
CARLA
CARLA: Open-source Simulator for Autonomous Driving Research
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CVC
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CARLA Simulator

Content

1. Introduction to CARLA architecture
2. Client API example: data acquisition
3. Highlighted features
4. Coming soon


Introduction to CARLA

CARLA Simulator

- **Open-source**
  All source code, 3D models, and maps fully open and redistributable.

- **Flexible API**
  Programmatic control over all the aspects of the simulation.

- **Autonomous driving sensor suite**
  Configurable sensors and ground-truth data.

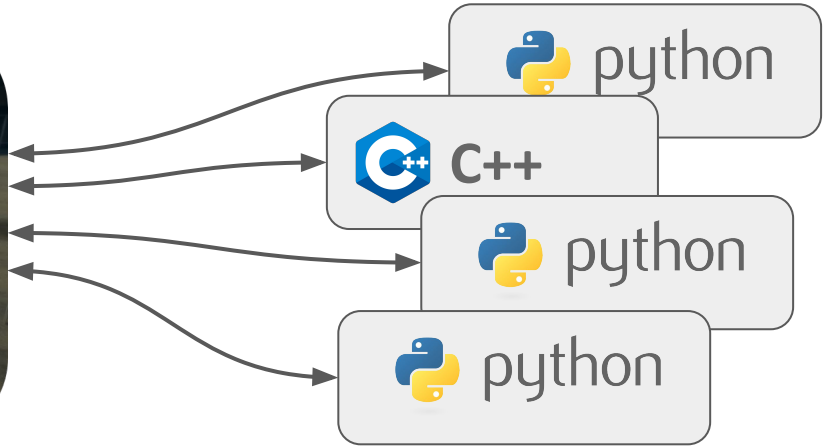
- **Integration**
  ROS and Autoware integrated via our ROS-bridge.

https://github.com/carla-simulator

New API

	0.8.x	0.9.x
Multi-client		✔
Multi-agent		✔
Network error proof		✔
Reset episode	✔	✔
Pedestrians	✔	✔
Synchronous mode	✔	✔
No-rendering mode		✔
OpenDRIVE navigation		✔
Map ingestion		✔
Logging and playback		✔

CARLA: Simulator + Client API



Simulator

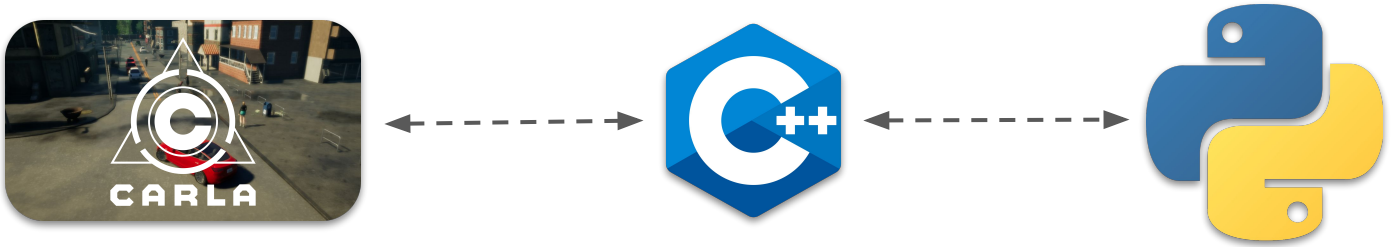
User scripts

- Simulator computes the physics and renders the scene.
- Users control the simulator from the Client API.

Client API: Python vs C++

All the functionality is available for both Python and C++

- The C++ API provides a lower-level fast-performance communication.
- The Python API provides convenient bindings for easy-to-use communication.



CARLA Modules

Modules

- **Render:** Unreal Engine 4
- **Physics:** PhysX
- **Networking:** RPC + LibCarla
- **Navigation:** Scene graph based on OpenDRIVE
- **Traffic:** Agents & Autopilot

Modules: Unreal Engine 4

Game development framework

- AAA quality and performance render
- Lighting and post-processing
- Level editor
- Able to render multiple cameras in parallel

Modules: PhysX

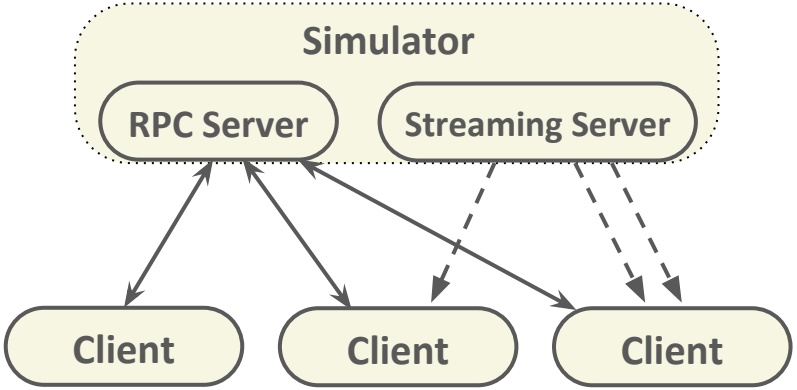
Configurable vehicles

- Mass and center of mass
- Engine and transmission setup
- Steering and torque curves
- Per wheel setup: tire friction, steer, damping rate

Client API can modify at runtime.

NVIDIA PHYSX

Modules: Networking



- Connect and control via RPC protocol, flexible but slow for big messages.
- Sensor data sent via the streaming server, unidirectional but fast.
- Transparent to the user.

Modules: OpenDRIVE Navigation

Navigation API based on OpenDRIVE standard.

Vehicles are able to navigate newly imported maps containing an OpenDRIVE file.

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managing the road ahead
+
Geometry

Modules: Agents & Autopilot

We should distinguish between two types of navigation agents in Carla:

- Client-side agents
  - Scalable, able to distribute load among different machines.
  - Python, easy and quick to modify.
- Server-side Autopilot
  - Less overhead, but load goes to simulator.
  - Not configurable.

Client API example: Data acquisition

Python API usage example:

Data acquisition:

- Set up environment, choose map and weather conditions.
- Add background traffic and ego-vehicle.
- Set up sensors.
- Acquire measurements and ground-truth.

Client API: Basics

- **World:** Currently loaded map.
- **Blueprint:** Specifications for creating an actor.
- **Actor:** Anything that plays a role in the simulation.
  - **Sensor:** Special type of actor that streams data.

```
actor = world.spawn_actor(blueprint, transform)
actor.foo()
```

Loading the world

Connect to the simulator

```
client = carla.Client('localhost', 2000)
```

Retrieve active world

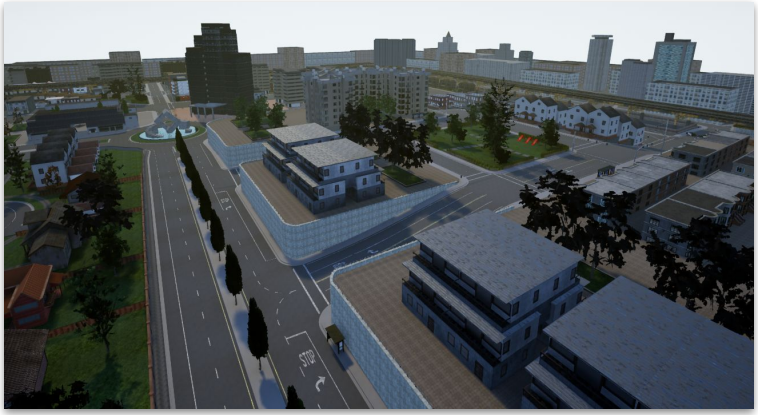
```
world = client.get_world()
```

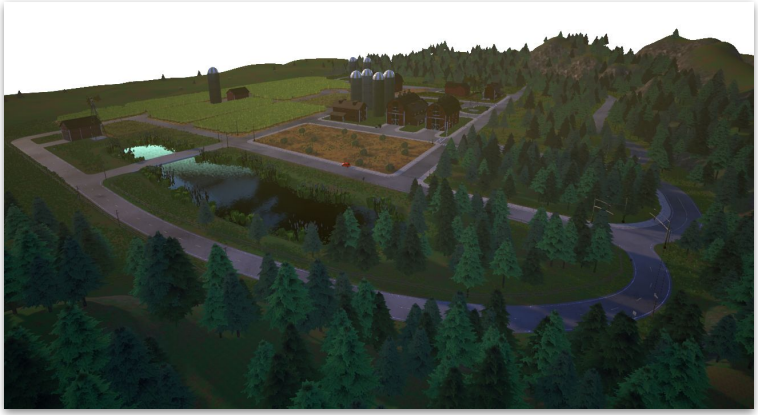
Reload active world

```
world = client.reload_world()
```

Load a world by map name

```
world = client.load_world('Town05')
```





Changing the weather

Parametrized weather and lighting conditions, fully controllable at run-time

```
world.set_weather(WeatherParameters(precipitation=70))
```

The blueprint library

- The list of all available blueprints is kept in the blueprint library.
- Blueprints contain the information necessary to create a new actor.
- Provides methods for filtering and finding blueprints.
- Includes: sensors, vehicles, pedestrians, and static props.

```
blueprint_library = world.get_blueprint_library()
traffic_cone = blueprint_library.find('static.prop.traffic_cone')
sensors = blueprint_library.filter('sensor.*')
```

Spawning actors

```
actor = world.spawn_actor(blueprint, transform)
```

CARLA provides basic transform objects

- `carla.Location(x, y, z)` (in meters)
- `carla.Rotation(pitch, yaw, roll)` (in degrees)
- `carla.Transform(carla.Location, carla.Rotation)`

Important: CARLA uses left-handed coordinate axis

Spawning vehicles in autopilot

- Find the blueprint.
- Use a recommended spawn point.
- Enable autopilot.

```
for blueprint in blueprint_library.filter('vehicle.*'):
    spawn_point = random.choice(world.get_map().get_spawn_points())
    vehicle = world.spawn_actor(blueprint, spawn_point)
    vehicle.set_autopilot(True)
```

Spawning ego-vehicle

- The ego-vehicle is spawned as any other vehicle.
- Tagged as “hero” role.

```
blueprint = blueprint_library.find('vehicle.ford.mustang')
blueprint.set_attribute('role_name', 'hero')
vehicle = world.spawn_actor(blueprint, spawn_point)
```

```
vehicle.apply_control(VehicleControl(steer=0.0, throttle=0.7))
```

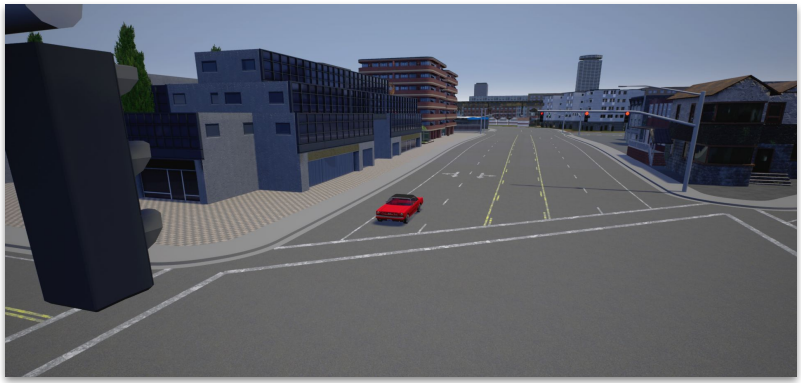
Spawning sensors

Sensors, as any other actor, can be spawned anywhere in the world

```
camera = world.spawn_actor(camera_bp, transform)
```

They can also be attached to other actors to follow them as they move around

```
camera = world.spawn_actor(camera_bp, relative_transform, attach_to=my_vehicle)
```



Fine tuning sensors

Blueprints provide a way to customize the attributes of a sensor too

- **Camera resolution, FOV, update frequency, gamma, blur, etc.**
- **Lidar range, channels, number of points, rotation frequency, etc.**

```
camera_bp.set_attribute('sensor_tick', '0.5')
camera_bp.set_attribute('fov', '120')
camera_bp.set_attribute('image_size_x', '1920')
camera_bp.set_attribute('image_size_y', '1080')
lidar_bp.set_attribute('channels', '64')
lidar_bp.set_attribute('rotation_frequency', '30.0')
```

Listening to sensors

Everytime a measurement is produced, an event is triggered in the client-side. We can register a callback that is going to be call on each new measurement

```
camera.listen(lambda image: image.save_to_disk('%06d.png' % image.frame_number))
```

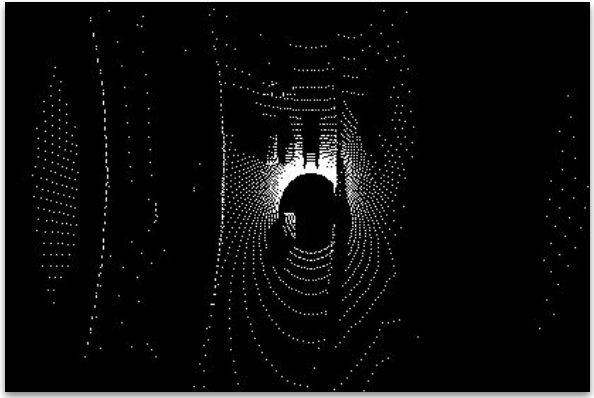
The callback is executed asynchronously in the background.

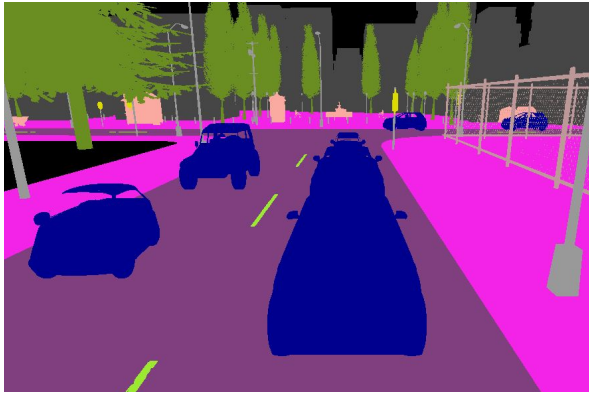



Listening to sensors

Different sensors produce different types of data

- Image
- Point cloud
- GNSS coordinate
- Collision event
- Lane invasion event
- Obstacle event

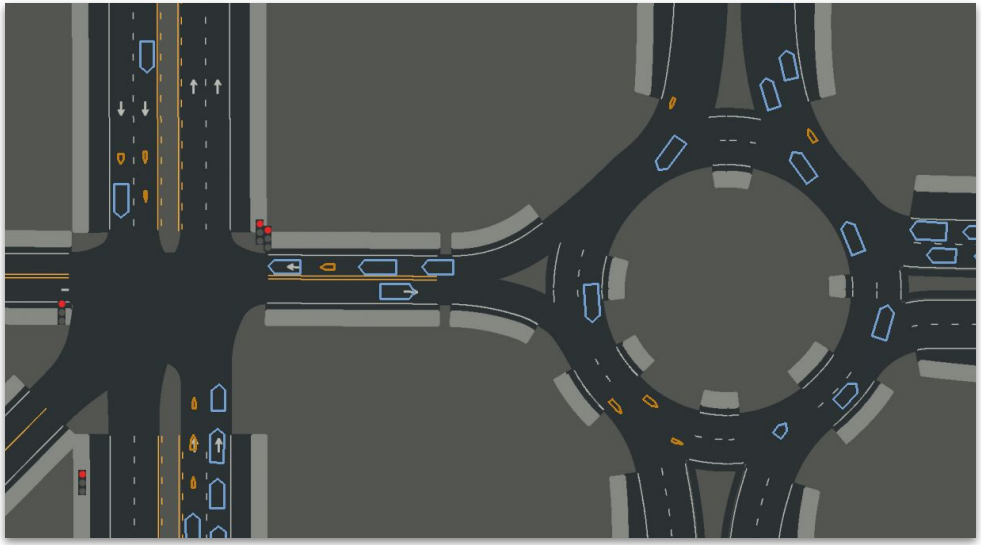


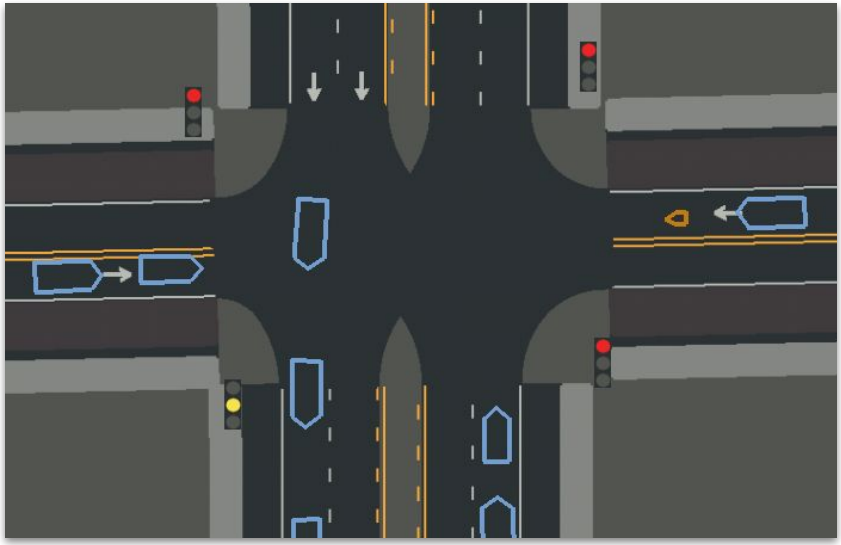



Highlighted features

High-performance traffic simulation

- No-rendering mode for faster than real-time traffic simulation.
- Client-side 2D visualization of the scene built on top of our API.





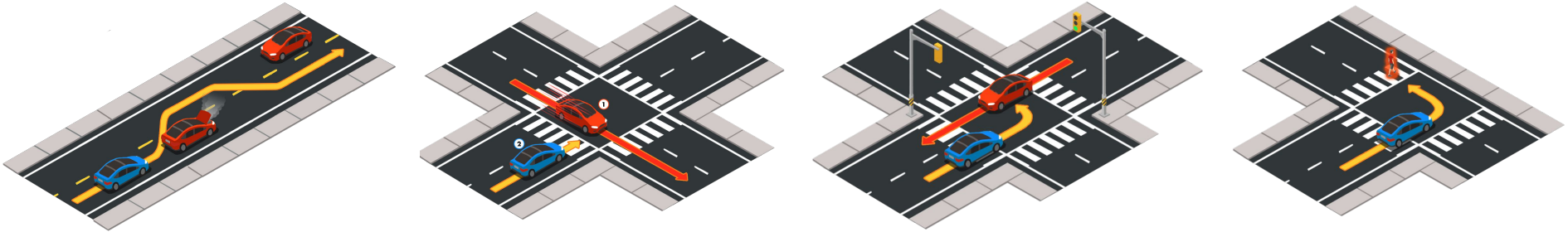
Logging and playback

- Record the simulation to a file on disk.
- Simulation summary with important events, collisions or blockers.
- Replay only important events.
- Resume simulation at any time, diverging from replay.
- Replay in different weather and lighting conditions.
- Replay at different speeds.




Scenario runner

- Execute complex traffic scenarios.
- Define new scenarios based on behaviour trees.
- Future: support for standard formats as OpenSCENARIO.

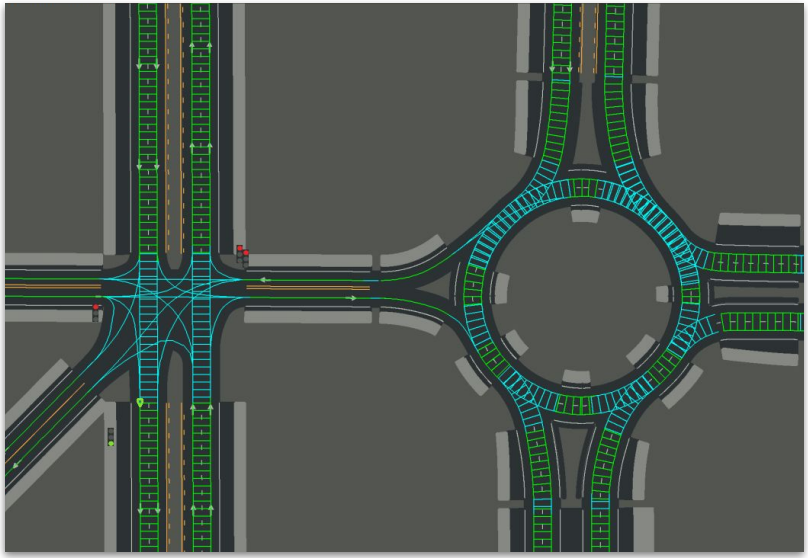


https://github.com/carla-simulator/scenario_runner

Map and waypoints API

CARLA loads OpenDRIVE files to a graph in memory providing

- Easy API for map queries
- Waypoint generation
- Topology



This map can also be created off-line

```
map = carla.Map(opendrive_contents)
```

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Map creation and ingestion

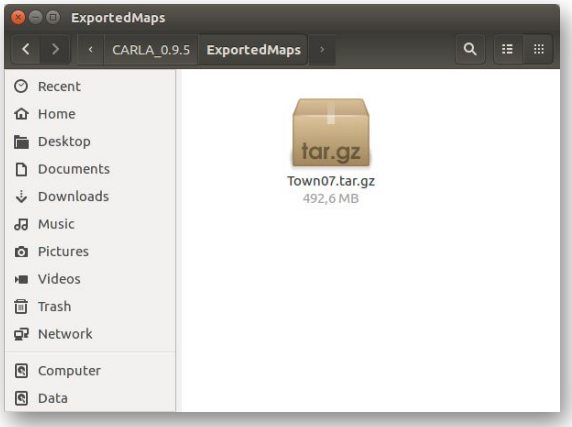
- Create your own map, e.g. with VectorZero's RoadRunner.
- Import the map into Carla (geometry + OpenDRIVE).
- Cook the map for distribution.
- Users can import cooked maps into release package.

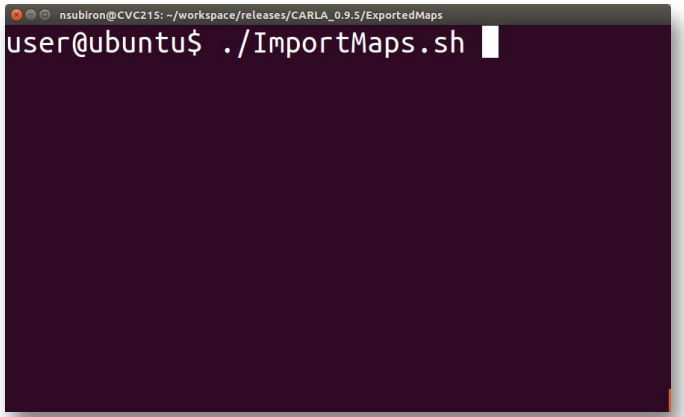
Importing cooked maps in release package

Cooked maps can be imported into a release package in just two steps

- **Place the package in** `ExportedMaps` **folder**
- **Run** `ImportMaps.sh` **script**

The new map then becomes accessible from Client API, even if imported at run-time.



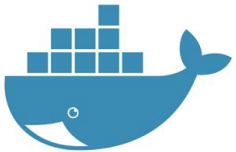


CARLA Docker image

Docker image publicly available at DockerHub

```
docker pull carlasim/carla:latest
docker run -p 2000-2001:2000-2001 --runtime=nvidia -e NVIDIA_VISIBLE_DEVICES=0 carlasim/carla:latest
```

Use `NVIDIA_VISIBLE_DEVICES` **to select GPU**



https://hub.docker.com/r/carlasim/carla


Coming soon

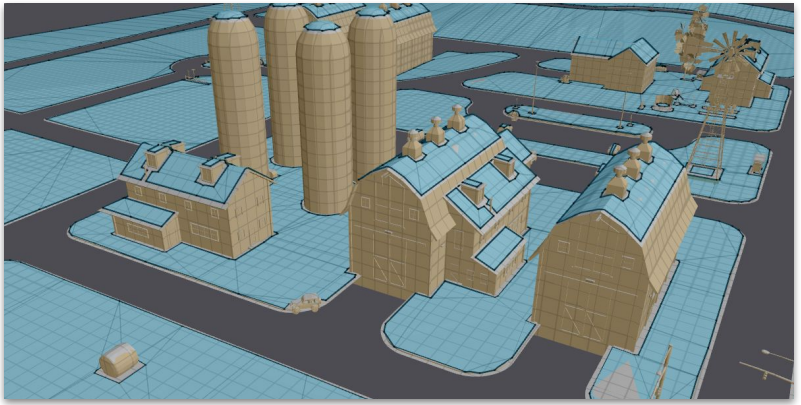
Pedestrian navigation

Exposing new API to control pedestrians

- “Go to location” commands
- Stop-resume navigation

Efficient navigation algorithms

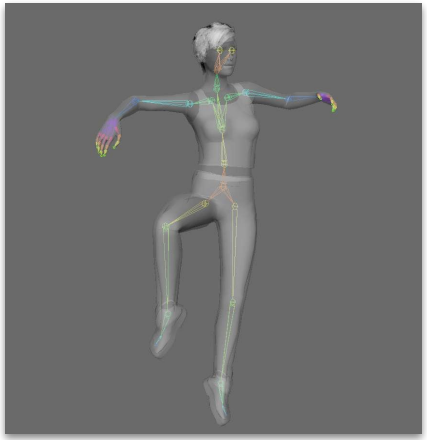
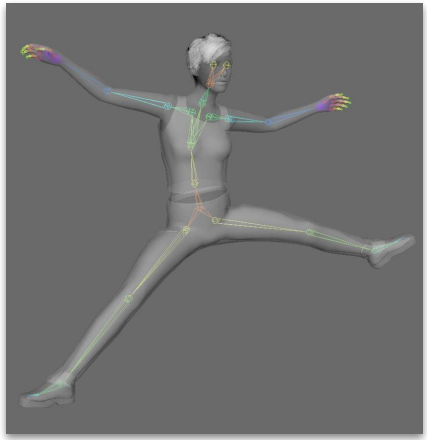
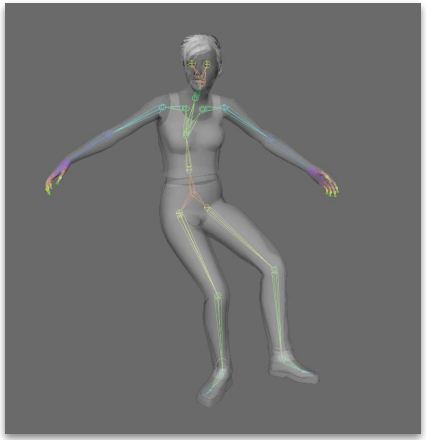
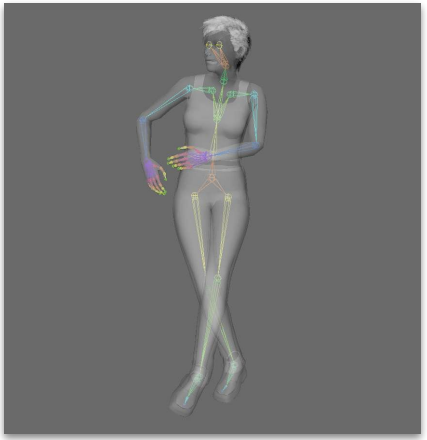
- Navigation mesh for quick path finding.
- DeTour avoidance to avoid collisions.
- Different weights for roads and sidewalks.



Pedestrian skeleton control

Simulate realistic poses for pedestrian detection

- Support for controlling each individual bone from Client API.
- 64 bones: 24 body + hands and eyes.


Thanks!

CARLA Simulator

http://carla.org

https://github.com/carla-simulator

Open chat for getting support from the community!

https://discord.gg/8kqACuC