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Virtual Prototyping

# Design Optimization Technique for Mechanical System


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Mechanical Dynamics

# Optimization Technology

- Optimization of complex phenomenon

  Concept of Multidisciplinary Optimization

- Development of New Methodology

  Genetic Algorithms

  Response Surface Methodology

  e.g. Crash Optimization by RSM

# Background

## Optimization for Structural Design

- Objective Function: Structural Weight
- Component, Stiffness, Crash

## Optimization for Fluid Dynamics Design

- Objective Function: Lift, Drag
- Wing Section Design, Blade Design

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# Background

## Optimization for Mechanical System Design

Few Achievement

- Many design parameters
- Strong nonlinearity
- Difficult to define objective function

In order to clarify the benefit of design optimization technique,

we conducted case study of suspension design.

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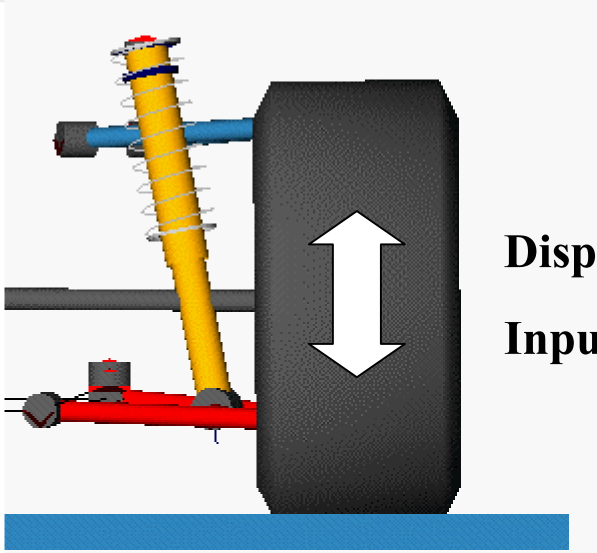
# Suspension Design

<Analysis 1>

Vertical Motion ±100mm

Evaluate Toe Characteristic



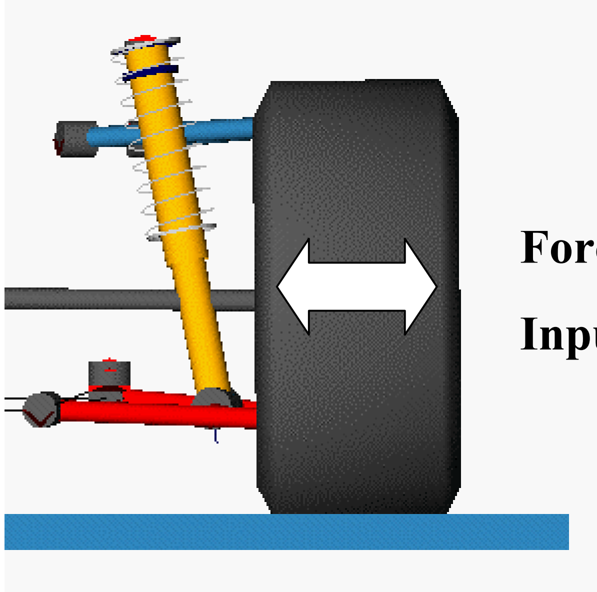
Displacement

Input ±100mm

<Analysis 2>

Static lateral Force ±2,000N

Evaluate Lateral Stiffness



Force

Input ±2000N

# Suspension Design

## 20 Design Variables

**Geometry: 18 Variables**

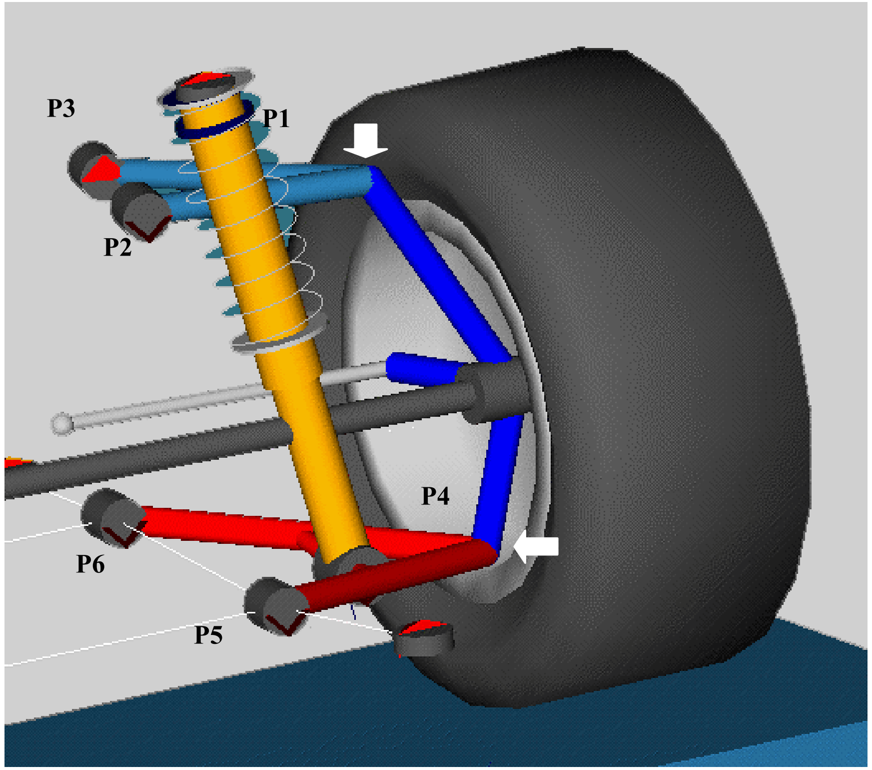
P1(x,y,z)-P6(x,y,z)

Original ±100mm

**Bush : 2 variables**

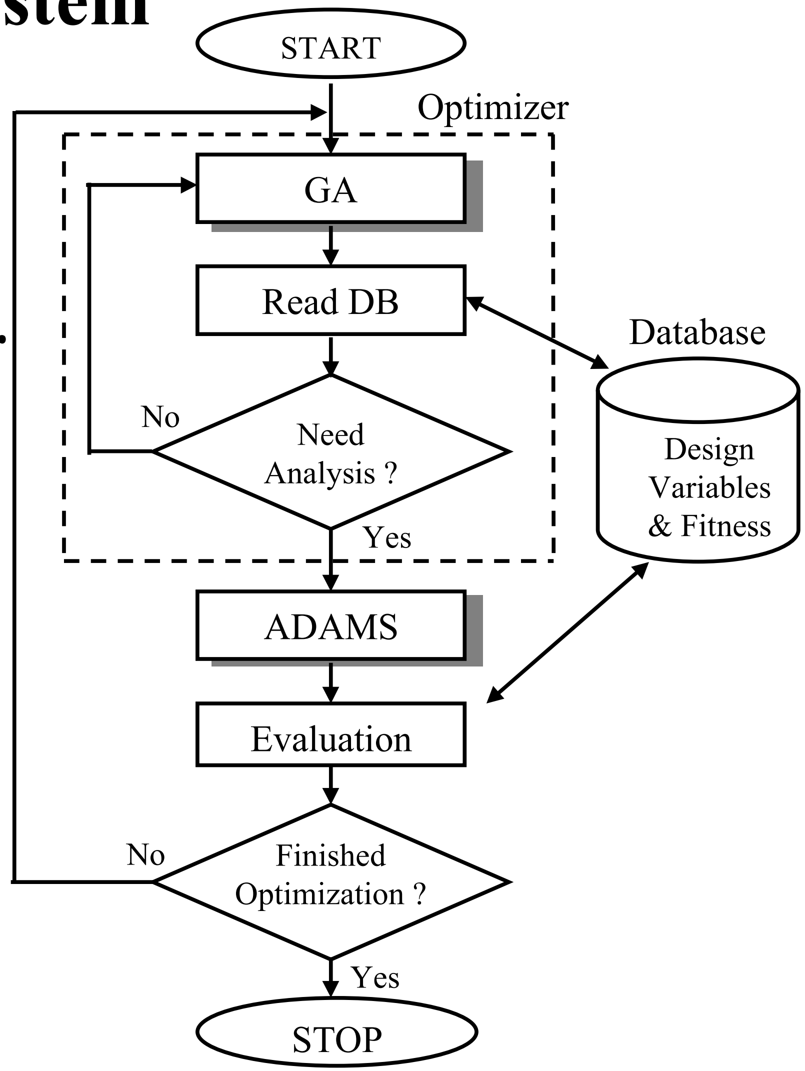
Bush_upr/Bush_lwr

40%-200% of original



# Developed Optimization System

- **Optimization Algorithm**
  - **By Genetic Algorithms (GA)**
- **Interface with ADAMS/Solver**
  - **Generate ADAMS Solver file using GA information**
  - **Evaluate the request data file and save data into database**
- **Skip the ADAMS simulation if conducted previously**



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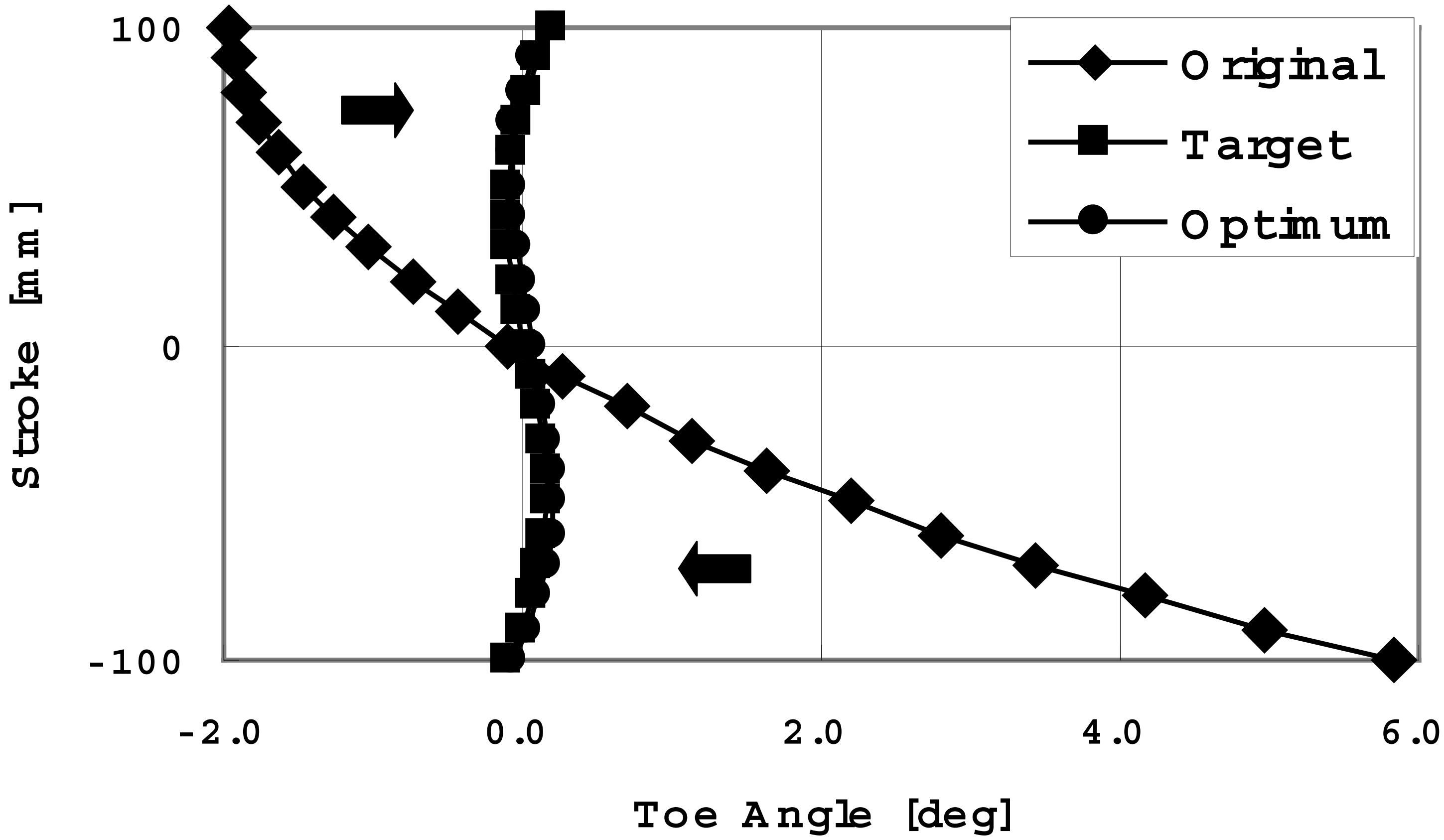
Case Study

- *Optimized Toe Angle*
- *Target Toe : From Prof. Abe's Data*

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## Case Study

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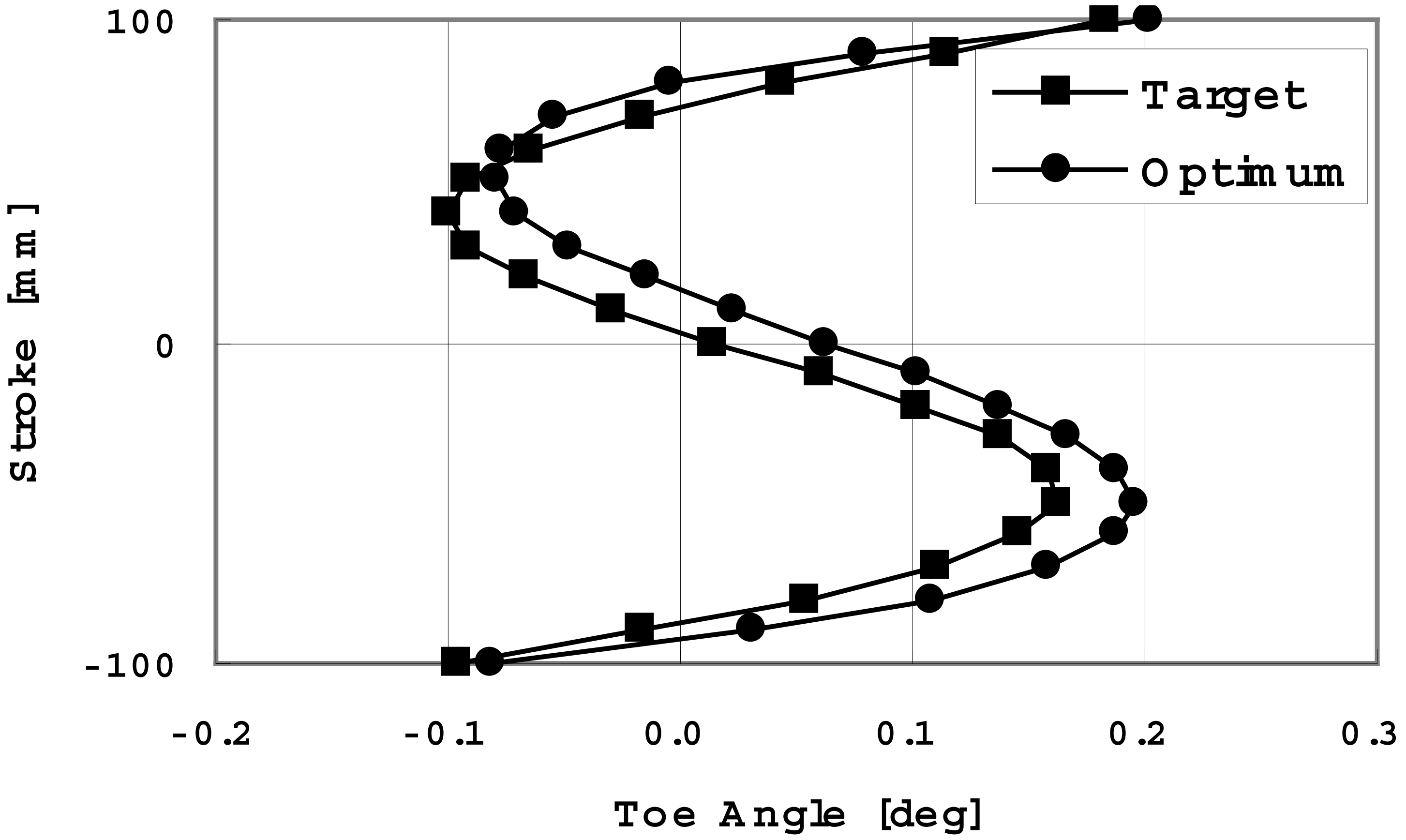


***Maximum Error=0.05 deg after 3000 analyses***

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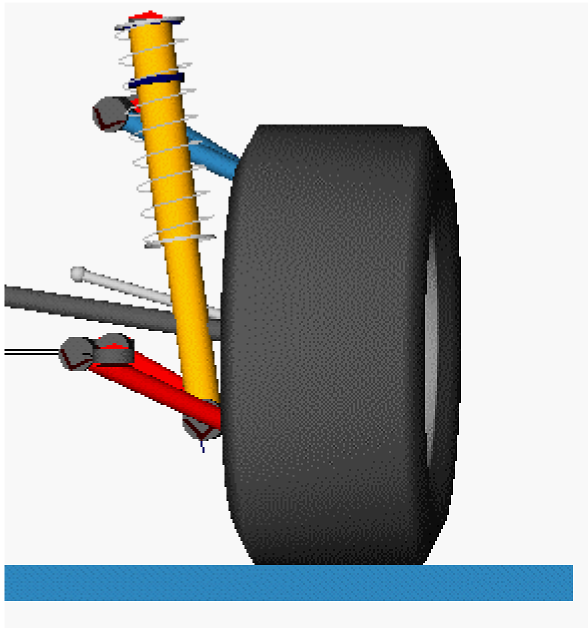
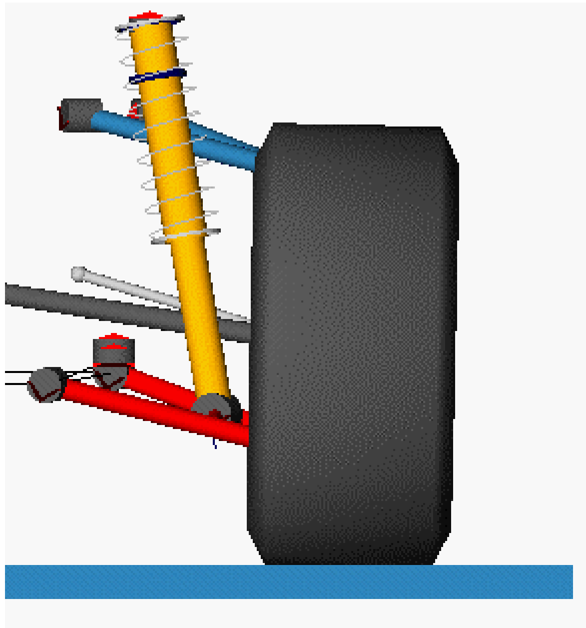
# Case Study

- *Optimized Toe Angle*



***Original Model***



***Optimized Model***

***Comparison Toe Angle at Vertical Displacement -100mm***

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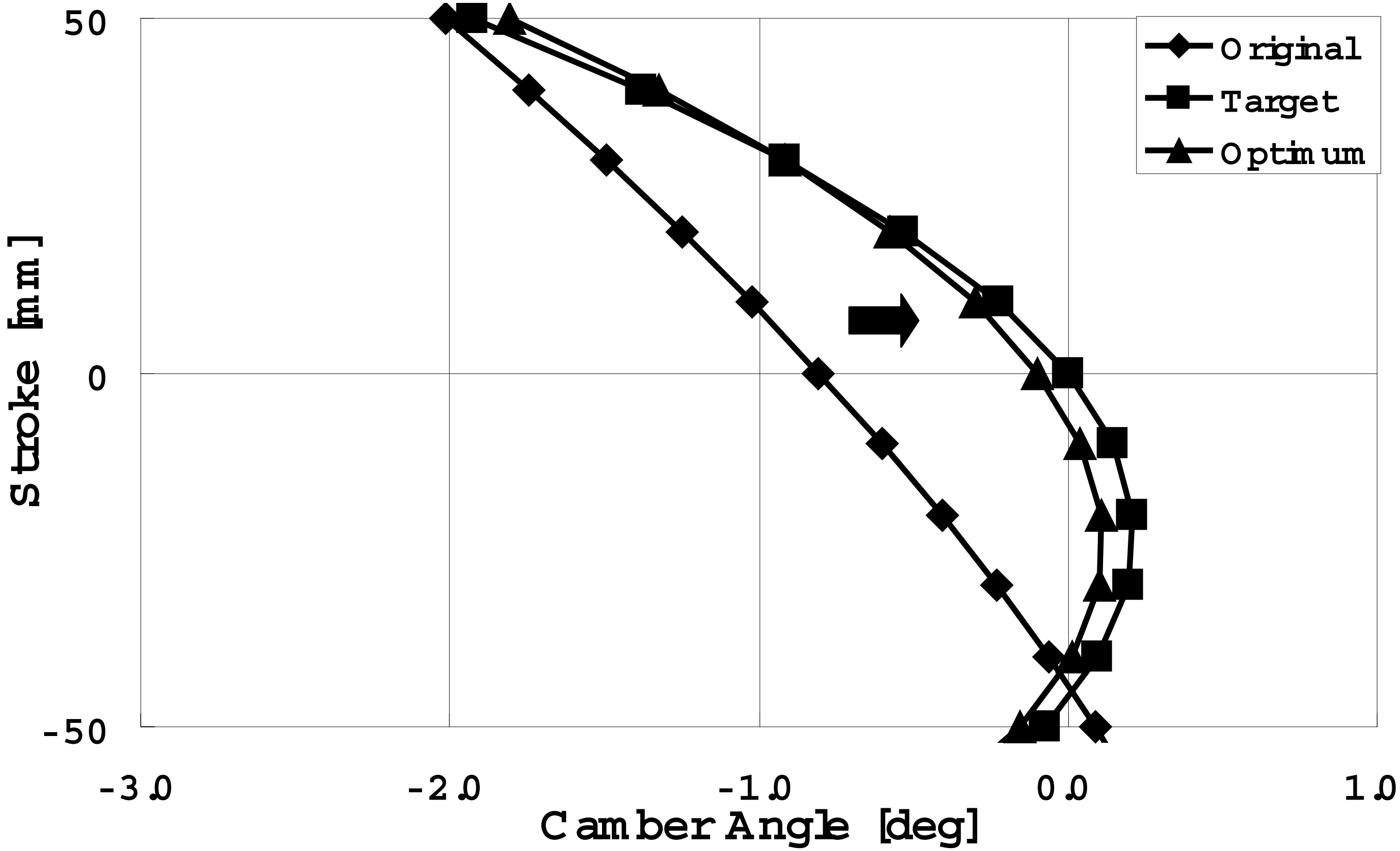
## Case Study

- *Optimized Camber Angle*
- *Target Camber : From Prof. Abe's Data*




***Maximum Error=0.05 deg after 3000 analyses***

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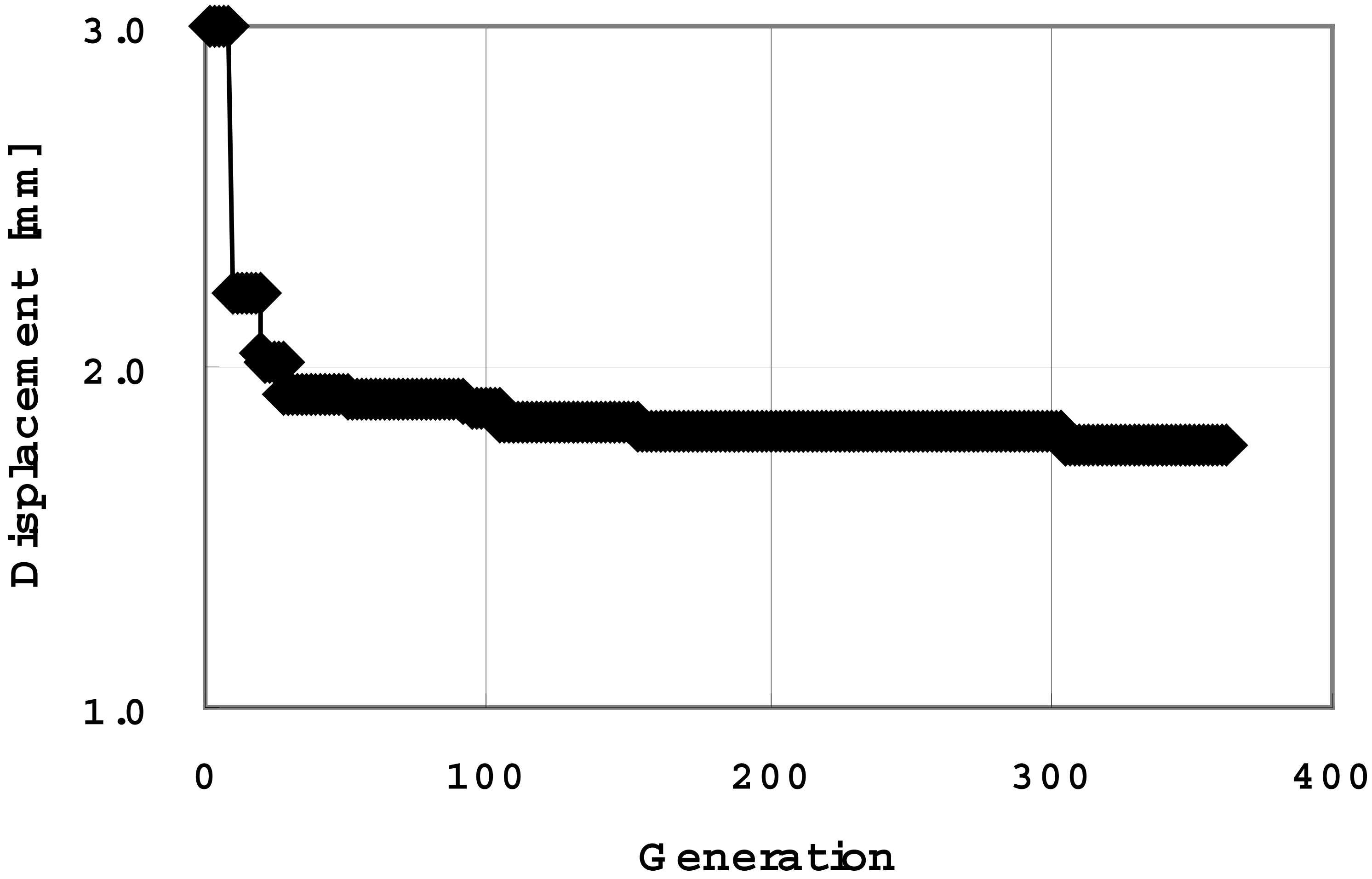
## Case Study

- ***Minimized Lateral Displacement***




***Constraint: Toe Error less than 0.1 deg***

***Objective Function: Maximize Lateral Stiffness***

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# Conclusion

1)We have developed optimization system based on Genetic Algorithms for Mechanical System Design.

2)Using this system, we have optimized suspension system. Through the case study, the validity of the system was clarified.

3) We will apply optimization technique for complex systems.

4)Design optimization technique will supply outstanding contribution for the mechanical system engineering.

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# Comparison of Gradient Search with Genetic Algorithms for Nose Landing Gear

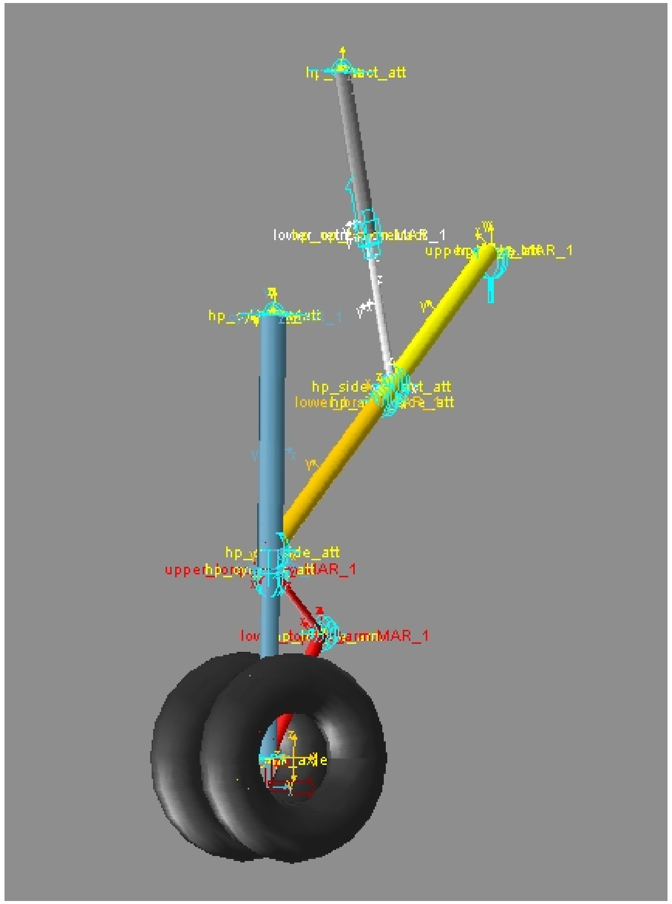
Patrick McNally, MDI

Mechanical Dynamics

# Comparison of Genetic Algorithms with Gradient Search for Landing Gear Optimization

- Optimize geometric layout
- Maximize retraction efficiency
  - used in actuator sizing
  - ensures constant demand on hydraulic system
- Optimization constraints to ensure full retraction and avoid lockup conditions

# Nose Landing Gear for Optimization



- Conventional aft-deploying nose gear with collapsing brace
- Rigid Model only
- Design Variables:
  - 20 geometry variables
  - P1(x,y) -> P10(x,y)

# Retraction Efficiency Function

$$\left|\max\left(F_R\right)\cdot\theta_{\max}\right| - \int_{\theta_0}^{\theta_{\max}} F_R(\theta)\cdot d\theta$$

Where

$F_R$ ~ retraction force

$\theta$ ~ retraction angle

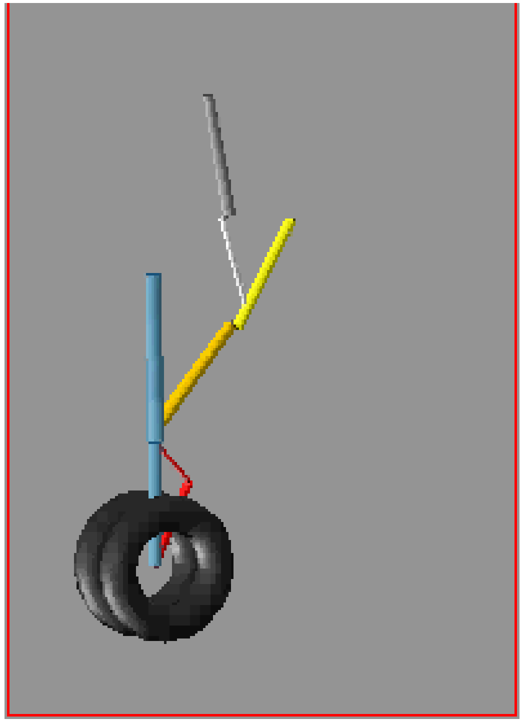
Rewritten as time function:

$$\left|\max\left(F_R\right)\cdot\theta_{\max}\right| - \int_{t_0}^{t_{\max}} F_R(\theta)\cdot\dot{\theta}\cdot dt$$

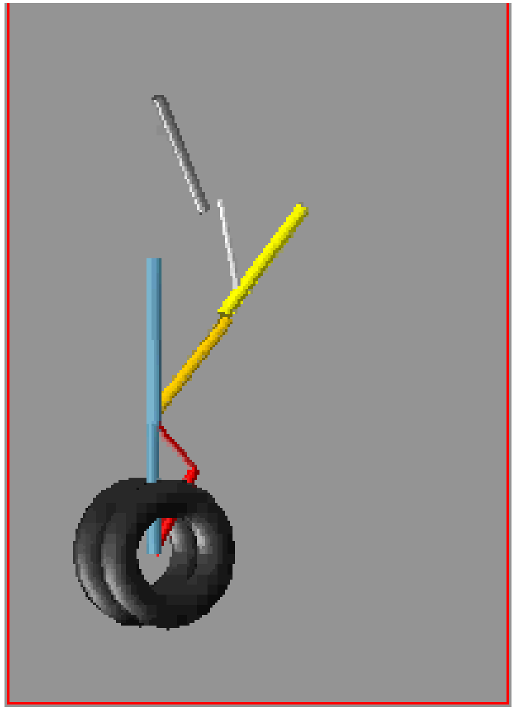
Solver language:

- fun = (MAX( ABS(MOTION(.nosegear.MOT1, 0, 1, 0)) , 0 )*ABS(AZ( .nosegear.cylinder.MAR1100, .nosegear.PAR99.MAR_1))- DIF(.nosegear.DIFF_1))
- DIFF_1=MOTION(.nosegear.MOT1, 0, 1, 0) *VZ(.nosegear.lower_retraction.MAR507, .nosegear.upper_retraction.MAR407)

# Initial Results Show Different Optimums Found through Different Searches

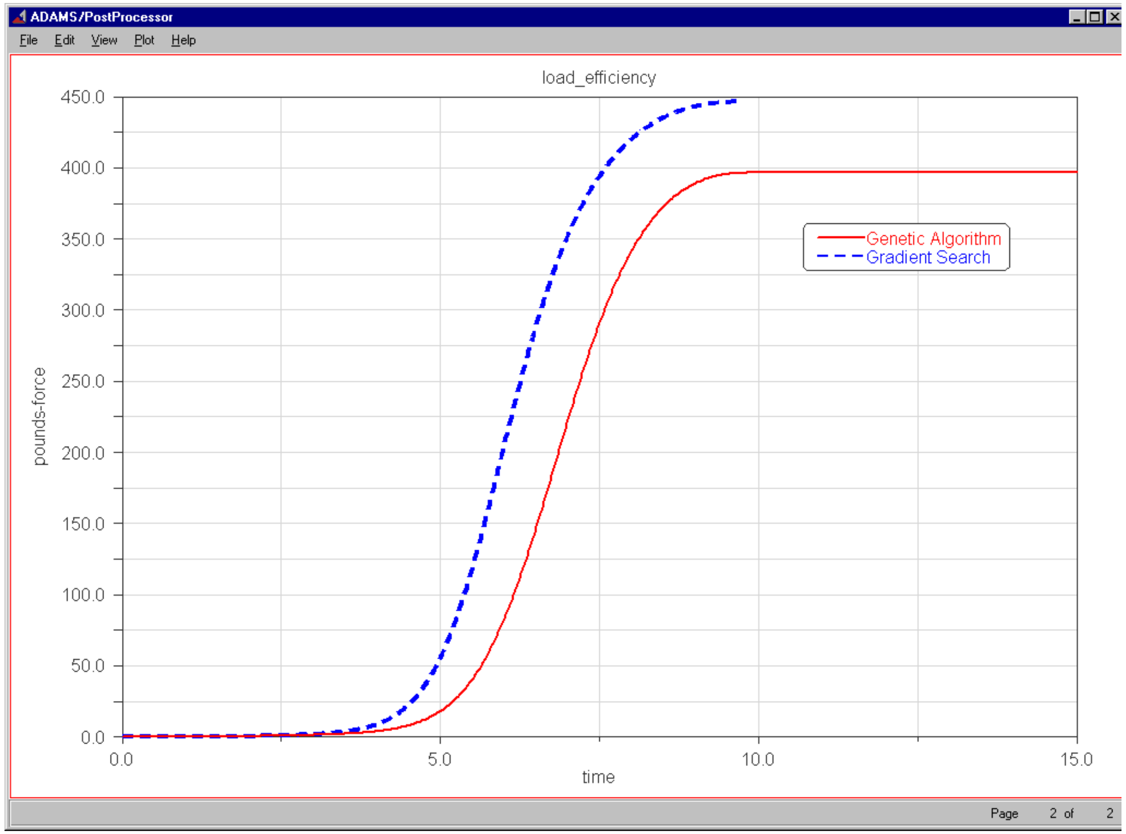


Gradient Search Optimization



Genetic Algorithm Optimization

# Initial Results Show Gradient Search Found Optimal More Quickly

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# Conclusions for Landing Gear Problem

- ADAMS architecture allows easy comparison between design study and optimization methods
- Simplified problem (kinematic/planar) means gradient search may find global optimum
- Hydraulic system effects to be added to understand effect on optimal
- Main gear (nonplanar) mechanism to explore effects of more complex layouts

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