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

“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

Motion Platform History
Early Flight Simulators

1900 1950 2000
Motion Platform History

1900 1950 2000

Gough Platform ‘54  C. Kappel ‘60s  Stewart Platform ‘66  First Patent ‘67

VW 70’s  VTI ‘84  IFAS (IKK) ‘84  Daimler Benz ‘85
Motion Platform History

1900 1950 2000

Mazda '90 Trygg Hansa '91 Daimler Benz '93 JARI '96

Ford VIRTTEX '94

1900 1950 2000

Motion Platform History

1900 1950 2000

- Ford VIRRTEX new '01
- IFAS MARS '01
- NADS-1 '02
- BMW '03

VTI III '04  TU München '04  IFAS MARS '04  ULTIMATE '04  Katech KAAS '05
Motion Platform History

Overview

1900 1950 2000

1980 1990 2000 2010

DLR SimCar '05  LADS '06  MPI RoboCoaster '07  TNO DESDEMONA '07
Motion Cueing Algorithms

MCA structure

- Scaling
- Tiltering
- To position/angle
- Washout

Vehicle's dynamics

Gain

High-pass Filter

Double Integrator

Tilt coordination

Single Integrator

High-pass Filter
Tilt Coordination

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

MCA hexapod

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

\[ \begin{align*}
\text{rate limit} & \quad \omega \\
\text{point of tilting} & \quad g^* \\
\end{align*} \]
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

Motion Cueing

Visualization Characteristics

Motion Perception

Motion Platform Type

Application

Driving Dynamics

Subjective Ratings

Motion Cueing Algorithm

Tuning Method

Opposing Aspects I

Motion Response

- adaptive
- homogeneous

Realism

- objective
- subjective

Tuning Options

- variable
- simple
Opposing Aspects II

**Tuning Criteria**

- manoeuvre
- subject

**Sustained Accelerations False Cues**

- tilt rate
- delay

Thank you for your Attention!