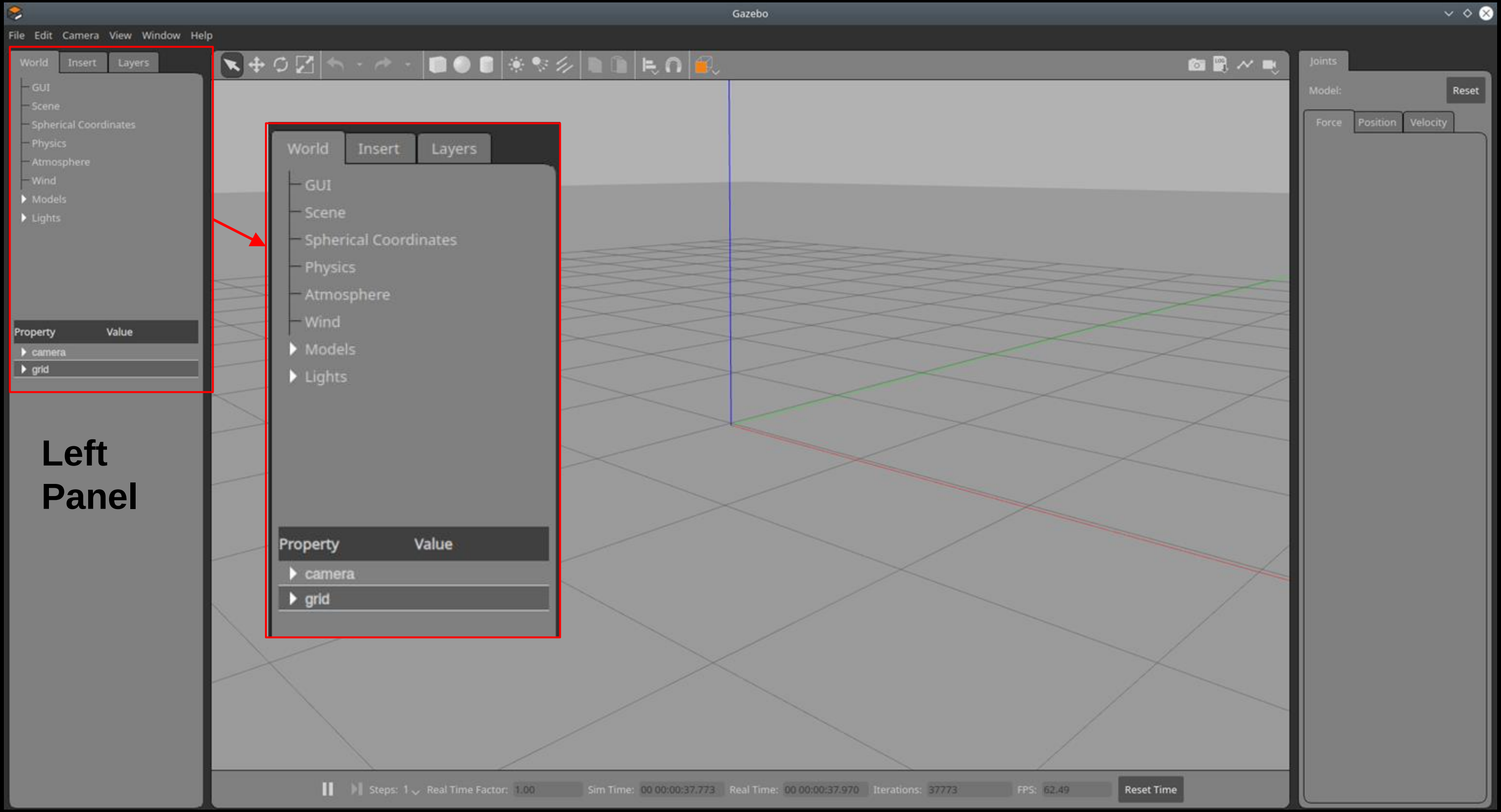

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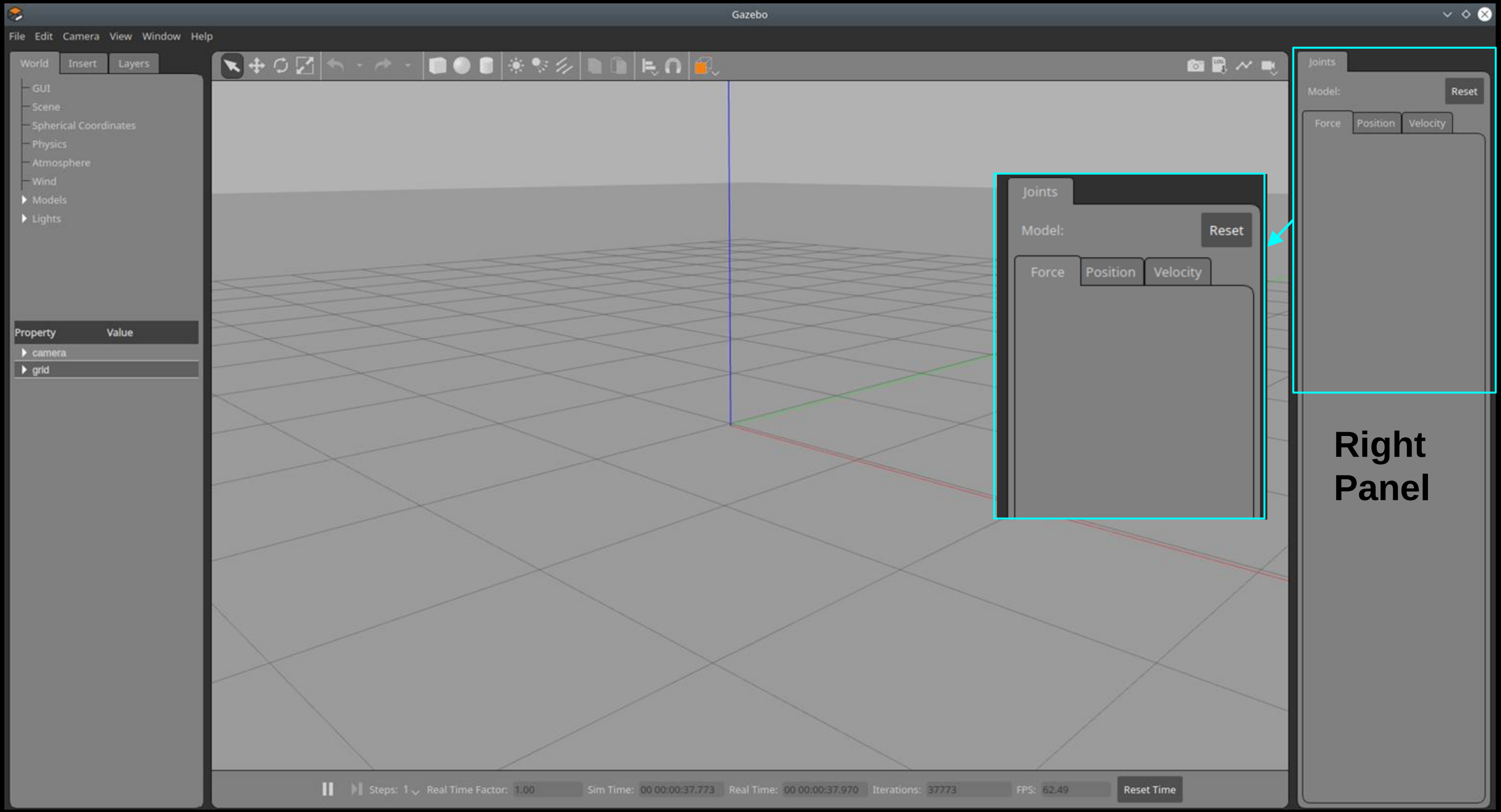

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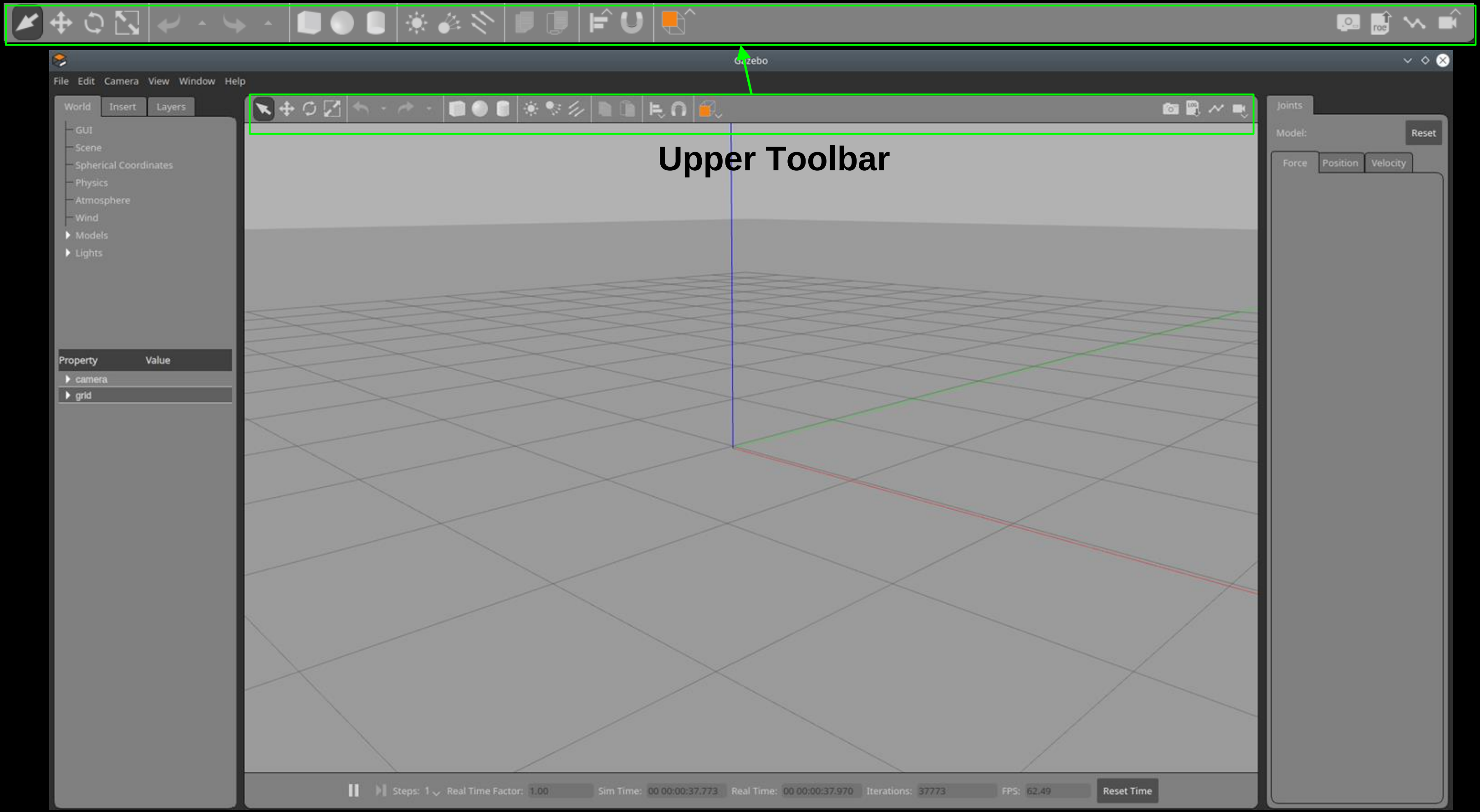

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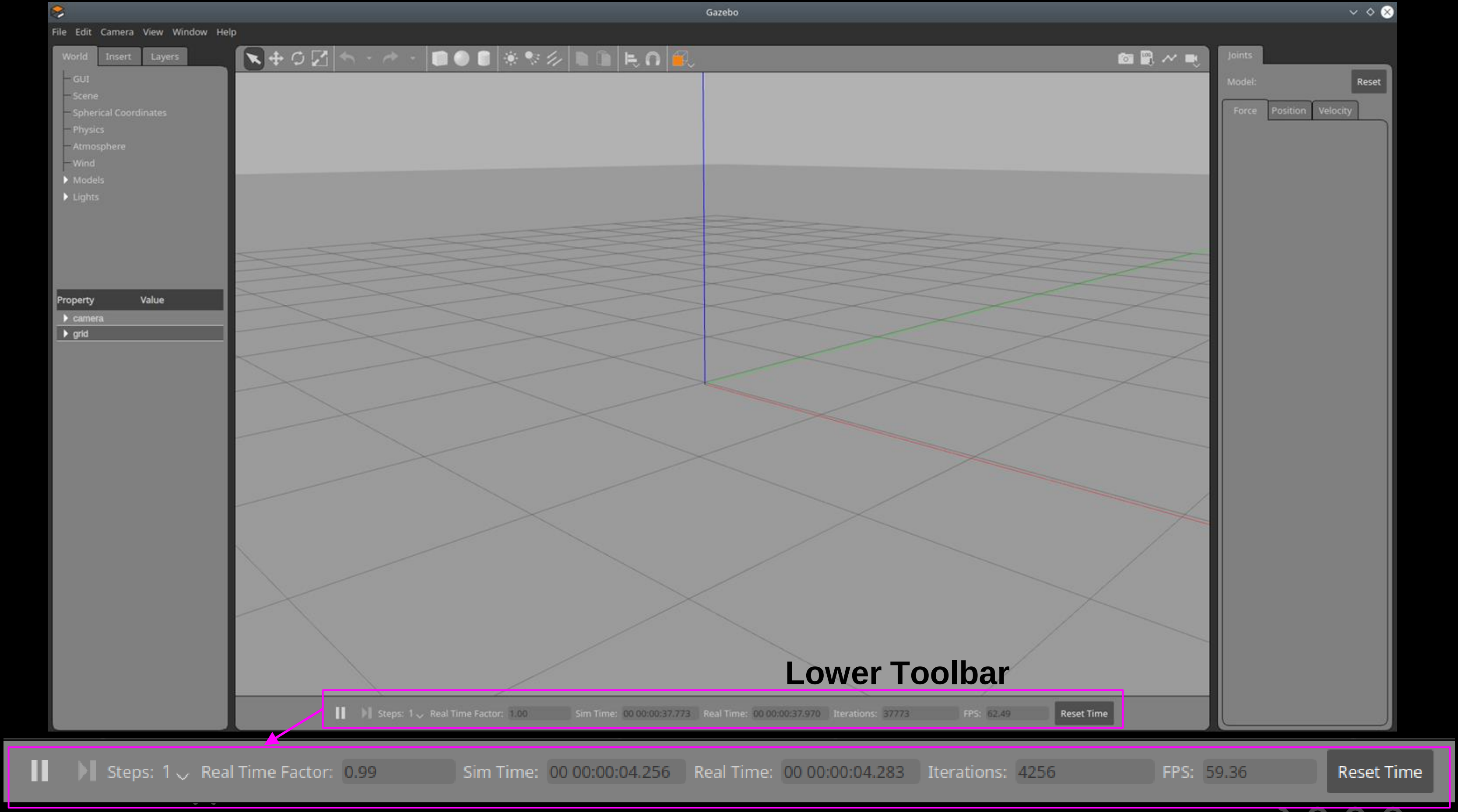

Gazebo GUI

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- Scene
  - where simulated objects are animated and where interactions with the objects is done at
- Left Panel
  - World - displays models currently in the scene
  - Insert - where models are stored at (for adding models into the scene)
  - Layers - organizes and displays different visualization groups available in the simulation

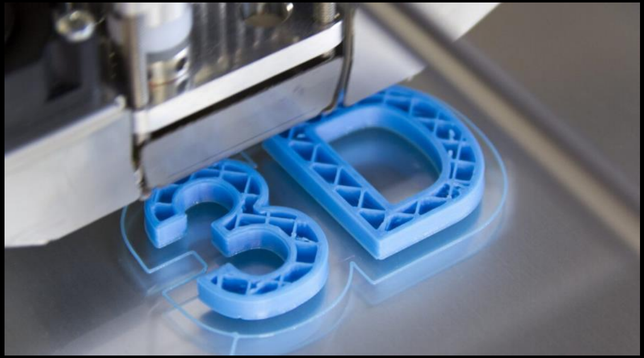
Gazebo GUI

- Right Panel (Hidden by default)
  - Used for interacting with mobile parts of selected model
- Toolbars
  - Upper Toolbar (Most used options for interacting with simulators
    - Select, Translate, Rotate, …
  - Lower Toolbar (Displays data about simulation)
    - Play/Pause sim, Timed passed in simulation, …

3D Printing

3D Printing

- Introduction to 3D printing
- How it works
- Real-world applications
- Common materials used for 3D Printers
- Traditional Manufacturing
- 3D Printing or Traditional Manufacturing
- Benefits and Limitations of 3D Printing



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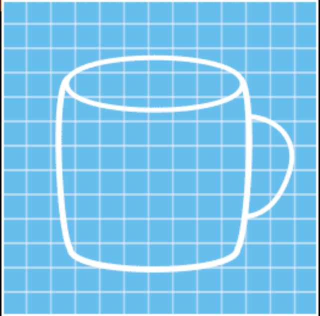
Introduction to 3D printing

- Known as Desktop Fabrication or Additive Manufacturing
    - The process for making a physical object from a 3-dimensional digital model, usually through laying down several thin layers of a material



Start with a 3D CAD file either by creating the 3D model or scanned with a 3D scanner

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How 3D printing works

Modelling

Creating 3D models(.stl file) with software like Solidworks or Fusion 360

Slicing

Using slicing software to allow 3D printer to calculate route and amount of filament needed

Printing

Uploading of slice file to printer and calibrating printer to prepare for printing

Post-processing

- Removing of supports
- Sanding
- Colouring
- Polishing
- Welding/ Assembling

Real-world application

- Medical Applications
  - 3D printed prosthetics
- Construction
  - Fabricating buildings or construction components
- Prototyping and Manufacturing
  - 3D printing reduces lead time required in traditioning manufacturing

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Common materials used

Filaments	PLA	ABS	TPU
Pros	• Biodegradable • Low odor • Smooth surface • Less warp worries	• High impact strength • Easy to move out support	• Elastic and soft material • Low warpage and shrinkage • Good impact resistance
Cons	• Low impact strength • Hard to move out supports	• Might have plastic odor • Need hotbed to be of high temperature • Hard to control warp	• Need to be printed at low temperature • Difficult to post-process • Prone to stringing and clogging

Traditional Manufacturing

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- Refers to the four main subtractive manufacturing methods
  - **CNC Machining** - for three-dimensional cutting tasks using pre-programmed computer software
  - **Injection Moulding** - injecting of molten material into a mould
  - **Plastic Forming** - utilizing air pressure and male plugs to form sheets of plastics into a shape
  - **Plasting Joining** - joining of semi-finished parts (fastening, adhesive bonding, welding)

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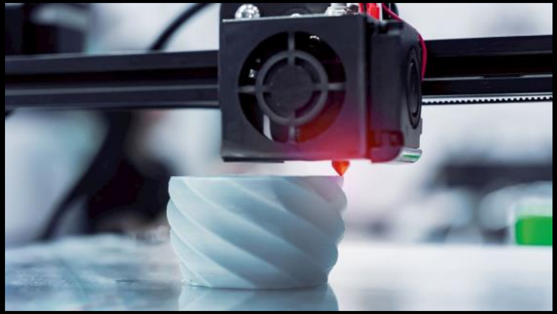
3D Printing or Traditional Manufacturing

3D printing	Traditional Manufacturing
• Short production runs • Prototyping • Reducing of wastes • Need for customizability and adaptation • Need for speed for production	• Long production runs • Need for a perfect finish • Manufacturing with materials otherwise not available in 3D printing • Very large parts

Benefits of 3D printing

- Less waste
  - Thermoplastic materials can be re-melted and cured, thus reducing manufacturing waste since it can be reused for other prints
- Rapid prototyping
  - Ability to design, manufacture and test a customized part in as little time as possible
- Flexibility
  - Able to create almost anything that fits within the build volume of the printer



Limitations of 3D printing

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- Limited printing materials
  - For cheap printing, plastic is widely used. Other materials are more costly to print.
  - Some printers only allow for printing of PLA material
- High consumption of energy for operation
  - 100 times more power consumed compared to traditional manufacturing

ROS Navigation

Odometry

- Use of sensors to estimate change in relative position over time
- Robot needs to know its position to execute autonomous path planning
- Various sensors/ methods are used

Localisation sensors

- Wheel Odometry
  - Simplest
  - Calculates robot position using number of revolutions of wheels
  - Typically used for differential drive

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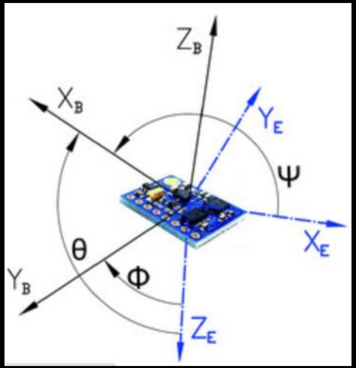
Localisation sensors

- Global Position System
  - Radio-navigation system easily found in cars and phones
  - Good for outdoors
  - Immune to accumulation of error
- Inertial Navigation System (INS)
  - Relative position through Inertial Measurement Unit
  - Prone to error accumulation/ sensor noise
  - Typically used to supplement other sensors



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Localisation sensors

- Cameras (Visual Odometry)
  - Mono/ Stereo Optical Camera
  - Relatively low cost sensor
  - Image processing is computationally intensive
- LiDAR
  - Laser based
  - Measures the return time of a fired pulse of light
  - Generates a point cloud
  - Expensive sensor

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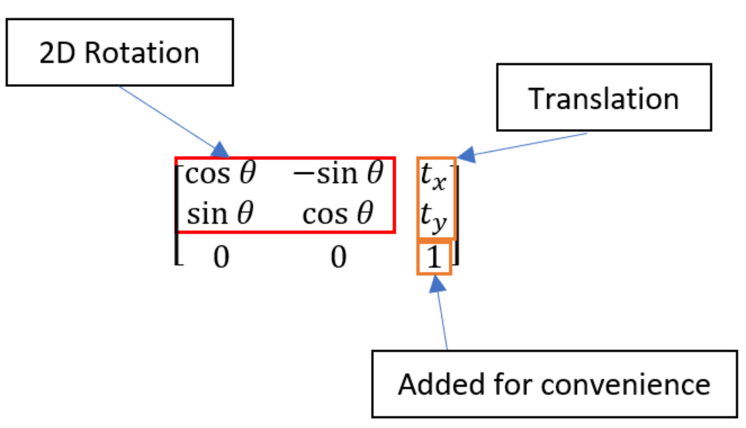
Coordinate Transformation

- Transform the coordinates of a point from a world frame to another
- Cartesian/ XYZ Transformation
  - Linear Algebra
  - 3 x 3 Matrix for 2D Transformation
  - Matrix contains the rotational and translational information
- GPS to Local Cartesian
  - Geodetic to Earth-Centered Earth-Fixed (ECEF) to East North Up (ENU)
  - For own reading: https://www.mathworks.com/help/map/choose-a-3-d-coordinate-system.html



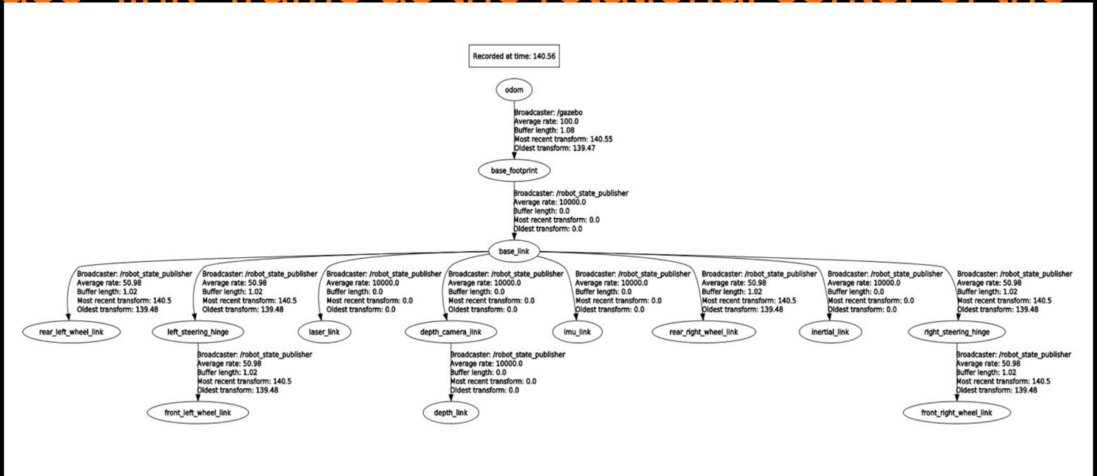
$$\begin{bmatrix} \cos\theta & -\sin\theta & t_x \\ \sin\theta & \cos\theta & t_y \\ 0 & 0 & 1 \end{bmatrix}$$

Transforms in robotics

- Used to define the positions of sensors or joints relative to the robot/ world
- Sensors typically provide data relative to the sensor origin
- Sensor origin is a fixed offset from the robot origin
- Robot is constantly moving, robot coordinate frame is constantly moving
- Transform sensor data to map frame
  - sensor frame -> robot frame -> map frame

Example Transform Tree

- A transform tree can be used to visualise relationships of coordinate frames of nodes
- Generally define the “base_link” frame as the rotational center of the robot



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SLAM

- Simultaneous Localisation and Mapping
- 2 main sensor methods (optionally with IMU)
  - Visual Slam
    - Monocular/ Stereo/ RGB-D Cameras
  - LiDAR Slam
    - LiDAR

Notable SLAM Methods

- Benchmarked against KITTI Dataset in order
  - SOFT2 (Visual)
  - V-LOAM (Visual + LiDAR)
  - LOAM (LiDAR)