

# Optimum-J

## A Simulation Based Optimization for Vehicle Suspensions

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In this presentation, the various components of a suspension are color coded. The convention is as follows:

Shocks are Green  
A-Arms/Wishbones are Blue  
Toelinks are Purple  
Pushrods are Red

Steering Racks are Cyan  
Rockers are Magenta  
Wheel/Tire is Black

### Introduction to Suspension Geometry

In passenger cars, the main purpose of a suspension is to absorb road inputs and make the ride as smooth and as comfortable as possible. In race cars, a suspension's primary purpose is to maximize the force out of the tires over a wide range of driving conditions, which means optimizing the motion profile of the wheel as it travels through space. In most racecars, a suspension consists of 7 moving components, a Shock, two A-Arms, a Toelink, a Pushrod, a Steering Rack, and a Rocker

### Challenges of Suspension Design

There are many challenges of designing a suspension, a few are listed below:

- Nonlinear optimization problem of 36 independent variables
- Suspension components must not interfere with each other
- Suspension must have a motion profile that gives desired characteristics
- Suspension must integrate cleanly with the rest of the chassis

Designing a good suspension geometry has huge implications for the overall performance and packaging for the car. Being able to explore many possible candidate designs in short amounts of time is very powerful

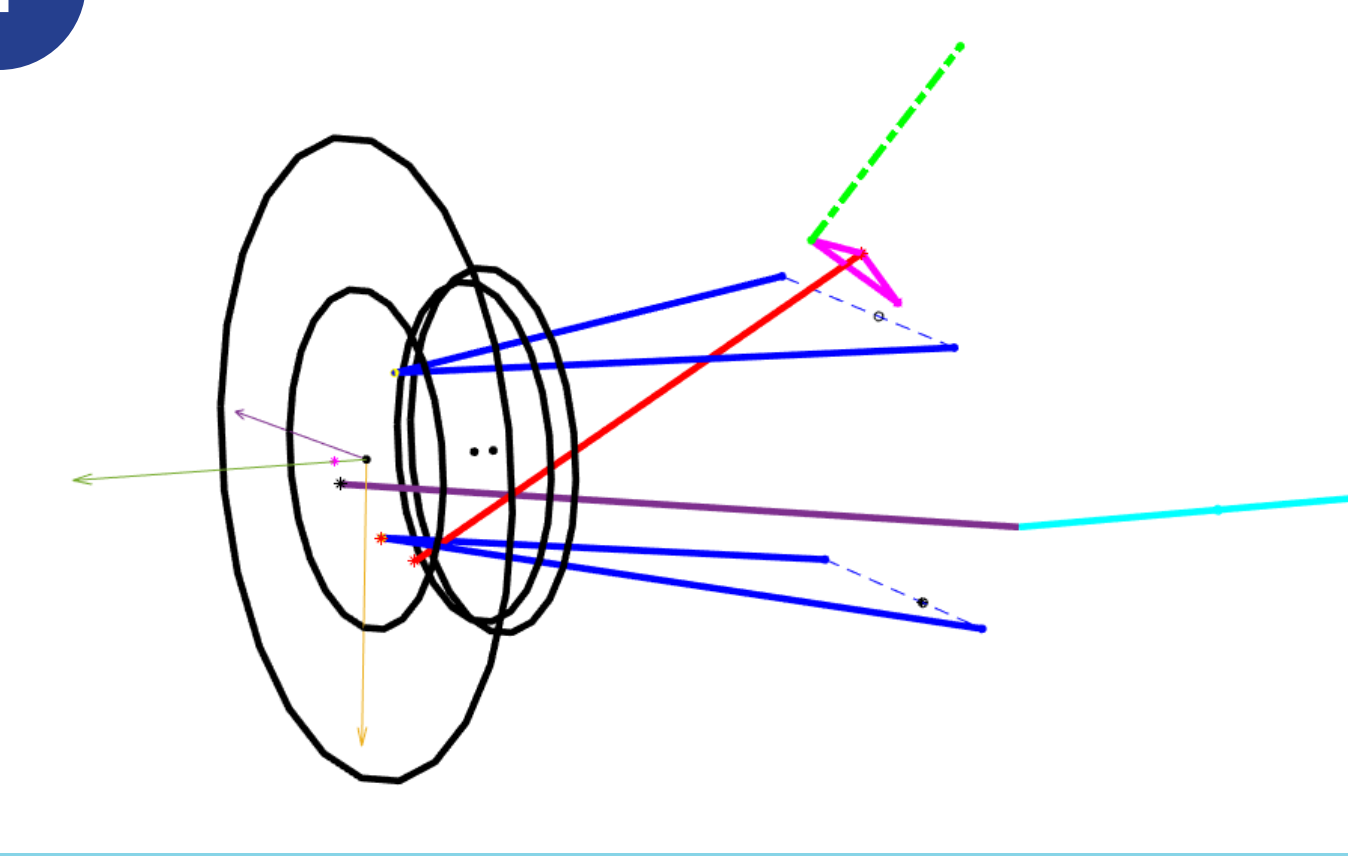
### Optimum-J Details

The purpose of Optimum-J is to expedite the suspension design process. It allows engineers to quickly explore generated designs for suspension that meet strict packaging and positional constraints that maintain desired high level characteristics.

This project was written completely from scratch and was implemented in MATLAB. It uses an object oriented forward kinematic simulation of a suspension through space and feeds the outputs of this simulation into an optimization function. The optimization function iteratively moves mounting points for the suspension components until it finds a local minimum in fitness. Because this is a very high dimensional problem, there exist many local minimum over the state space. As such, the program automatically re-seeds upon finding a local minimum to better explore the state space.

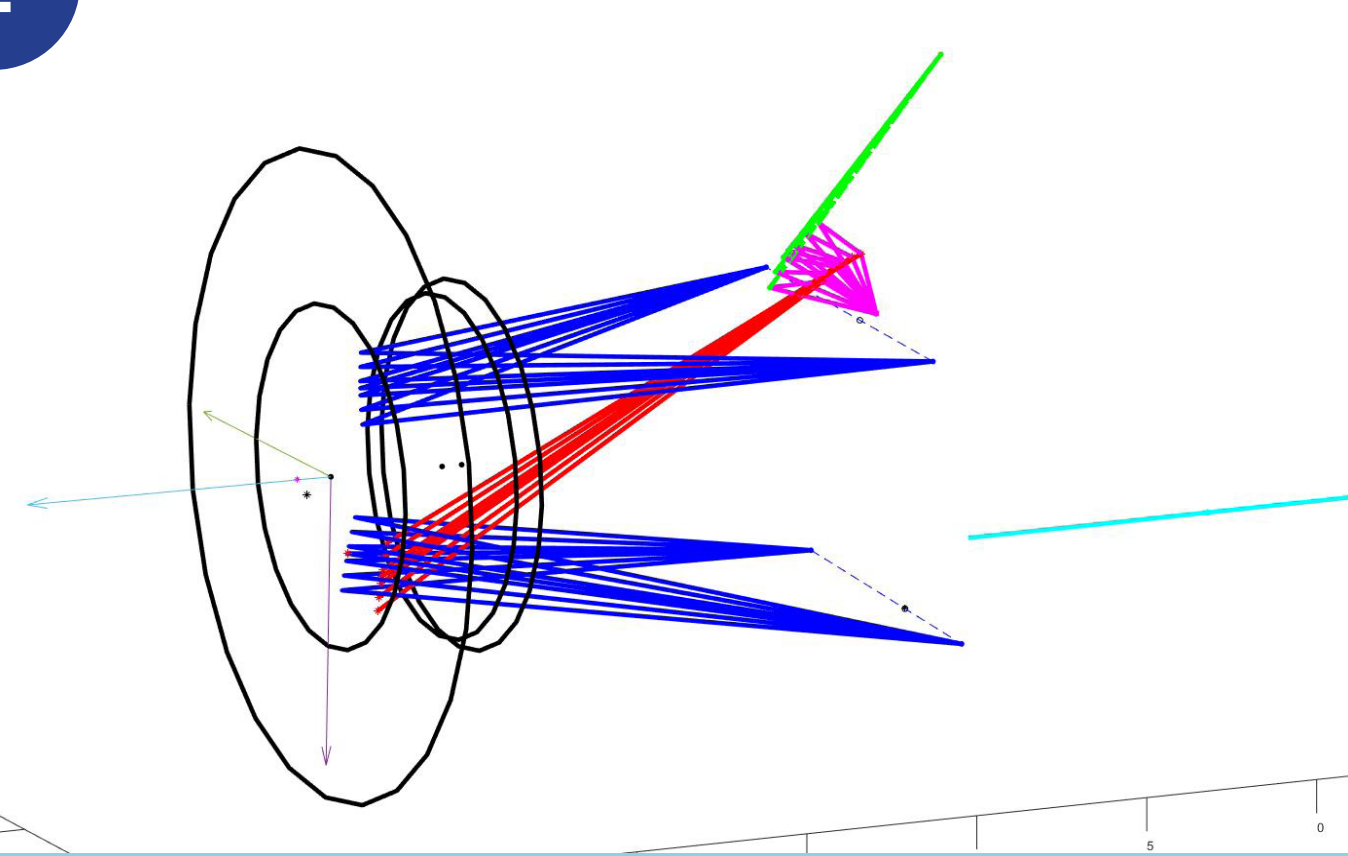
ActionGroup.m  
Manages simulations

**1**



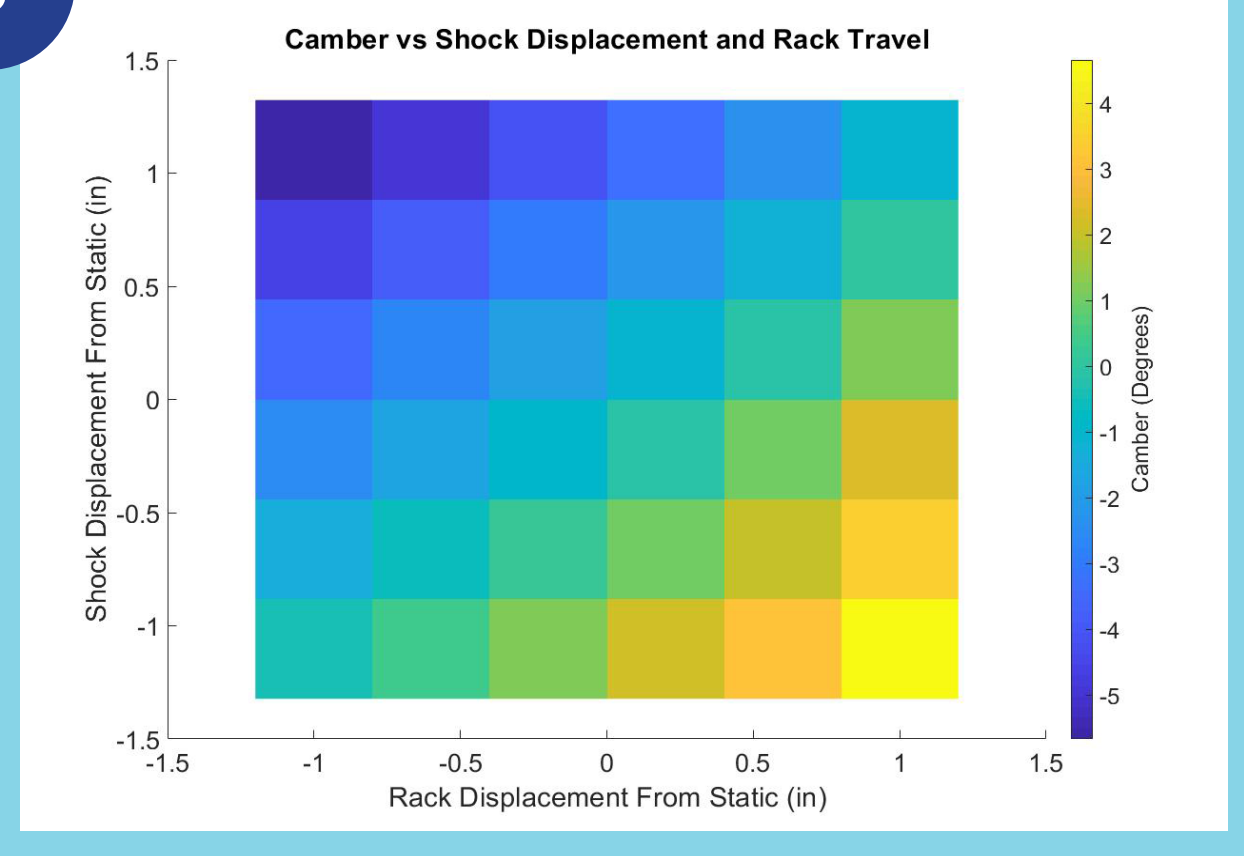
Load in initial conditions, desired characteristics, and geometric restrictions. Initialize component objects in 3d simulation.

**2**



Solve for the motion profile of the wheel over various shock and rack positions. This is done by changing displacement in the Shock or Steering Rack, and then using vector functions and trigonometry to calculate the resultant position of suspension members

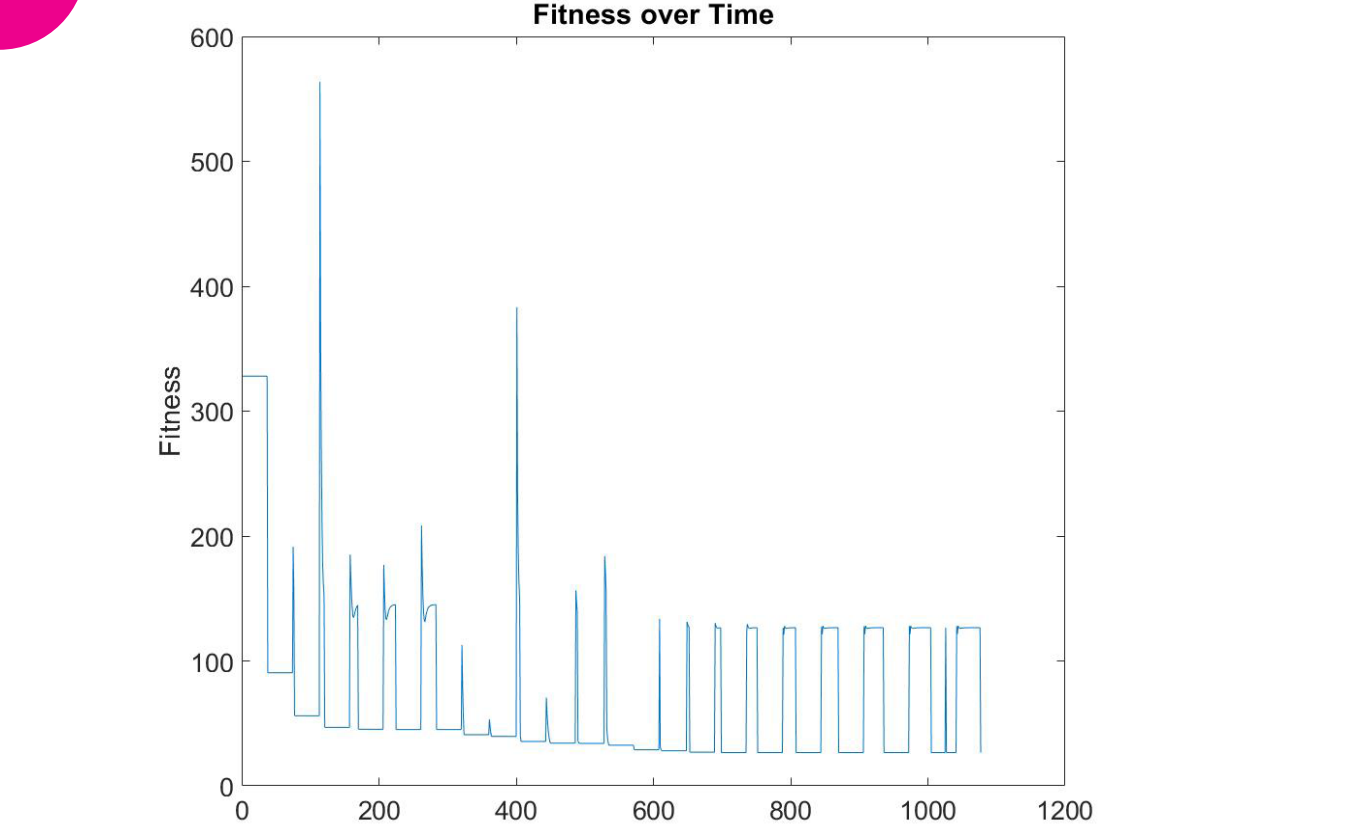
**3**



Calculate relevant characteristics associated with motion profile of wheel through travel. Above is a plot of camber gain over the motion profile of the wheel. Other things calculated are the roll centers, and bump steer.

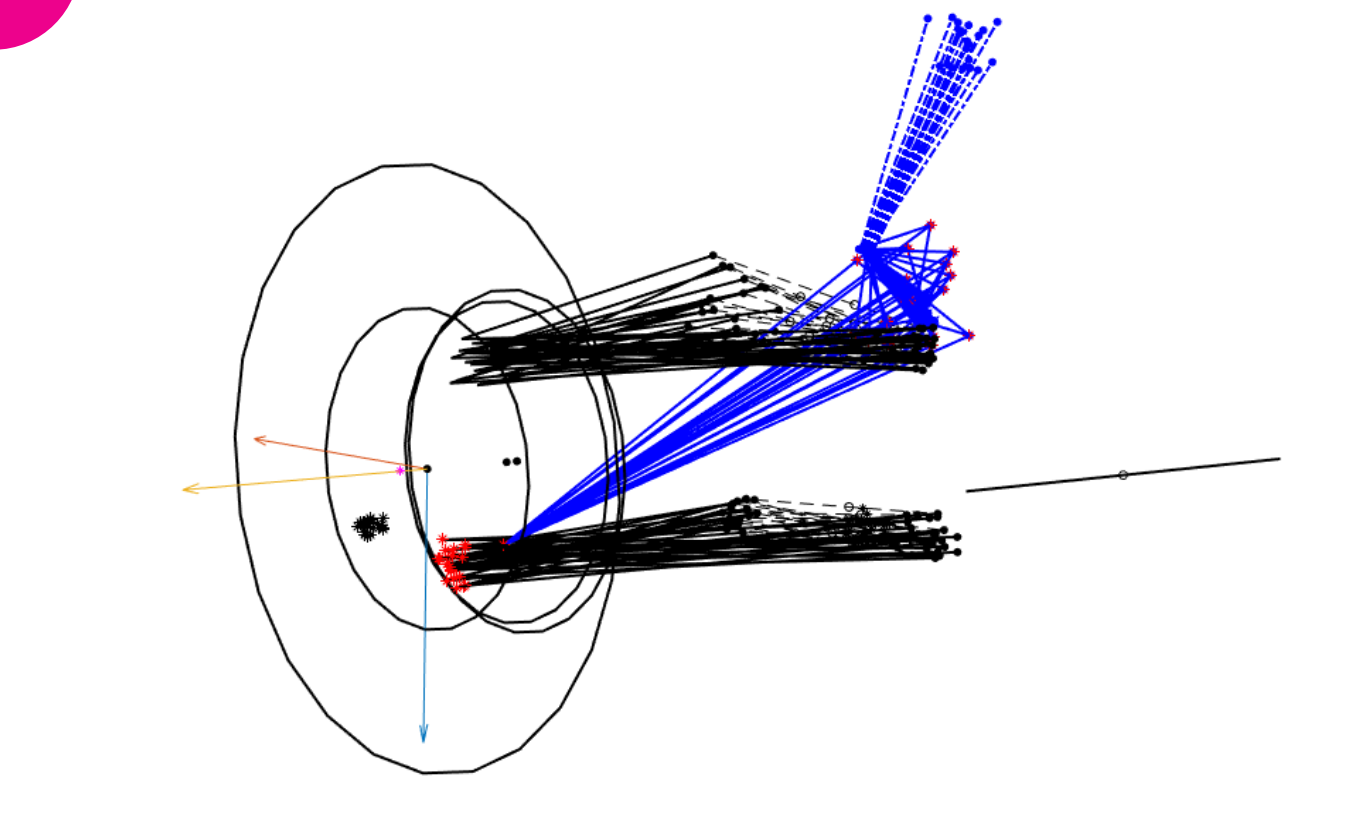
Optimizer.m  
Manages series of simulations

**4**



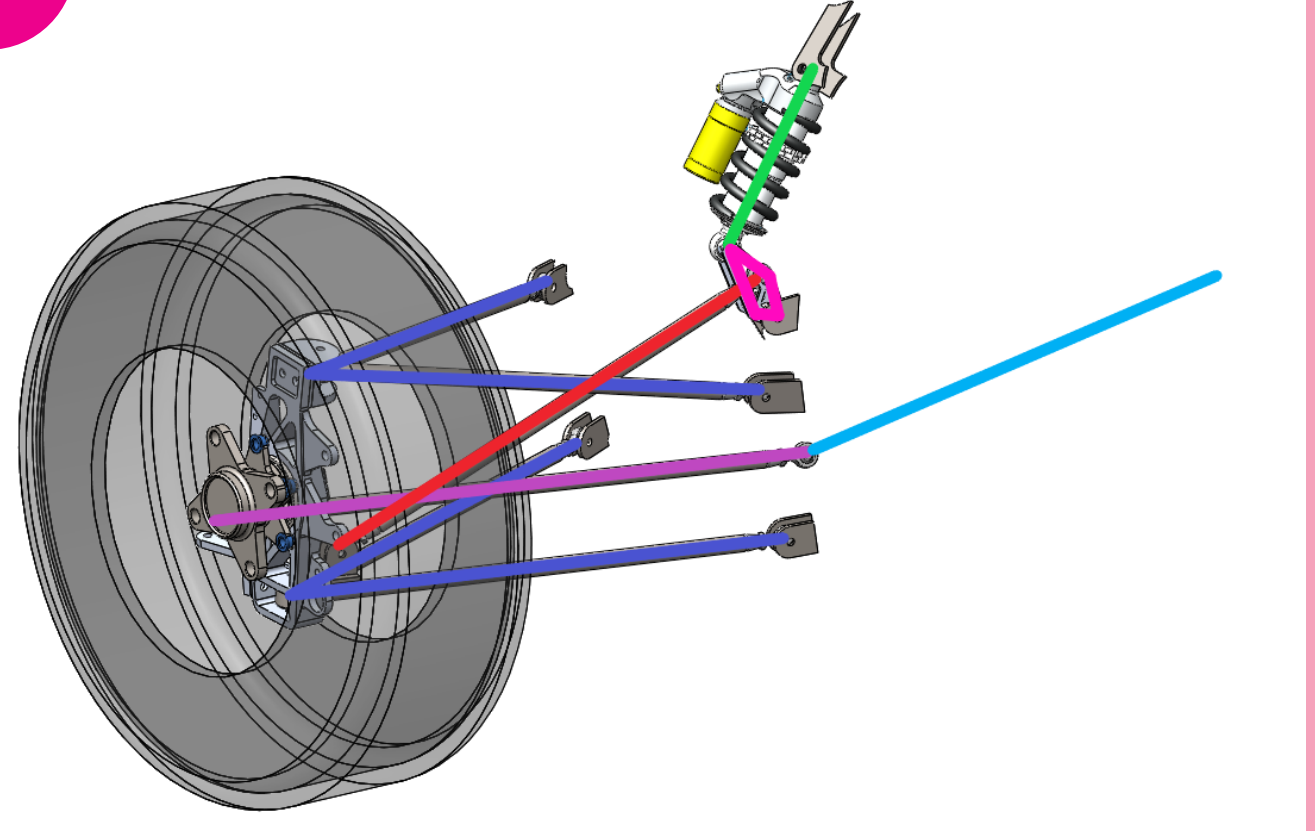
Compare relevant characteristics to desired characteristics from input and compute a fitness score. (Lower fitness is more desirable). Weights for each characteristic is also provided as an input. Use fmincon to find a local minimum in the fitness function while maintaining initial geometric restrictions

**5**



Re-seed the suspension within the geometric restraint areas and rerun step 4. This step is required because the fitness landscape is highly irregular and nonlinear, and as such, multiple random seeds allows for a more thorough searching of the fitness landscape. The best suspension is chosen from here

**6**



Compress suspension into 1x36 vector and import coordinates into Solidworks design table. Check packaging and move forward if deemed fit. Using this tool can reduce the suspension geometry design time by dozens of hours.

