



## A Survey of State-of-the-art Motion Platform Technology and Motion Cueing Algorithms

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2<sup>nd</sup> Motion Simulator Conference, 20.09.07



## Introduction

Motion Cueing Algorithm (MCA)


=

Motion Drive Algorithm (MDA)


=

Washout Algorithm (WA)


- „**Motion cueing**“ describes the presentation of visual, acoustic, vestibular and **haptic** information (cues) with the aim to resemble real movements in virtual environments



## Motion Platform Technology


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## Motion Platform History

### Early Flight Simulators

1900   1950 2000





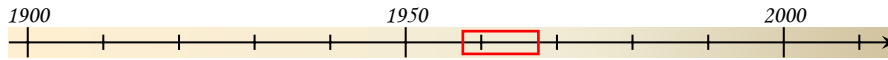


Photo in Airbus Training, Toulouse, of Antoinette Simulator - dated 1908


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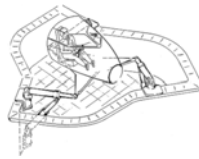
## Motion Platform History



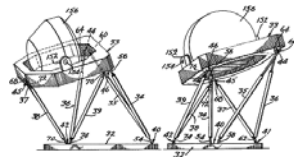
Gough Platform '54



C. Kappel '60s

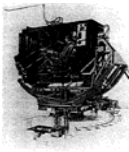
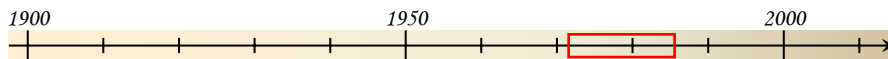


Stewart Platform '66



First Patent '67

## Motion Platform History



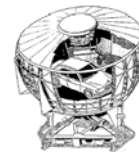
VW 70's



VTI I '84

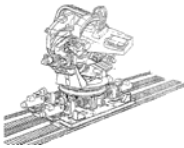
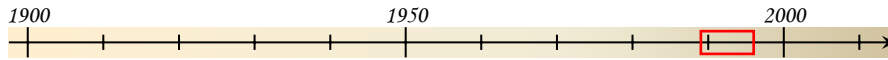


IFAS (IKK) '84



Daimler Benz '85

## Motion Platform History



Mazda '90



Trygg Hansa '91  
VTI II '02



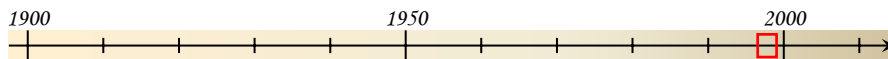
Daimler Benz '93



JARI '96

Ford VIRTTEX '94

## Motion Platform History



BMW ~'98/99



Renault '99

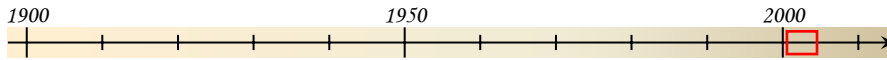


Nissan '99



IZVW '99

## Motion Platform History



Ford VIRRTEX  
new '01



IFAS MARS '01

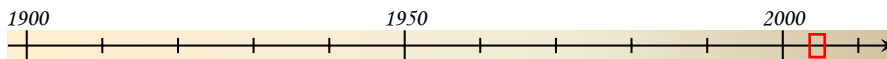


NADS-1 '02

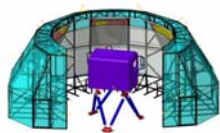


BMW '03

## Motion Platform History



VTI III '04



TU München '04



IFAS MARS '04

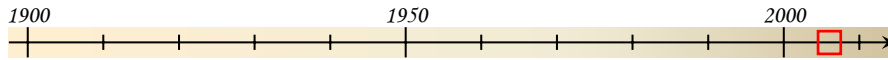


ULTIMATE '04



Katech KAAS '05

# Motion Platform History



DLR SimCar '05



LADS '06



MPI RoboCoaster '07

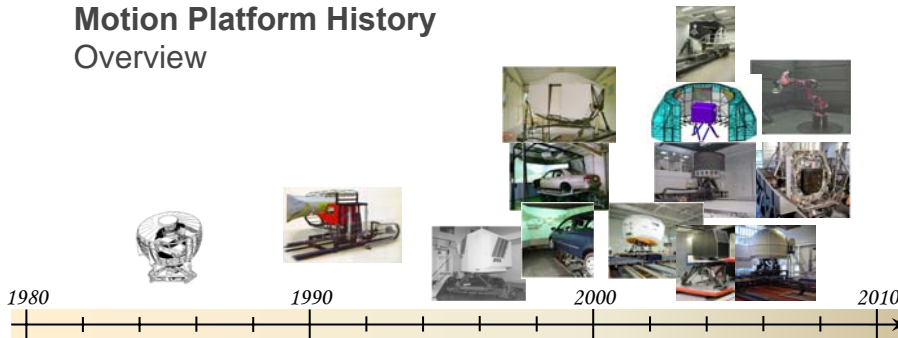


TNO DESDEMONA '07




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# Motion Platform History Overview




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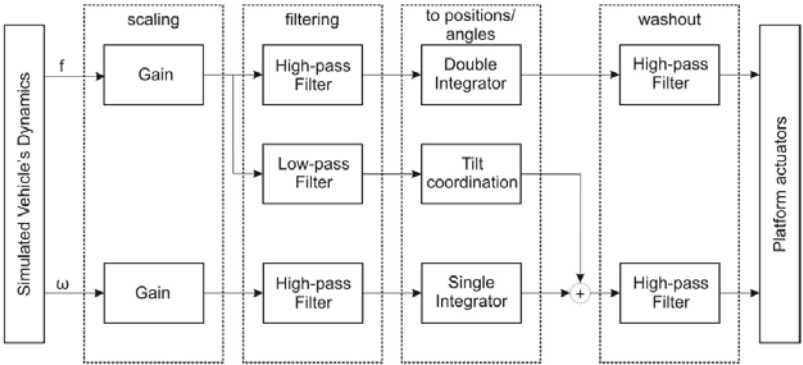
## Motion Cueing Algorithms


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## MCA structure



```

    graph LR
      subgraph SD [Simulated Vehicle's Dynamics]
        f[f]
        w[w]
      end
      subgraph scaling
        G1[Gain]
        G2[Gain]
      end
      subgraph filtering
        HP1[High-pass Filter]
        LP[Low-pass Filter]
        HP2[High-pass Filter]
      end
      subgraph to_pos_angles [to positions/angles]
        DI[Double Integrator]
        TC[Tilt coordination]
        SI[Single Integrator]
      end
      subgraph washout
        HP3[High-pass Filter]
        HP4[High-pass Filter]
      end
      PA[Platform actuators]

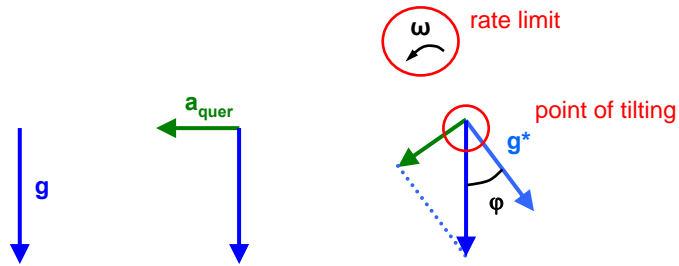
      f --> G1
      w --> G2
      G1 --> HP1
      G2 --> HP2
      HP1 --> DI
      LP --> TC
      HP2 --> SI
      DI --> HP3
      TC --> Sum((+))
      SI --> Sum
      Sum --> HP4
      HP3 --> PA
      HP4 --> PA
  
```


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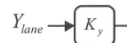
## Tilt Coordination

- Initial accelerations via translational movements
- Sustained accelerations via body tilt (tilt coordination)



## MCA hexapod

- Classical washout
- Optimal control
- Coordinated adaptive
- Lane based



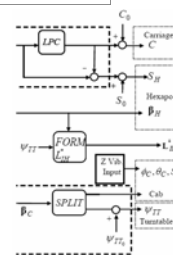
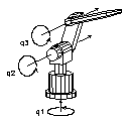
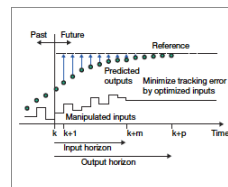


## MCA Add-on's

- Extensions to the classical MCA
  - Adaptive highpass filter (UTTIAS)
  - Nonlinear filter (Renault)
  - Adaptive gain & filter (Nihon University)
- Scenario dependent switching
  - Intelligent Adaptive MDA (NADS)
  - Time Variant MCA (DLR)

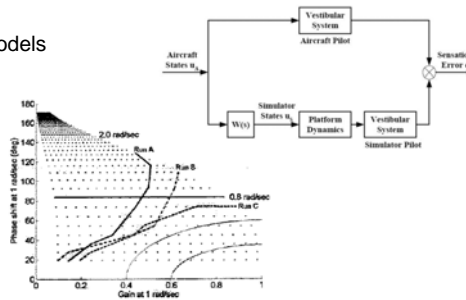
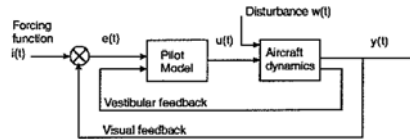
## Simulator specific approaches

- ULTIMATE – Model predictive control
- NADS – MDA for redundant DoF
- DESDEMONA – Spherical washout filter
- RoboCoaster – Robot arm MCA



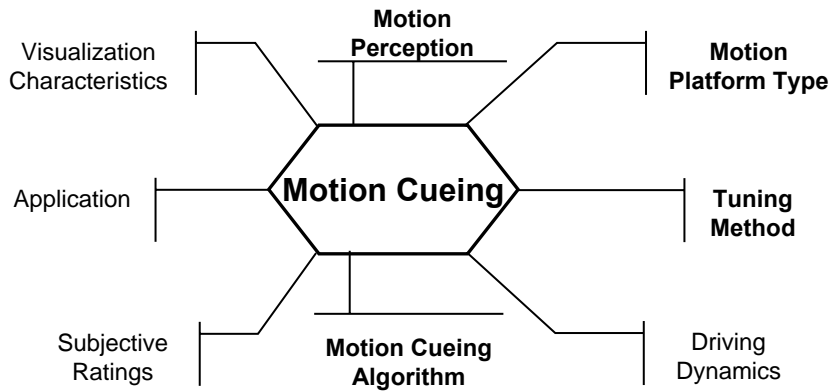
## Tuning

- Offline Tuning
  - Human control models
  - Human perception models
  - Empirical methods (Sinacori/Schroeder)
- Online Tuning
  - Human-in-the-loop



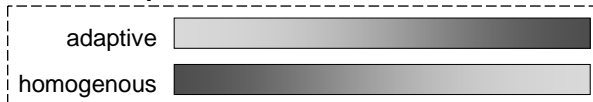
## Motion Cueing Issues

## Important Motion Cueing Factors



## Opposing Aspects I

### *Motion Response*



### *Realism*

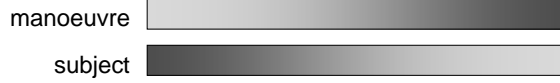


### *Tuning Options*

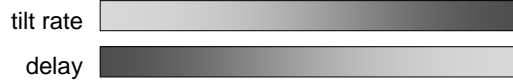


## Oposing Aspects II

### *Tuning Criteria*



### *Sustained Accelerations False Cues*



Thank you for your  
Attention!