Driver Modelling:
Two-Point-, Inverted Gaze-Beam-Steering or Moving-Lookahead-Control

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Outline

- Motivation
  - IMOST skill hierarchy

- Control Models of Human Driving
  - Kondo, 1953
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  - Salvucci & Gray, 2004

- PRO and CONTRA Salvucci & Gray 2-Point Model
  - PRO
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    - Experiment with Observation Slits (LAND)
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- New Hypotheses
  - Inverted Gaze Beam Steering
  - Right Edge Sampling
  - Moving Lookahead Control

- Layered Architecture
  - Autonomous Layer: Curvature Estimation and Longitudinal Control
  - Associative Layer: Cognitive Maneuvres „Ausholen“
skill lattice using farpoint control

- entering autobahn
  - no traffic left lane entering without GN
  - traffic left lane entering with GN far point on left lane
  - traffic right lane
    - Lane change far point on left lane
    - Car following with GN far point on front car
    - Car following far point on front car
  - no traffic right lane

- Curve negotiation
- Gap negotiation (GN)
- Lateral and longitudinal control
- far point management
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References S&G`s 2PVCMMoS

- **Lateral control**

- **Control and Monitoring**

- **Longitudinal control**
  - ?????
steering angle: \( \varphi = f(\theta_f, \theta_n) \)
Salvucci & Gray’s 2-Point-Steering Model, 2004

Salvucci's PI-Controller (continuous time)
\[ \varphi = k_f \theta_f + k_n \theta_n + k_I \int \theta_n \, dt \]

where: \( \theta_n = \text{error} \)

Salvucci's PI-Controller (discrete time)
\[ \Delta \varphi = k_f \Delta \theta_f + k_n \Delta \theta_n + k_I \theta_n \Delta t \]

Parameters of S&G original simulation drive:
- single lane; winded country road; length: 25 km
- speed: 16.9 m/s (= 60.84 km/h); time intevall: \( \Delta t = 50 \text{ms} \)
effects of angles on steering angle

Salvucci's PI-Controller

$\Delta \varphi = k_f \Delta \theta_f + k_n \Delta \theta_n + k_l \theta_n \Delta t$

$\theta_n = \begin{cases} + \\ - \end{cases}$

$\theta_f = \begin{cases} - \\ + \end{cases}$
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Empirical Evidence for Tangent Hypothesis

Land (1994, p. 743; 1998, p. 167) contour plots of eye Fixations, N=3; one way, single lane, 40-45 km/h; the contours give the density of fixations relative to the maximum; the 0.2 contour includes about 65% of all fixations (Land, 1998, p.167)
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Eye Fixation in Left Hand Bend
Chattington et al, 2007

N=10, Winding rural road
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Far- and Near-region Hypothesis
Measures of Driving Performance,
Land (1995)
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One-Point Sampling?

Measures of Driving Performance, Land (1995)

dynamic control?
„Durch die Versuche wird lediglich der Einfluss eines auf bestimmte Art und Weise verdeckten Blickfeldes belegt, nicht jedoch, wie später von S&G unterstellt, die Notwendigkeit zweier Fixationspunkte oder die Bedeutung einer irgendwie gearteten Winkelinformation“ (Martin Schröer, 2007, S.17).

Das Modellexperiment von S&G ist keine Replikation, weil das S&G-Modell innerhalb der Sehschlitze nur die Punktinformation extrahiert: „near and far points were locked at the center of the single road segment“ (S&G, 2004, p.1239).

Dennoch behaupten S&G die Identität der Experimente: „To validate the model with Land and Horwood‘s data, we provided the model with the same viewing conditions and analyzed ist steering behavior with respect to the same accuracy metric“ (S&G, 2004, p.1239).
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Simulation Run in TORCS

Reconstruction of Salvucci & Gray’s 2-Point Visual Control Model in TORCS

(LENK simulation - click me -)
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Empirical Evidence for Drive Trajectory Hypothesis
Wilkie & Wann, 2003, p.681

Gaze Behavior
2 sec before apex
N=6; single lane, one way, 29 km/h, 2 m (!) road width
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Hübner’s S&G simulation: TORCS Driving Course

Length: 1.5 km
Width: 10 m

far point on centre of lane;
distance to far point: 31.2 m; (ttfp = 1.34 sec)
Results of One-Point-Driving model: Fittest P-Controller

Distance to far point: 31.2 m; (ttfp = 1.34 sec)

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Result of Grid Search in Parameter Space

Simplification of Salvucci & Gray's Model in TORCS: P-Controller

(Hübner-Lenk simulation - click me -)
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Sampling Contours of Inverted Curvilinear Gaze-Beam Hypothesis

(left: driver’s view, right: bird’s eye view)

Far Points 4-6 of Subject HH
Far Points 1-3 of Subject CH

heading

left edge of lane
intended trajectory
right edge of lane

Tangent Far Point
Inverted Curvilinear Gaze-Beam
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thesis: the tangent hypothesis is an artefact of single-lane, one way simulation drives; instead in two way drives only the right edge of the road is sampled; this only seems to support the tangent hypothesis in right hand bends.
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hypothesis: the tangent hypothesis is a special case of the Moving Lookahead Control Hypothesis. The angle between the heading $H$ and the lookahead $L$ (middle of the road 1.5 sec ahead) influences the steering wheel angle (\textit{lateral control}) and the selected speed (\textit{longitudinal control}). In special cases the direction of the lookahead $L$ is identical to the tangent point $T$. Then this angle is identical to Salvucci's far point angle $\theta_f$. 
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Estimation of Curvature in Tangent Point Steering

Möbus, Hübner & Garbe, 2007
secant of circle segment
⇒ estimation of curvature of car's intended track
\[ 2D = 2\sqrt{2dr - d^2} \]
\[ D^2 + d^2 = 2dr \Rightarrow r = \frac{D^2 + d^2}{2d} \]
\[ \frac{1}{r} = \frac{2d}{D^2 + d^2} < \frac{2d}{D^2} < \frac{2d}{D} = \alpha \cdot \frac{d}{D} \]
\[ \frac{1}{r} < \alpha \cdot \frac{d}{D} = \frac{\text{intendedCar'sDistanceToRightLane}}{\text{distanceToTangentPoint}} \]
\[ \frac{1}{r} \approx \frac{d}{D} = \frac{\text{intendedCar'sDistanceToRightLane}}{\text{distanceToTangentPoint}} \]
≈ estimation of curvature of car's intended track
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Estimation of Curvature: Ausholen

third alternative proposal to Land, 1998, p.168

hypothetical simple visual strategy for estimation curvature and speed

1. Estimation of intendCar'sDistanceToRightLane d
2. Estimation of distanceToTangentPoint D
3. Relativation of distance estimation d to distance estimation D
4. IF d grows AND D remains constant THEN curvature grows AND speed has to be slower
5. IF d remains constant AND D grows THEN curvature gets smaller AND speed can grow (Ausholen)
Recommendations

- New Hypotheses
  - Single lane road: right and left tangent point steering
  - Double lane road
    - without center line
      - Right Edge Sampling
    - with center line:
      - Deterministic: right and center tangent point steering
      - Probabilistic: Inverted Gaze Beam Steering
  - Integrative hypothesis: Moving Lookahead Control
  - Delay within gaze-steering coordination of 60 sec (Chattington, 2007)

- More Experimental Test Drives!
  - S-Curves
  - Hundskurven

- Layered Architecture
  - Associative Layer: Planning of Maneuvres (Ausholen)
  - Autonomous Layer: Situational embedding
Thank you for your attention …