Real-Time Dynamic Simulation Tool

for Driving Simulator

FBK Solver Team

윤 덕 진

RecurDyn™
It just works better

실시간 차량 동적 거동 해석 툴

- Driving simulator
- Multi-Body Dynamics Model
- Quick solution

- Pre-processor Tool
- Simulation Tool

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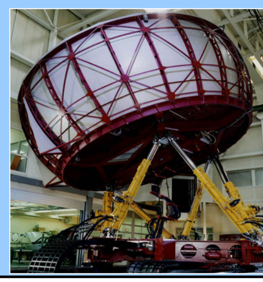
해외 주요 Driving Simulator

NADS (NHTSA)	FORD
 • 93년 ~ 현재	 • 01년 개발 완료
RENAULT	**BENZ**
 • 99년 개발 완료	 • 95년 1차 개발 • 99년 2차 개발 • 현재 3차 개발 중

Hyundai Driving Simulator

신기술/시스템 개발

실차 시험이 어려운 각종 시험 수행

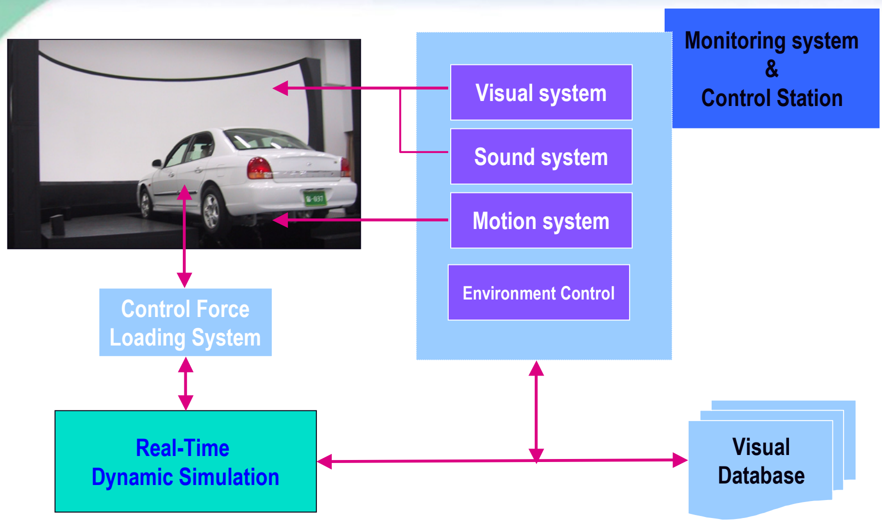
- 가상현실을 이용한 차량 시험
- ITS 관련 시스템 평가/시험
- 조이스틱 차량 등 미래차량 평가/시험
- 향후 차량 성능 정량화

운전자 인자연구

차량 상품성/편의성 증가위한 시험

- 노약자/장애인 운전형태 연구
- 운전자 감성품질 평가
- 각종 도로설계 및 관련법규 재정시 평가도구

Driving Simulator Architecture



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Vehicle Models in Driving Simulator

Parametric Model

- Based on Lumped model
- kinematics characteristics : parametric model(equation or map)

→ 기존의 차량모델 특성을 시뮬레이션, 구현 용이

- Ford Motors
- Renault Motors

Multi-Body Model

- Based on multi-body model
- kinematics characteristics : dynamic simulation

→ 새로운 차량모델 특성을 시뮬레이션, 구현 어려움

- NHTSA(NADS)
- IOWA
- Hyundai Motors

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Dynamic Model

Front suspension	MacPherson
Rear suspension	Multi 3 link
Tire	Fiala
Drive Train	Engine, Auto Transmission, Differential gear
Steering	Coefficient
Brake	Pressure map
Stabilizer bar	Coefficient

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MacPherson Strut Suspension

Body	LCA Knuckle Strut	Mass Inertia CM Position
Hard Points	Translation joint (Chassis to Rack) Revolute joint (Chassis to LCA) Ball joint (Chassis to Strut) Translational joint (Strut to Knuckle) Distance Cut joint (Knuckle to rack) Ball Cut joint (LCA to knuckle)	Joint Position
Spring	Knuckle to chassis	i,j Position K, C Free length

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Multi 3 Link Suspension

Body	Trailing Arm Axle	Mass Inertia CM Position
Hard Points	Left Ball joint (Chassis to Trailing Arm) Revolute joint (Trailing Arm to Left Axle) Revolute joint (Left Axle to Right Axle) Revolute joint (Right Axle to Right Trailing Arm) Spherical cut joint (Chassis to Right Trailing Arm) Distance cut joint (Chassis to Left Trailing Arm)	Joint Position
Spring	Chassis to axle	i,j Position K, C Free length

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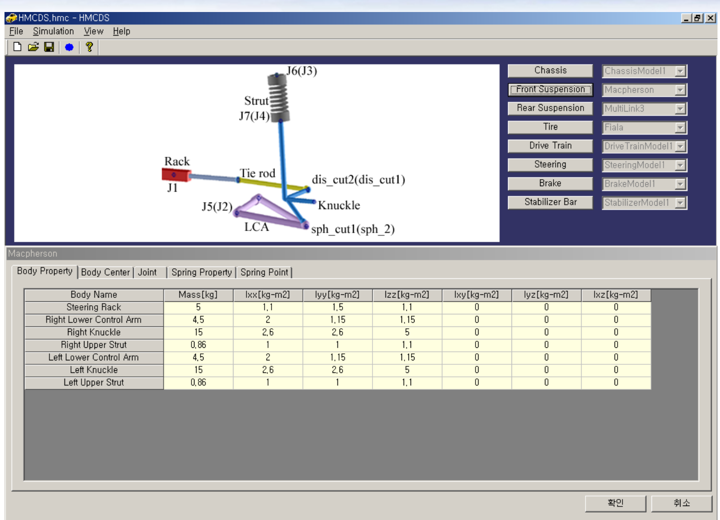
Pre-processor



Body Name	Mass[kg]	Ixx[kg-m2]	Iyy[kg-m2]	Izz[kg-m2]	Ixy[kg-m2]	Iyz[kg-m2]	Ixz[kg-m2]
Steering Rack	5	1.1	1.5	1.1	0	0	0
Right Lower Control Arm	4.5	2	1.15	1.15	0	0	0
Right Knuckle	15	2.6	2.6	5	0	0	0
Right Upper Strut	0.86	1	1	1.1	0	0	0
Left Lower Control Arm	4.5	2	1.15	1.15	0	0	0
Left Knuckle	15	2.6	2.6	5	0	0	0
Left Upper Strut	0.86	1	1	1.1	0	0	0

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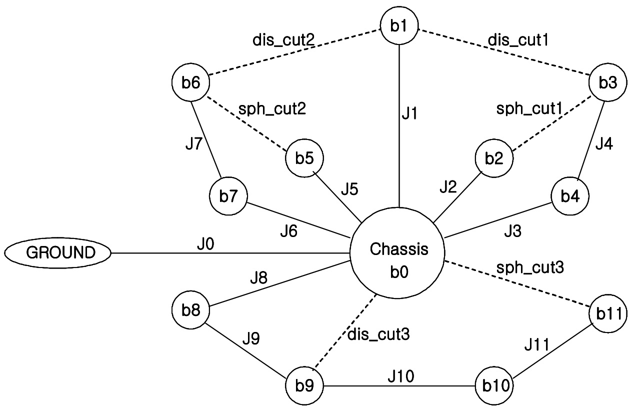
동적 거동 해석 방법

➢차량 시스템의 그래프 표현

- ➢**Joint** 와 **Cut joint**로 상대 좌표의 수와 구속 조건의 수 결정

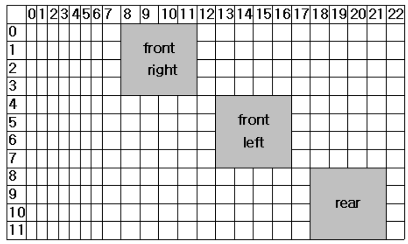


차량 시스템의 자유도

Relative coordinate		Constraint condition of cut joint	
Free Joint [1]	6x1 = 6	Spherical Cut Joint [3]	3x3 = 9
Translational Joint [3]	1x3 = 3		
Revolute Joint [5]	1x5 = 5	Distance Cut Joint [3]	1x3 = 3
Ball Joint [3]	3x3 = 9		
23		12	

동적 거동 해석 방법

- 위치와 속도 해석
  - **Independent coordinate, Dependent coordinate**
  - **Coordinate partitioning**



  - 위치 해석 방정식 $\boldsymbol{\Phi}(\mathbf{u},\mathbf{v})=0\,,\qquad \boldsymbol{\Phi}_{\mathbf{u}}\Delta\mathbf{u}=-\boldsymbol{\Phi}$
  - 속도 해석 방정식 $\dot{\boldsymbol{\Phi}}(\mathbf{q},\dot{\mathbf{u}},\dot{\mathbf{v}})=0\,,\qquad \boldsymbol{\Phi}_{\mathbf{u}}\Delta\dot{\mathbf{u}}=-\dot{\boldsymbol{\Phi}}$

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동적 거동 해석 방법

- 가속도 해석
  - **Holding System Matrix**
  - 가속도 해석 방정식

$$\begin{bmatrix} \hat{\mathbf{M}} & \boldsymbol{\Phi}_{\mathbf{q}}^{\mathbf{T}} \\ \boldsymbol{\Phi}_{\mathbf{q}} & 0 \end{bmatrix}\begin{bmatrix} \Delta\ddot{\mathbf{q}} \\ \Delta\lambda \end{bmatrix} = -\begin{bmatrix} \mathbf{F} \\ \ddot{\boldsymbol{\Phi}} \end{bmatrix}$$

- **Integration**
  - **Dynamic Model**
    - **2^{nd} order explicit integrator**
    - **Step size: 1msec**
  - **Drive Train Model**
    - **1^{st} order explicit integrator**
    - **Step size: 0.1msec**

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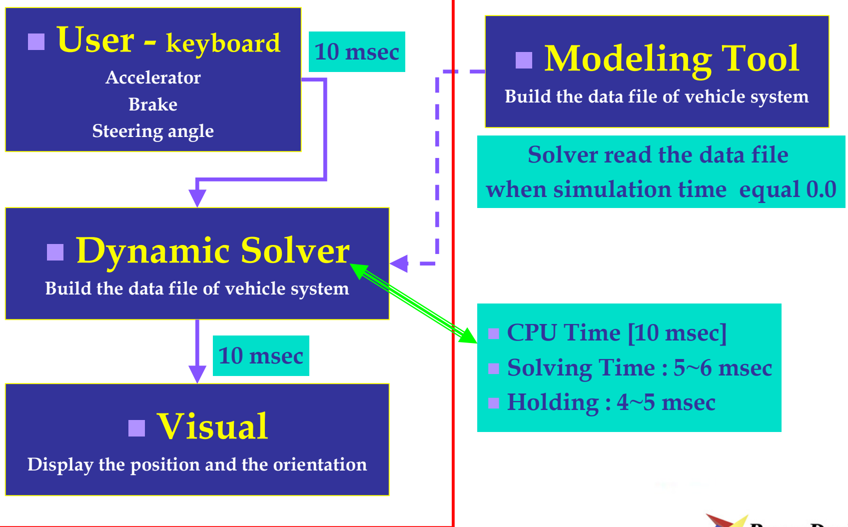
Simulation Tool



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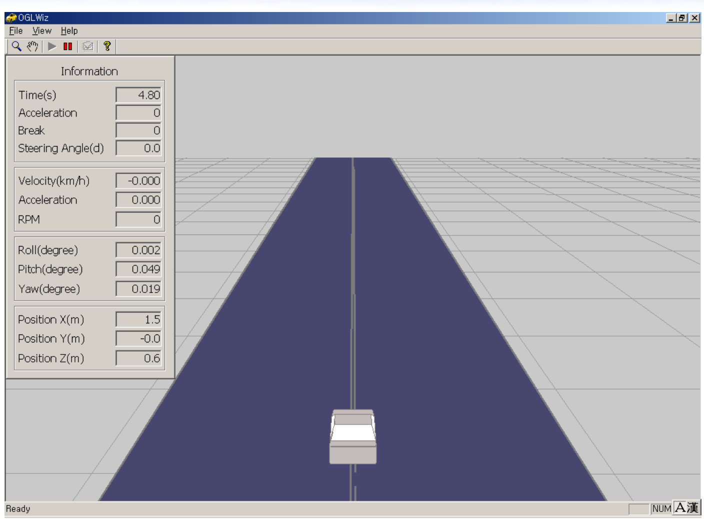
Simulation Tool



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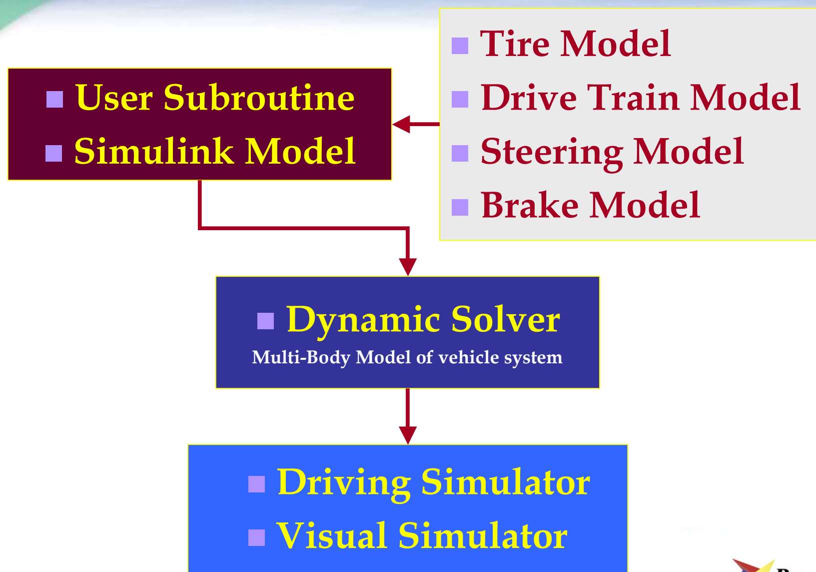
Application



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