Rig My Ride: Automatic Rigging of Physics-based Vehicles for Games

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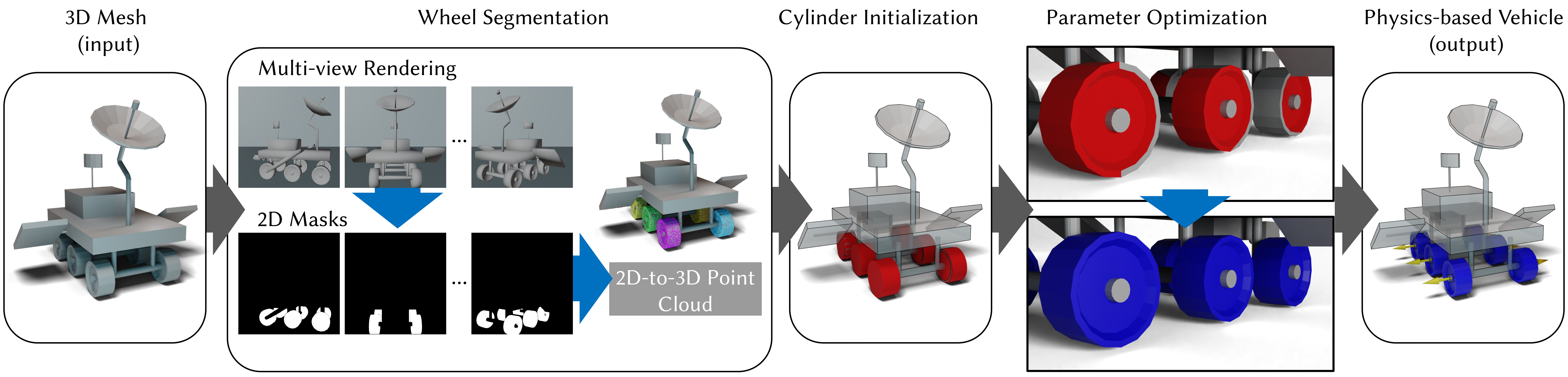


Introduction

The process of rigging associates a mesh with an underlying articulation. In the context of rigid bodies, physics-based rigging requires assigning a set of joints and bodies to animate the surface geometry.

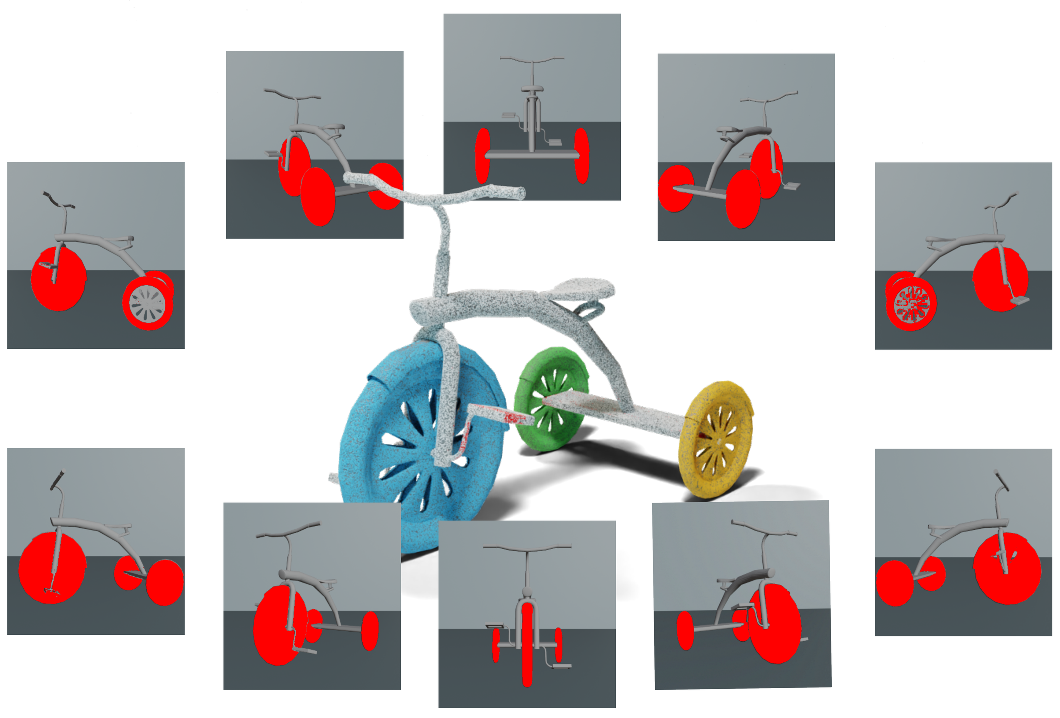
Our goal is to create rigs for physics-based vehicle models, starting only from a 3D polygon mesh. The traditional process goes as follows: the mesh is separated into sub-components (the chassis and wheels). Each component is then assigned a collision geometry, and joints that link the chassis to the wheels are created. Both collision proxy creation and joint placement require manual fine-tuning and are model-specific, and thus cannot easily be reused. Overall, this **process is repetitive and tedious**.

We propose Rig My Ride, a process for automatically rigging physics-based vehicles, eliminating the need to The vehicle mesh is not required to be topologically or geometrically valid.

Wheel Segmentation

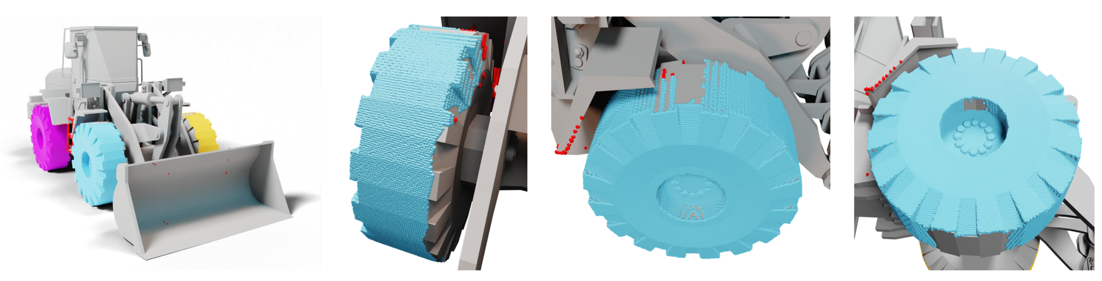
A series of renders of the vehicle will be used to identify the pixels that contain wheels:
- Prompt GLIP for the "wheel of a vehicle" to get bounding boxes.
- Feed the boxes into SAM to get one mask per box.

To transfer these masks into 3D:
- Create a dense point cloud $\mathcal{P}$ of the model.
- Ray-cast from each mask to the model, tagging the points of P.
- Cluster the tagged points using DBSCAN.



Areas missing from segmentation

The 2D segmentation tends to miss the **top**, **bottom**, and **back** of the wheels. On average, only about 70% of the wheels are identified. This must be optimized to capture more area.

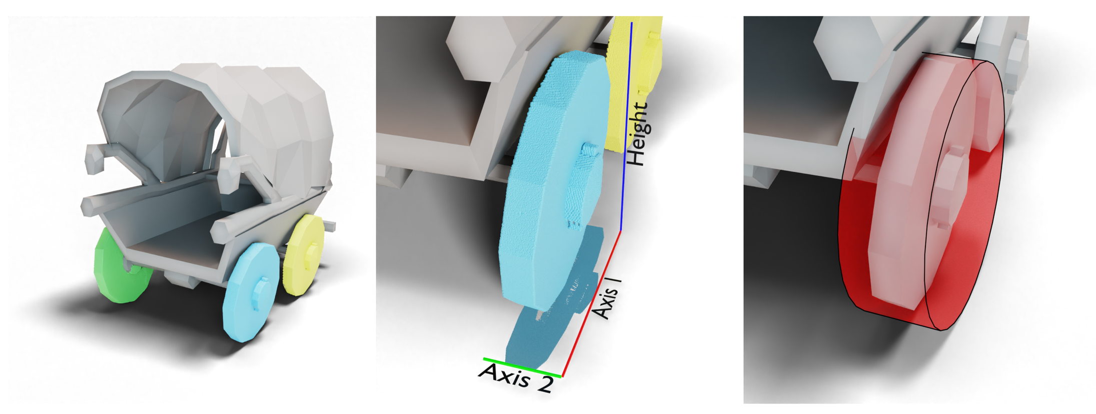


Cylinder Initialization

Cylinders perfectly capture all the data that should be optimized:
- The **inside** of the cylinder defines the **vertices** of each wheel.
- The **axis** of the cylinder defines the axis of rotation of joints.

They are initialized using the point cloud:
- Save the height $\mathcal{H}$ of the points as an axis-aligned dimension.
- Project the point cloud into 2D, then find its two principal axes.
- Identify the axis $\mathcal{X}$ which is most similar in length to $\mathcal{H}$.

Axis $\mathcal{X}$ determines the diameter of the cylinder, the other one determines the depth and the orientation. The position is equivalent to the center of the bounding box.



Parameter Optimization

CMA-ES is used to optimize the rig by performing rigid body simulation rollouts.

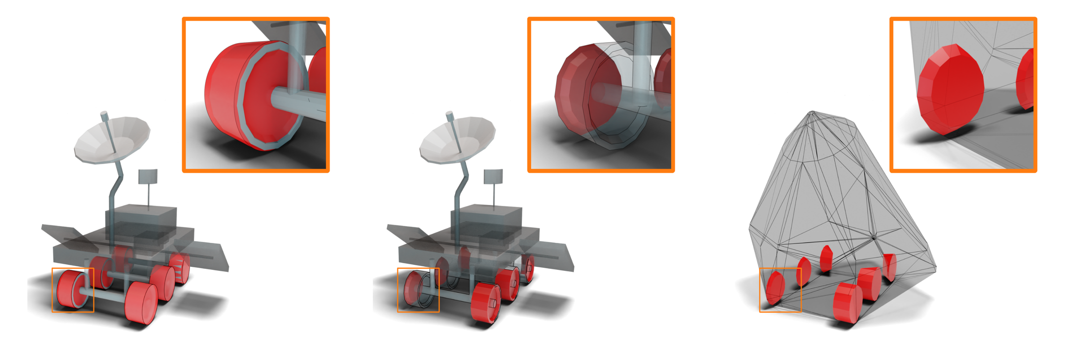
For the rigid body simulation:
- Any vertex in a cylinder is part of a wheel.
- All other vertices make up the chassis.
- The convex hull of each group define the collision proxy.
- The cylinder axes and the convex hull centers define the joints.

The quality is evaluated on these criteria:
- How far did the vehicle travel?
- Are the volumes of the convex hull and cylinder similar?
- How many border loops did the intersection process create?
- Is the current cylinder similar to the initial one? (MSE)

	Wheel Count		Segmentation		Optimization	
Model	Ground Truth	Created	True Positive	False Positive	True Positive	False Positive
Bicycle	2	2	77.6%	10.6%	65.7%	13.9%
Bulldozer	4	4	71.7%	0.0%	100.0%	0.0%
Bus	4	4	72.4%	0.6%	100.0%	0.0%
Carriage	4	4	83.3%	0.2%	100.0%	0.0%
Cement mixer	10	6	74.5%	1.5%	80.2%	0.1%
Old pickup	4	4	94.0%	5.3%	100.0%	1.8%
Racecar	4	4	60.7%	1.3%	100.0%	3.0%
Rover	6	6	94.0%	5.2%	100.0%	0.0%
Scooter	2	2	71.7%	0.2%	50.6%	1.7%
Suspension	4	4	60.0%	3.5%	100.0%	2.5%
Taxi	4	4	60.6%	4.3%	100.0%	2.0%
Tricycle	3	3	78.3%	14.8%	87.7%	6.5%
Truck	10	10	68.1%	0.9%	100.0%	0.0%
		Average	**70.2%**	**3.3%**	**91.1%**	**2.4%**

The issue of cylinders as collision proxies

(Left) Cylinders are aligned with the correct axis of rotation. They will roll perfectly. But, the geometry inside the cylinder (middle) does not capture the entire wheel. **The good rolling behaviour is misaligned with each wheel's poor visual appearance.** (Right) The convex hull will directly cause poor rolling behaviour, fixing the misalignment of the cylinder proxies.

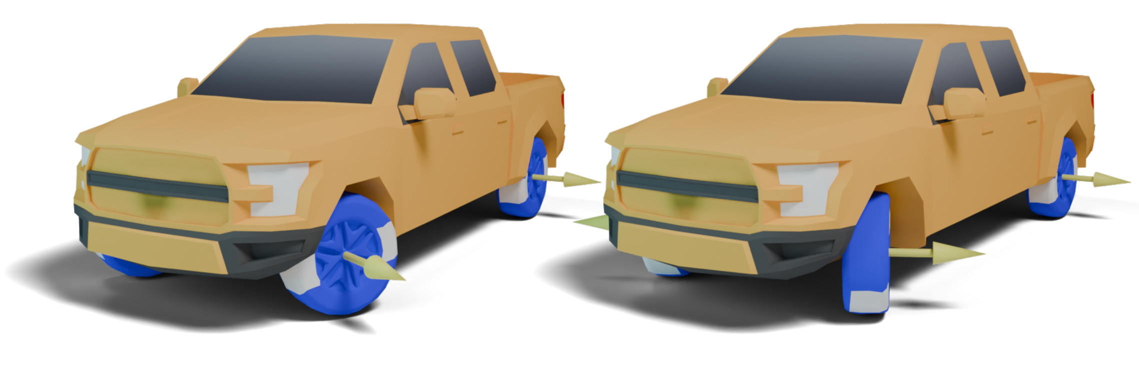


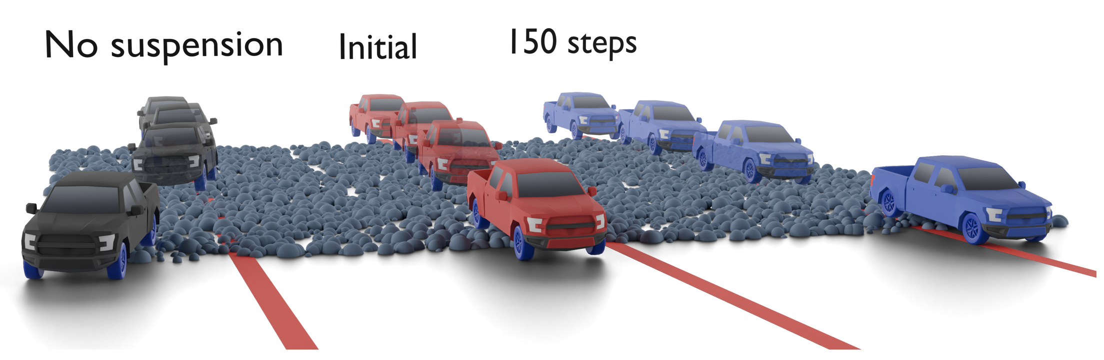
Steering and Suspension

The pipeline not limited to straight motion:

Steering: prompt GLIP for the "front of the vehicle"

Suspension: drive the optimized vehicle over rough terrain. The new quality criteria are:
- How straight is the vehicle driving?
- How much is the chassis colliding with the ground?





Reference

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