VERITAS project

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HOW DO HUMAN BEINGS MOVE? A LESSON FROM DRIVER MODELS

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Introduction

- STATE OF THE ART AND IDEAS CONCERNING THE PLANNING OF HUMAN MOVEMENTS

  - Driver models as a guideline

  - Hierarchical models

    - Perception Action loops
    - Optimal control and receding horizon
    - Human tracking skills

Introduction

- Humans move in smooth gracious fashion.
- Human movement is predictable and understandable to other humans.

  - ... there must be basic rules that generate movement and people are naturally aware of them

  - How do humans move and which rules generate movement?

DRIVER MODELS

- The domain of driver models can teach us some lessons
  - Driver models are models of how humans move in a restricted domain (driving). Yet this can tell usa many things.
  - Plöchl and Edelmann review lists 215 papers.
  - MacAdam review lists another 159 papers
  - there are many others.....

Hierarchical Models

- Several concurrent control, planning, sensing and cognition tasks that occur simultaneously.

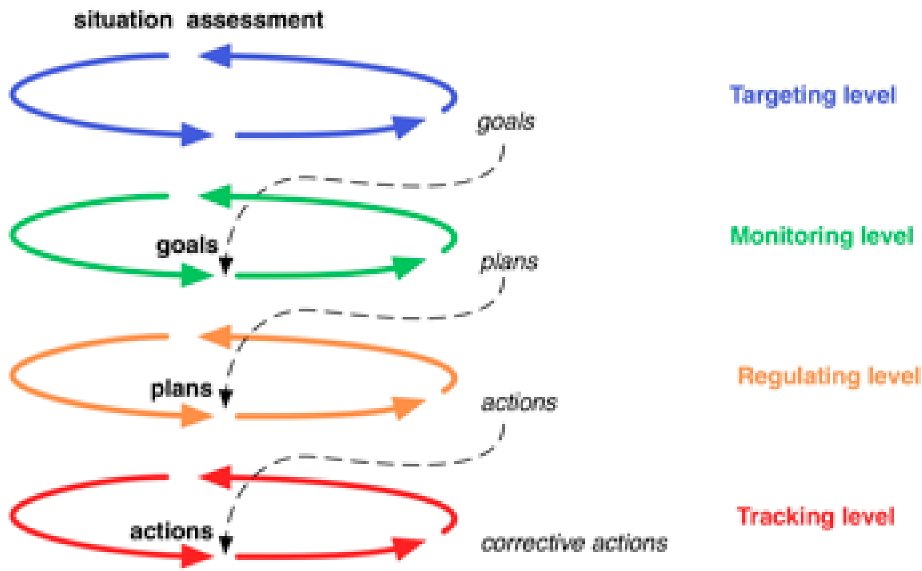
- These can be organized in a hierarchy:
  - Slow cognitive tasks occur atop
  - Fast compensatory tracking loops occur at bottom

Michon Model

- Three layers:
  - Strategic level (goals as to where to go are set consciously) - tenths of seconds
  - Tactical level (how to move to achieve a goal) - seconds
  - Control level (micromanagement) - fraction of seconds

The Extended Control Model

- The Extended Control Model by Hollnagel.



The Extended Control Model

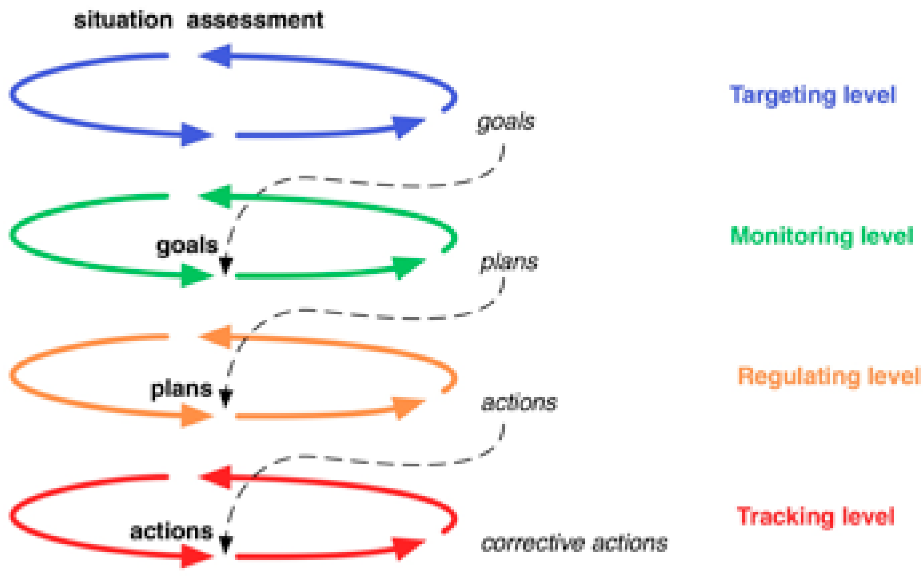
- In the ECOM the four layers implements a **subsumptive** architecture.
  - **Subsumptive**, means that each level can turn on and off a plethora of different sub-loops.
  - For example a speed-keeping loop (regulating level) can be turned off and replaced by a distance keeping loop when a a leading vehicle is met.

The DIPLECS porject

- The FP7 DIPLECS project successfully implemented a model of driver according to the ECOM architecture.
- ECOM states/loops are modeled as *Perception-Action* (reactive) loops that can be learnt by an artificial cognitive system

Optimized trajectories

- The two mid layers concerns mapping of goals into movement plans (trajectories) and into primitive motor task (actions).



Optimized trajectories

- Optimal control has been successfully used to explain the (optimized) trajectories that humans implement to reach targets.

- Todorov and Liu (grasping)
- Biral et al. (driving)

- Optimal trajectories means that the final target is reached according to some optimality criterion

Which criterion?

- Minimum jerk has been shown to hold for writing-like task (Viviani).
- Minimum jerk holds in many driving trajectories

- Minimum jerk means
  - Maximum smoothness
  - A principle of “laziness” or minimum effort
  - Minimization of brain-muscle throughput (related to Fitts’s law).

  - e.g., “lazy” drivers smooth curves and trace minimum jerk trajectories

Which criterion?

- Minimum energy in energy demanding task also holds.

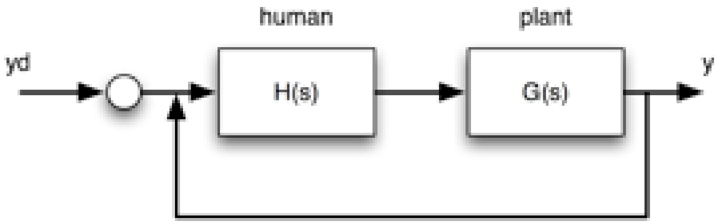
- In general multi-objective criteria can be used
  - eg. combination of minimum jerk and minimum time travel explains different types of driver behavior

Receding horizon

- Planning of Optimized trajectories is continuously update even during the execution of the trajectory itself.
  - If a deviation from plan occurs a new trajectory from the perturbed position is developed *without* returning to the previous plan.
  - Task irrelevant deviations are left uncorrected (minimum intervention principle) - Todorov et al.

Human tracking skills

- Largely studied in the earliest driver models. They describe the bottom control layer.



- Humans have anticipatory and adaptive capabilites.
  - Typical transfer function:

$$H(s) = \frac{K e^{-\tau s}}{T_N s + 1} \cdot \frac{T_L s + 1}{T_I s + 1}$$

The crossover model

- Humans adapt to plants in a fashion that the combined transfer function is nearly constant in the vicinity of the crossover frequency:

$$H(s)G(s) = \frac{\omega_c}{s} \cdot e^{-\tau s}$$

Conclusions

- Hierarchical model
  - Many concurrent processes at different rates.
  - Subsupmtive architecture.
  - Perception-Action loops were successfully used
  - Optimized trajectories
  - Multiple criteria and tradeoff explains a large variety of behaviors
  - Receding horizon (re-planning) explains the minimum intervention principle
  - Tracking skills are adaptive.
  - Typical human transfer function
  - Crossover model.