iLLS

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

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  - **Right Edge Sampling**
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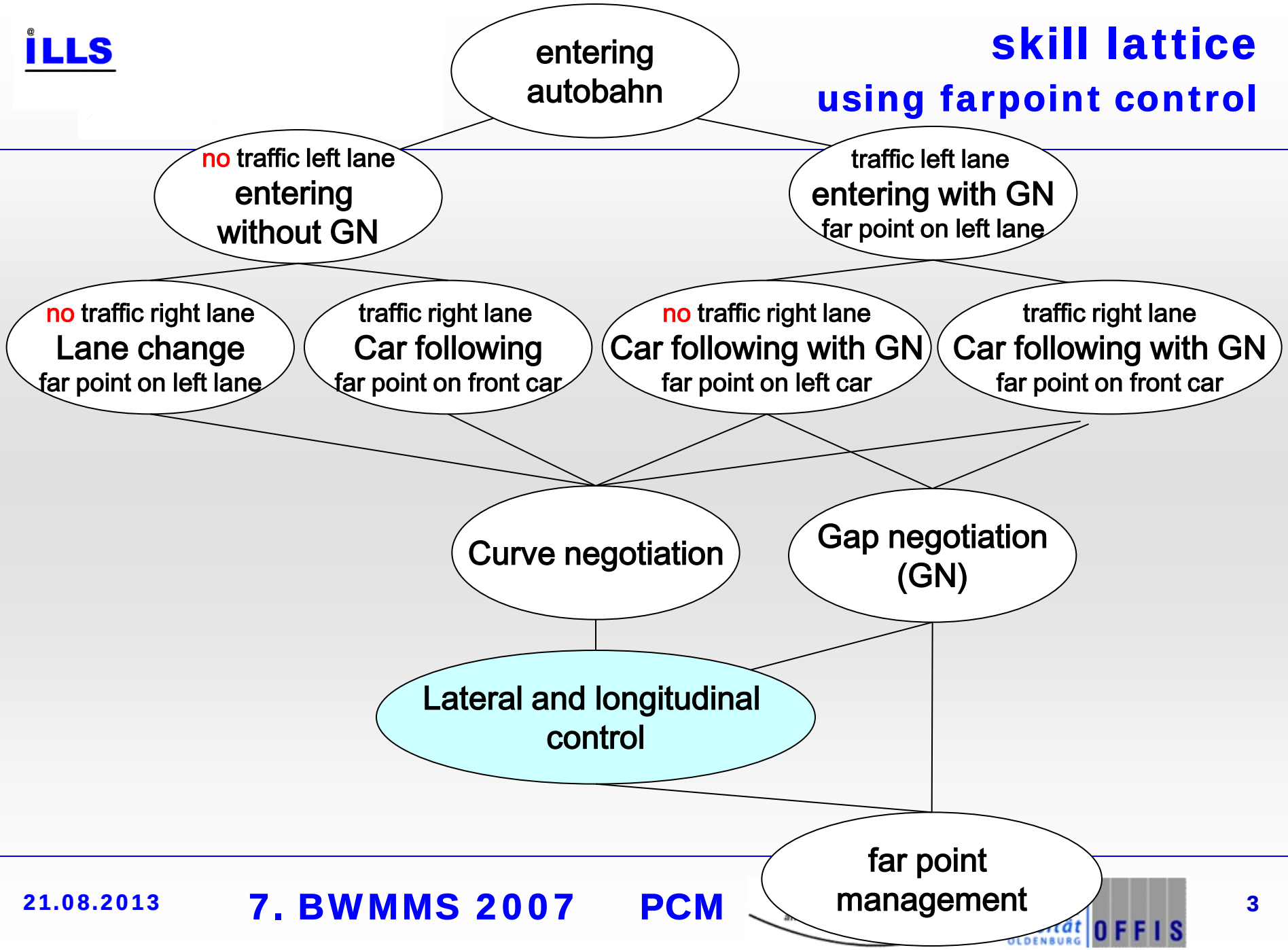
skill lattice
using farpoint control



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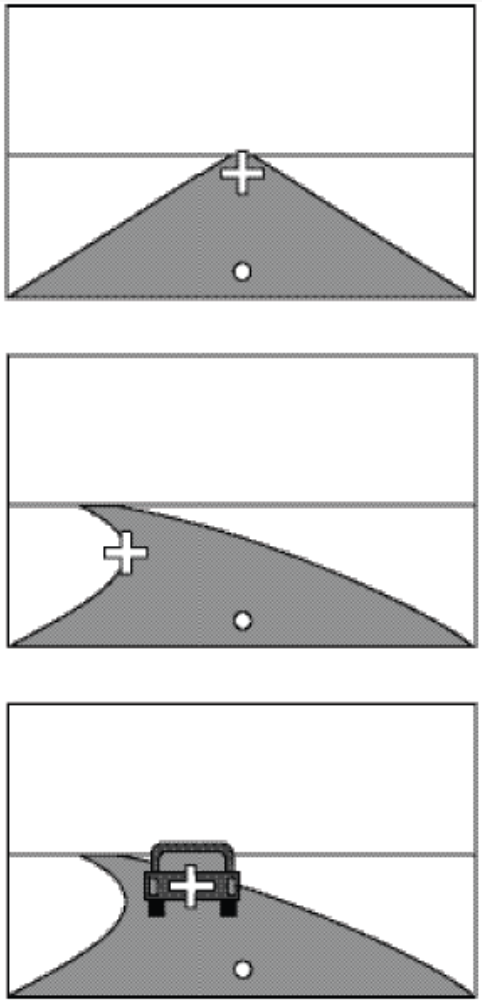
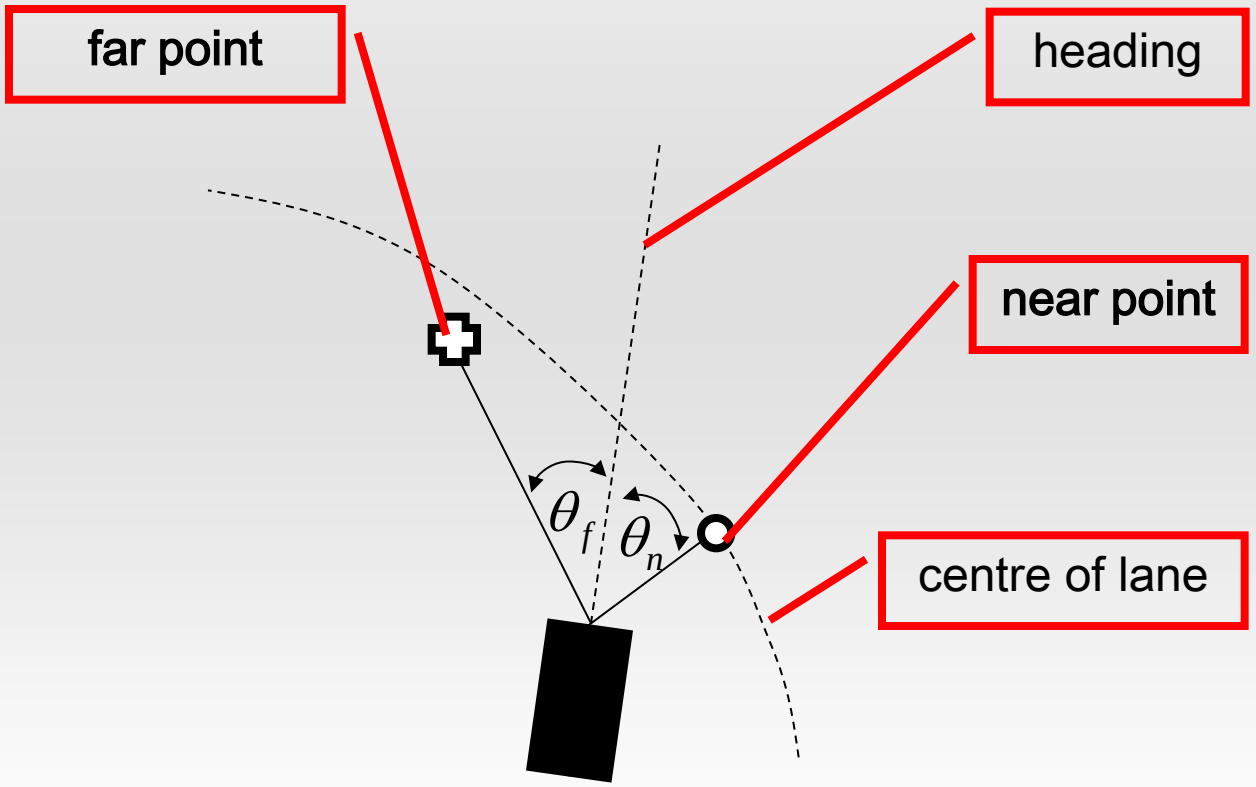
References S&G's 2PVCMoS

- **Lateral control**
  - Salvucci & Gray, 2004, A Two-Point Visual Control Model of Steering, Perception, 33, 1233 – 1248
  - Salvucci, D.D., 2007, Integrated Models of Driver Behavior, in: Gray (ed), Integrated Models of Cognitive Systems, ch.24, 356 – 367
- **Control and Monitoring**
  - Driving Modules in Action (reference to Salvucci's papers), in J. R. Anderson, 2007, How Can the Human Mind Occur in the Physical Universe, Oxford University Press, 62 – 66, ISBN 978-0-19-532425-9
- **Longitudinal control**
  - ?????

Salvucci & Gray's 2-Point-Steering Model, 2004



steering angle: $\varphi = f(\theta_f, \theta_n)$



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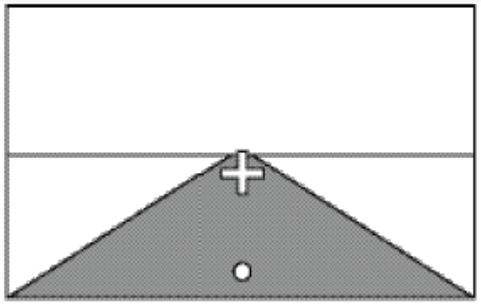
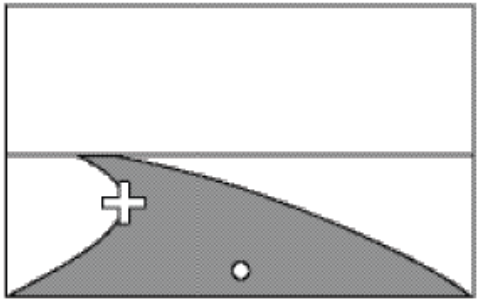
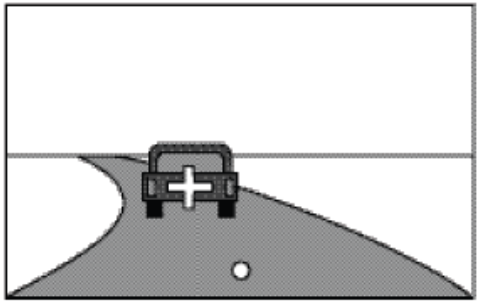






Salvucci's PI-Controller (continous time)

$$\varphi = k_f \theta_f + k_n \theta_n + k_I \int \theta_n dt$$

where: $\theta_n = error$

$$\dot{\varphi} = k_f \dot{\theta}_f + k_n \dot{\theta}_n + k_I \theta_n$$

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

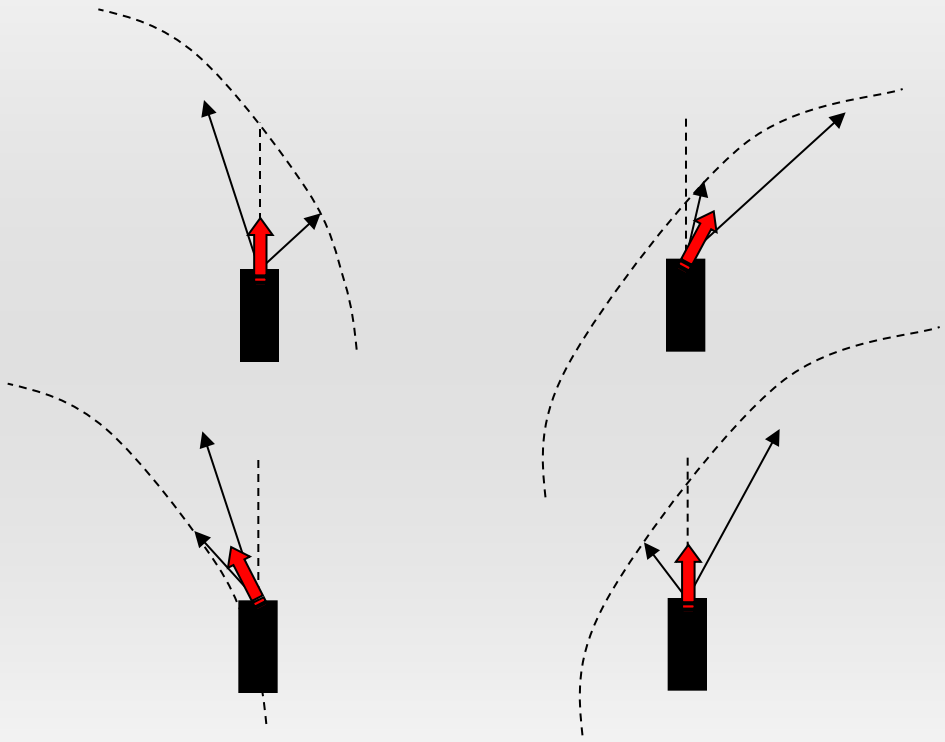
speed: 16.9 m/s $(= 60.84\ km/h)$; time intervall: $\Delta t = 50ms$

effects of angles on steering angle

Salvucci's PI-Controller

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

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



$$\theta_f = \langle - \quad , \quad + \rangle$$

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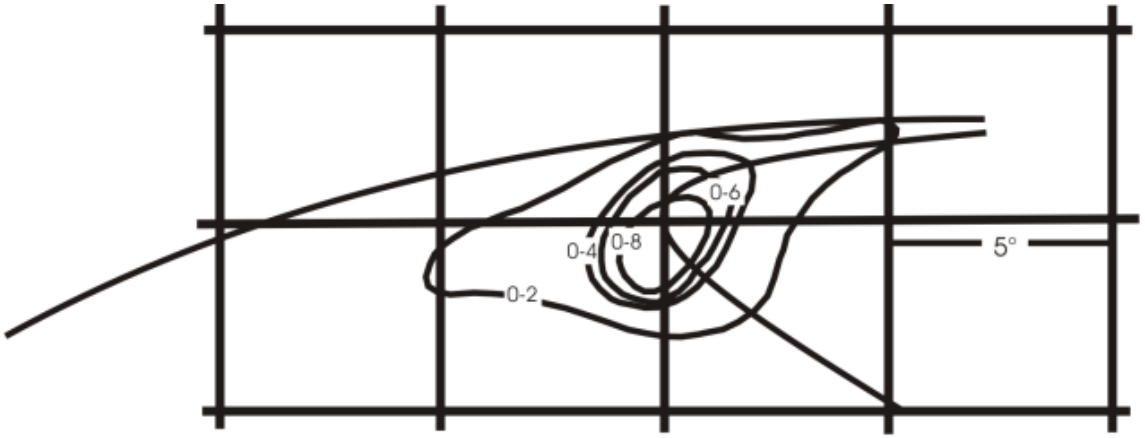
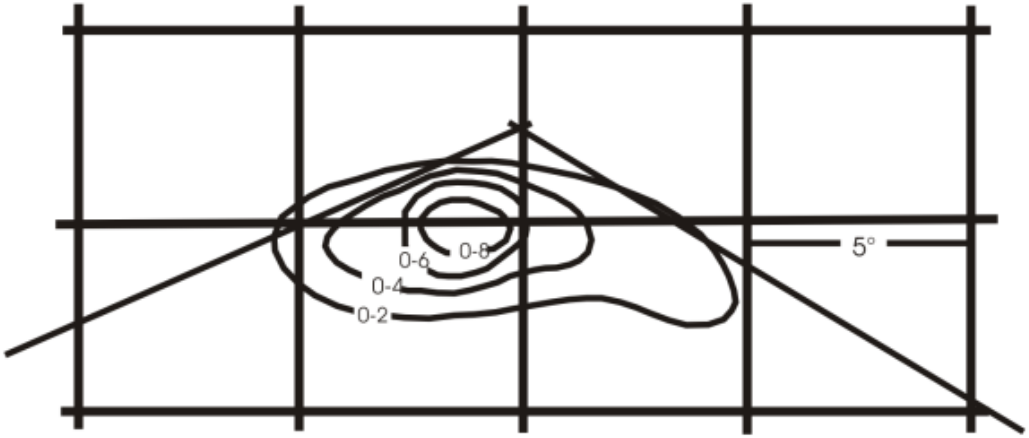
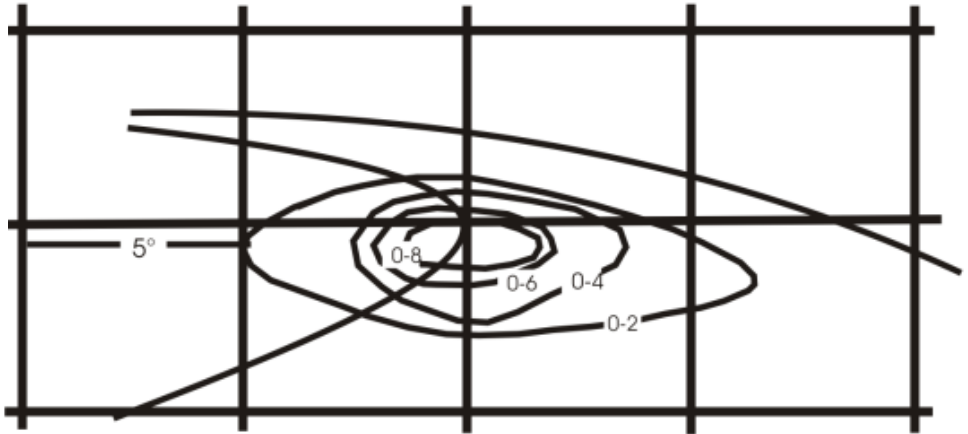
Empirical Evidence for Tangent Hypothesis

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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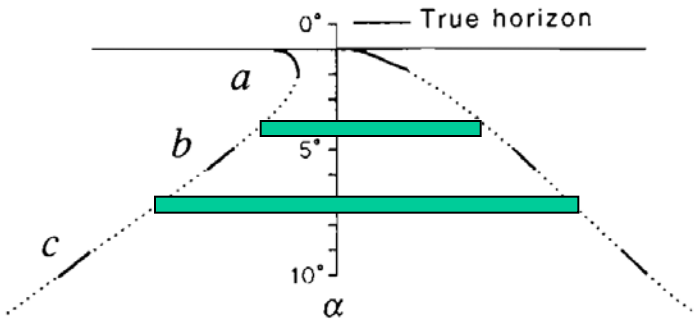
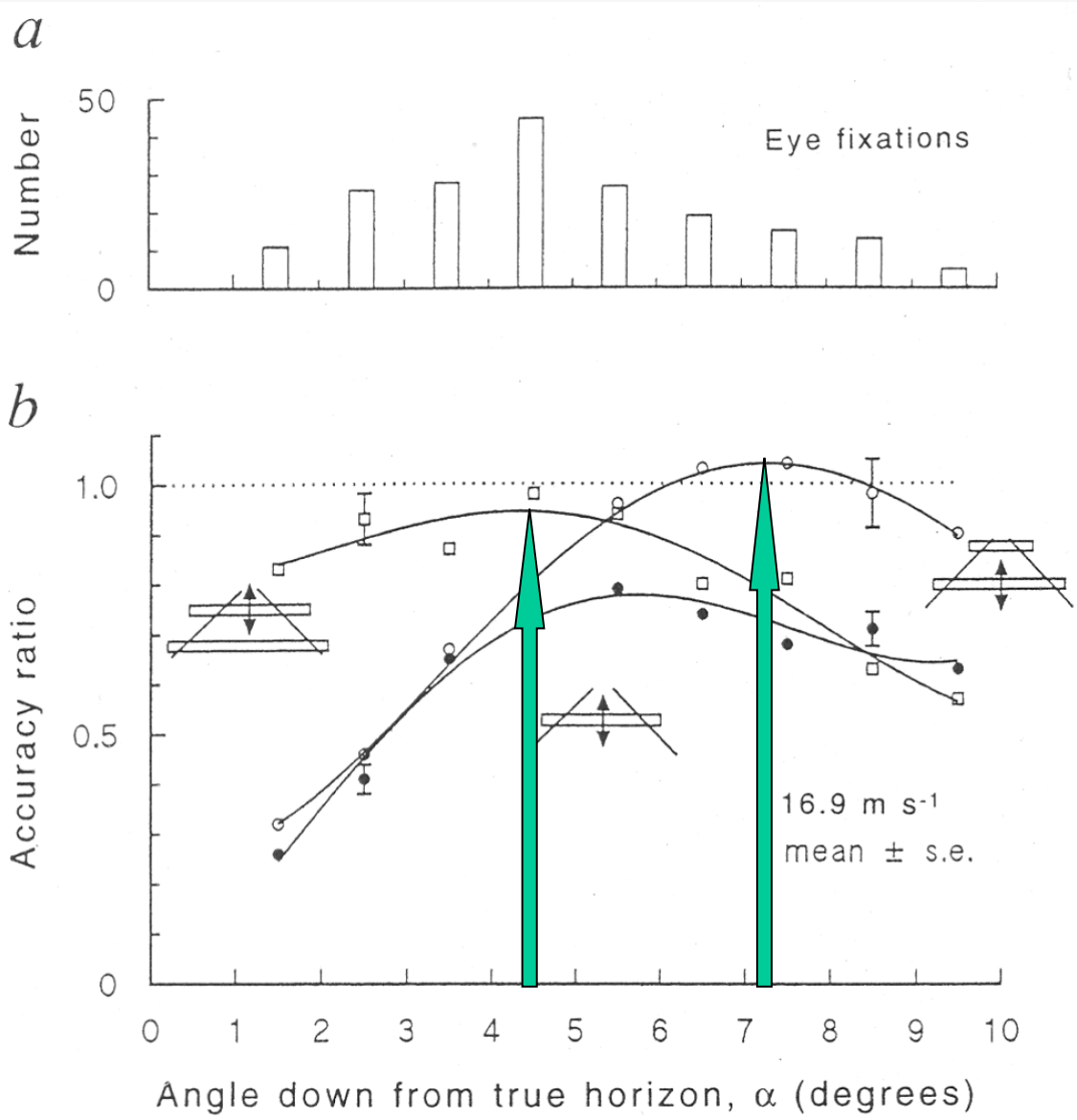
Far- and Near-region Hypothesis Measures of Driving Performance,

Land (1995)





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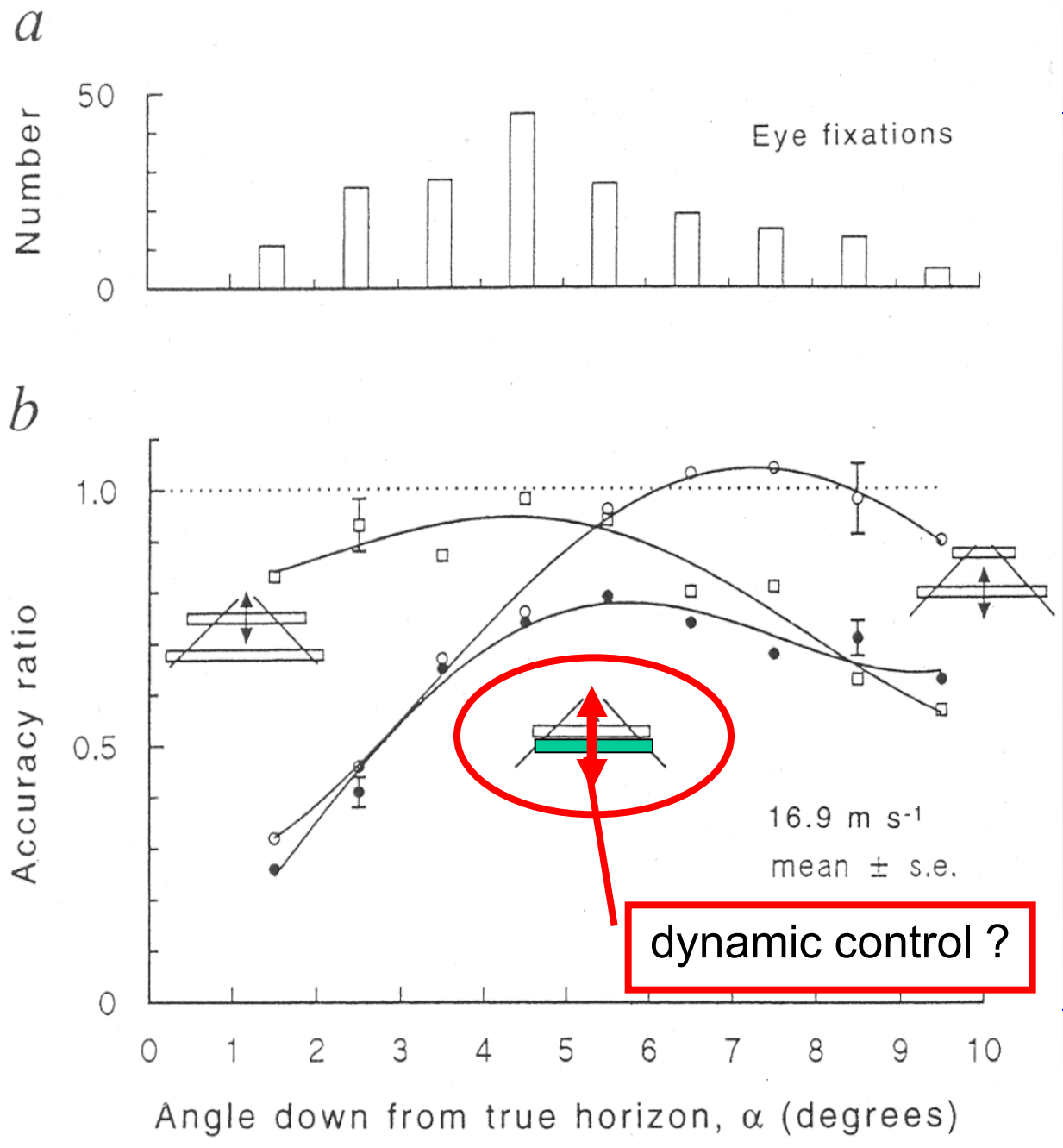
One-Point Sampling ?

Measures of Driving Performance, Land (1995)



Misinterpretation of Land's results by Salvucci & Gray

- „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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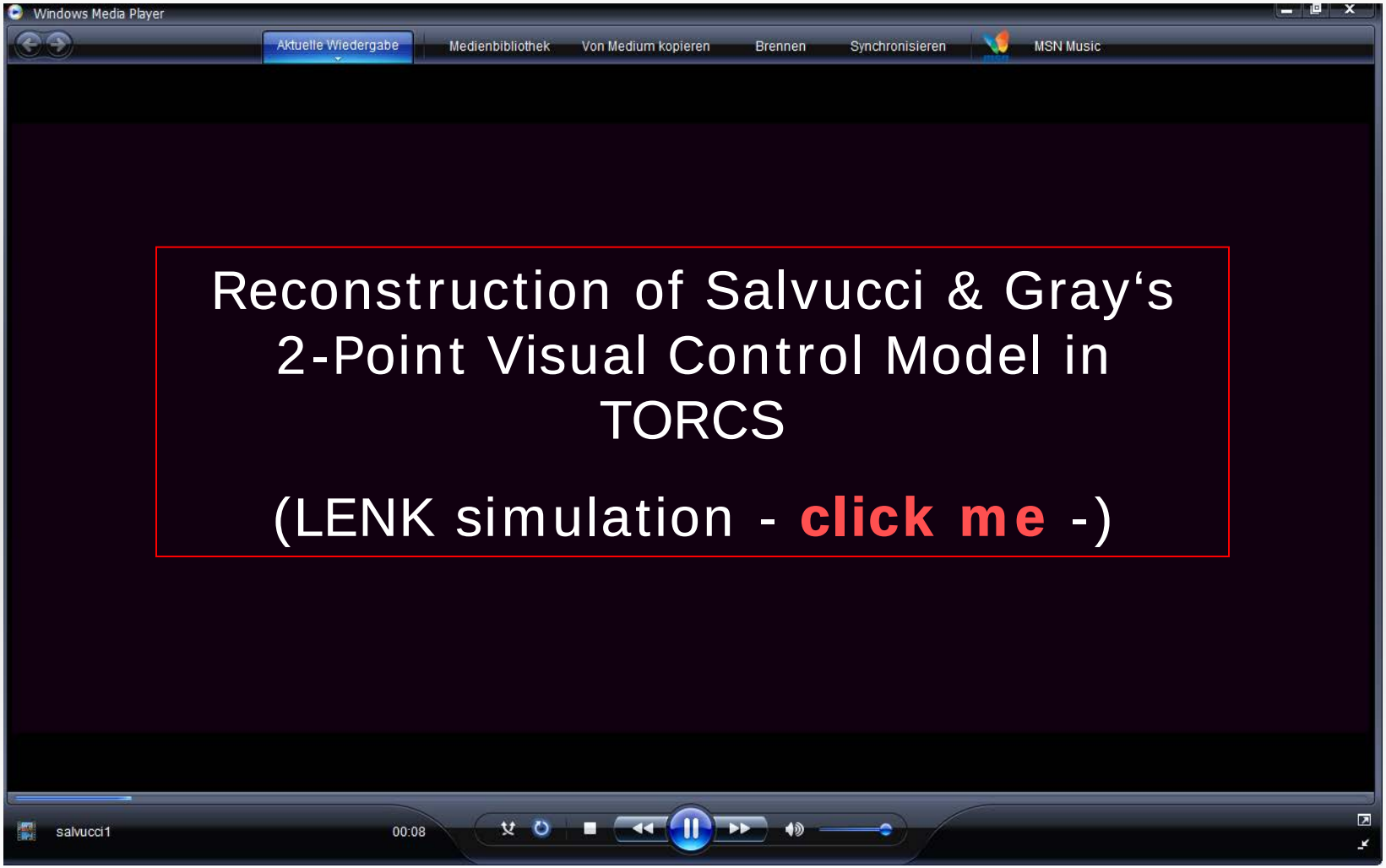
Simulation Run in TORCS



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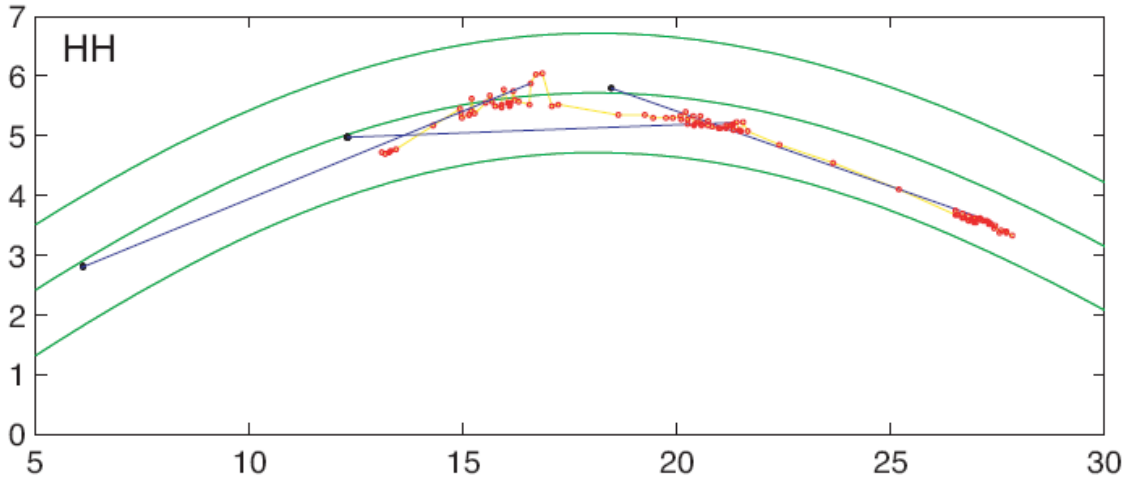
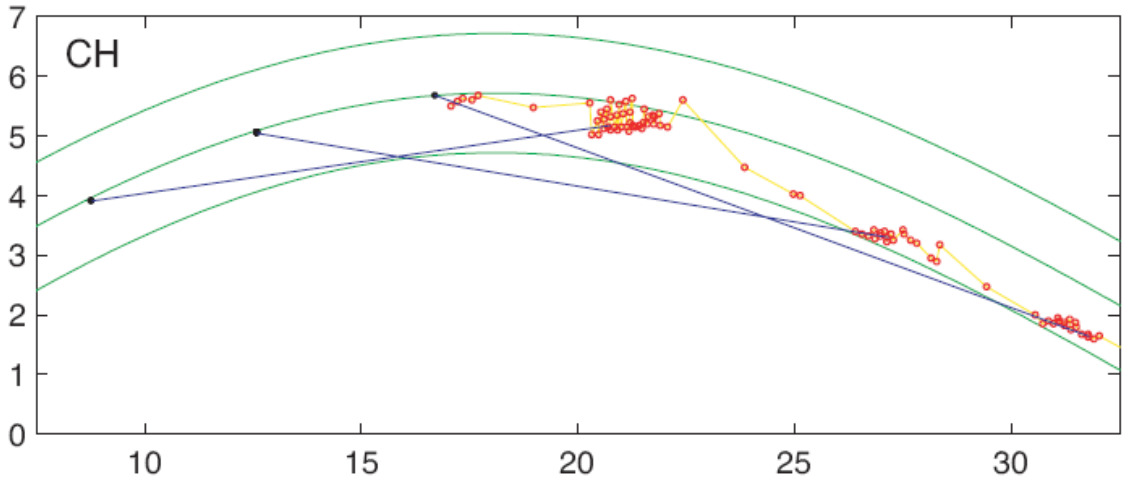
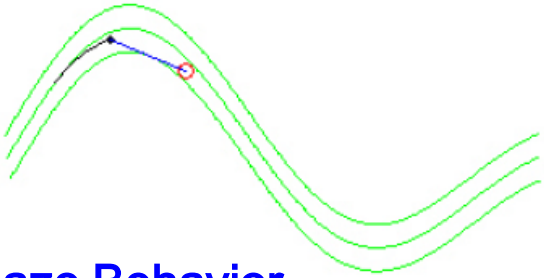
Empirical Evidence for Drive Trajectory Hypothesis

Wilkie & Wann, 2003, p.681

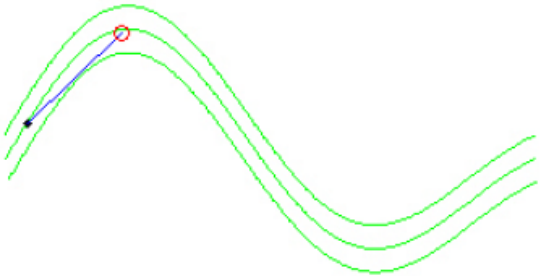






Gaze Behavior
2 sec before apex

N=6; single lane, one way,
29 km/h, 2 m (!) road width



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Eye Fixation in Right Hand Bend

Chattington et al, 2007

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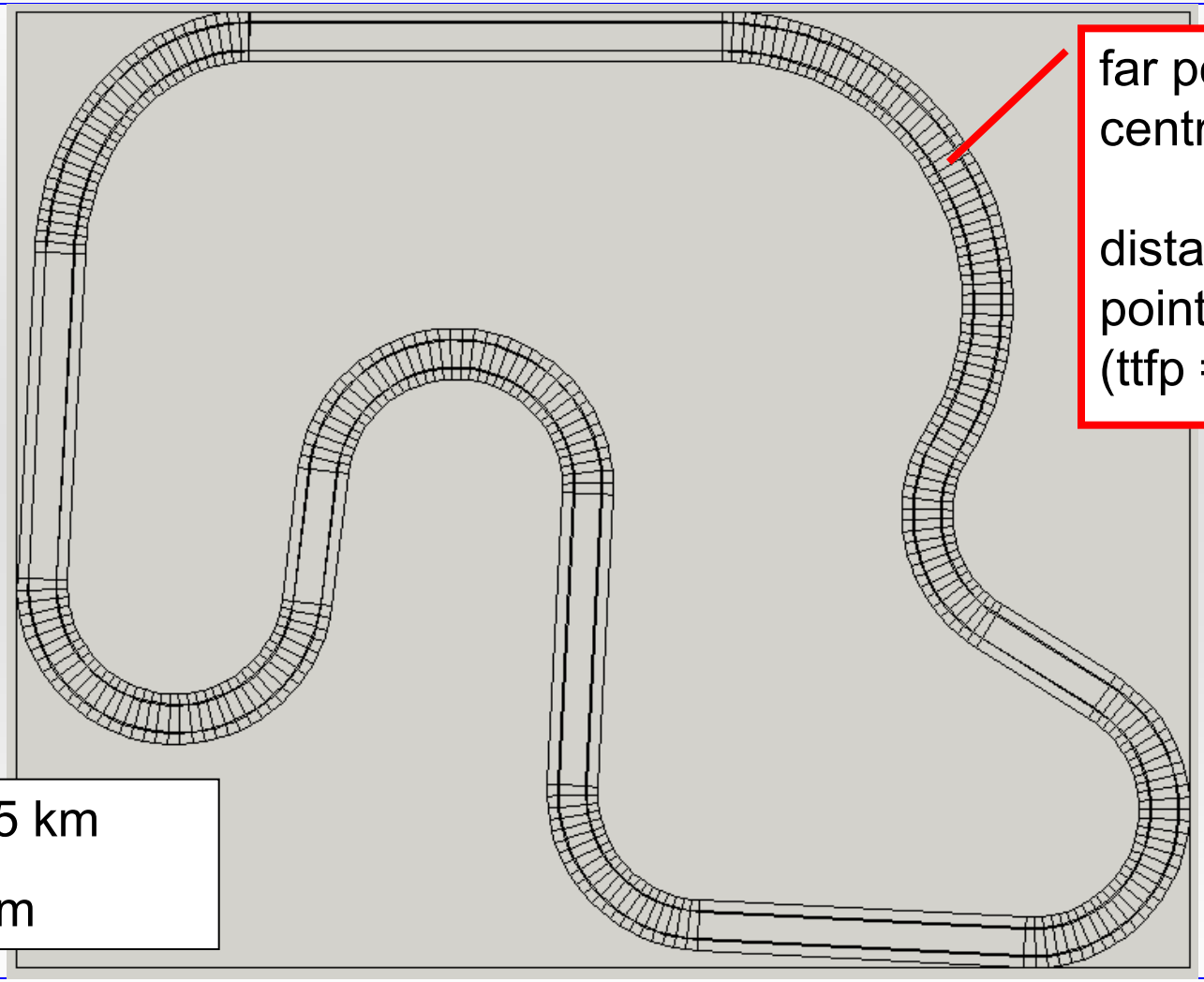
Hübner's S&G simulation: TORCS Driving Course



far point on centre of lane;

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

Length: 1.5 km

Width: 10 m

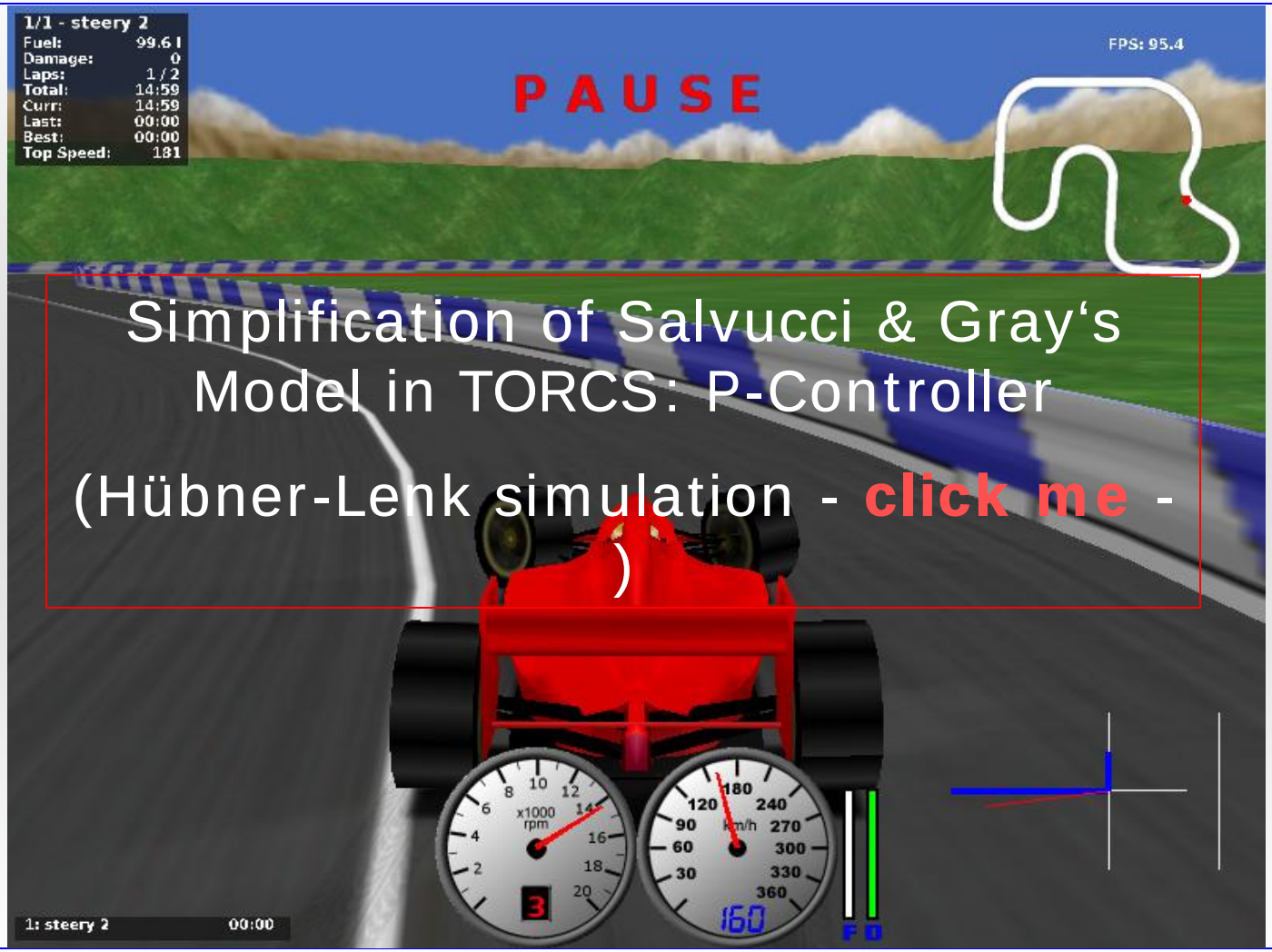
Results of One-Point-Driving model: Fittest P-Controller

150 km/h

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

k_f	k_n	k_i	Laptime	Accuracy
0.80	**0.00**	**0.00**	**41.682**	**0.0624536**
0.85	0.00	0.00	41.688	0.0632709
0.75	0.00	0.00	41.736	0.0611271
0.70	0.00	0.00	41.798	0.0596544
0.85	0.05	0.00	41.854	0.0563547
0.65	0.00	0.00	41.870	0.0582930
0.80	0.05	0.00	41.908	0.0549781
0.75	0.05	0.00	41.962	0.0539133
0.70	0.05	0.00	42.030	0.0528256
0.80	0.10	0.00	42.074	0.0502342

Result of Grid Search in Parameter Space



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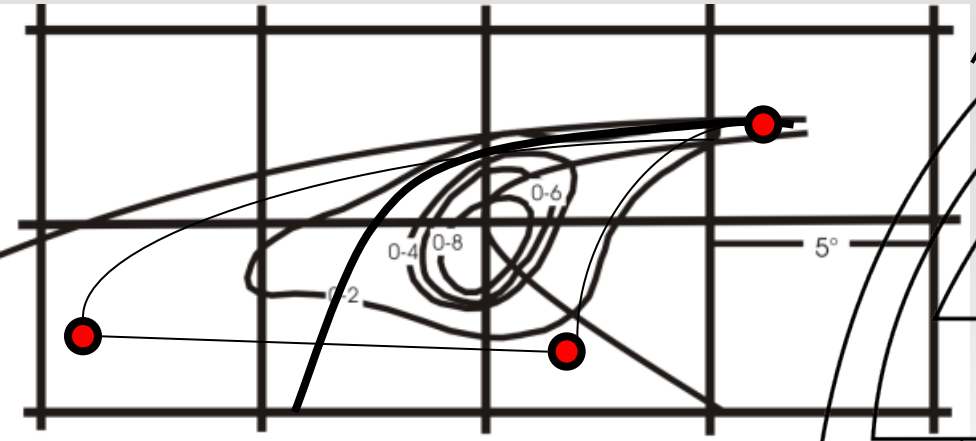
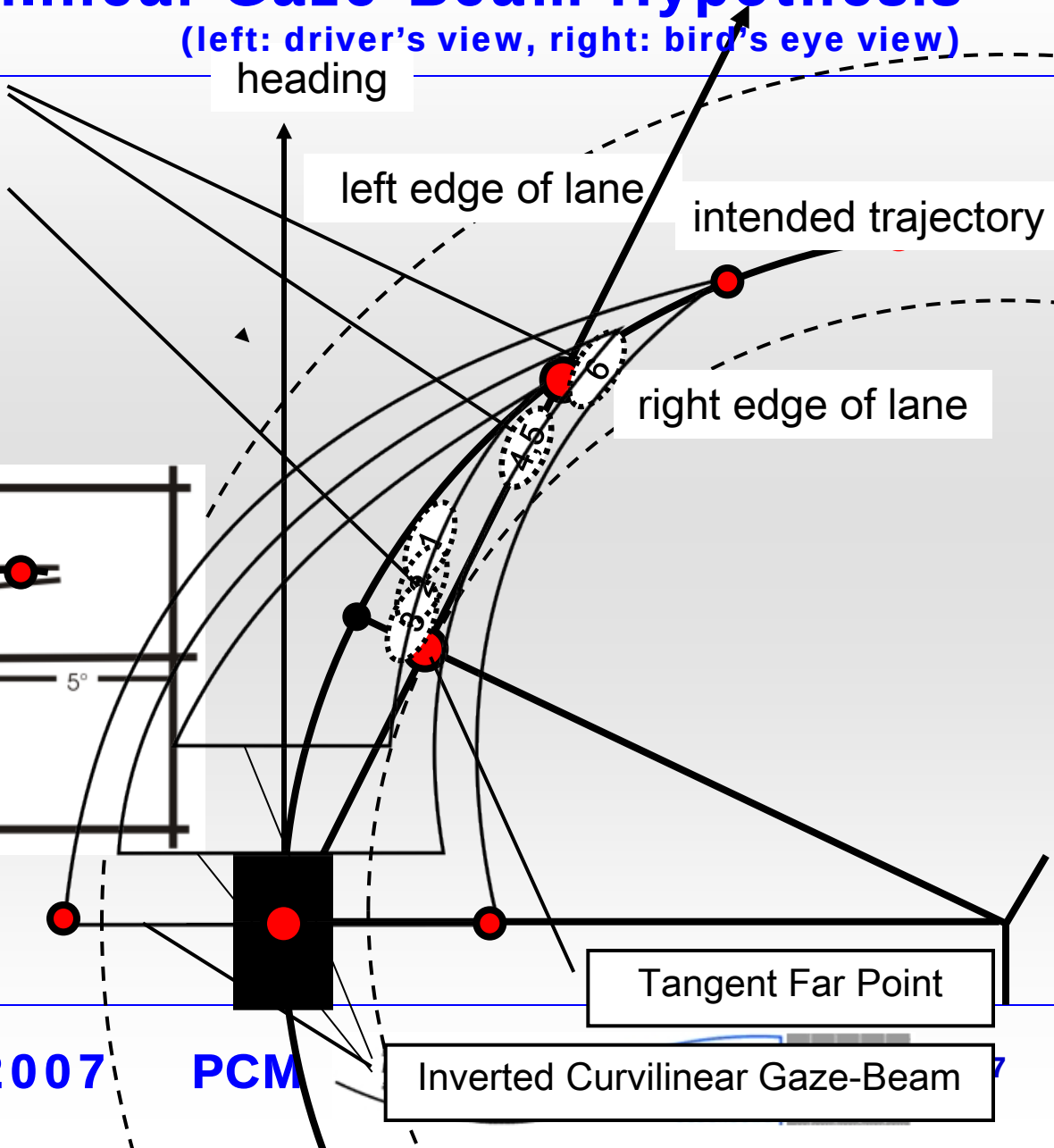
Sampling Contours of Inverted Curvilinear Gaze-Beam Hypothesis

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





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  - **Inverted Gaze Beam Steering**
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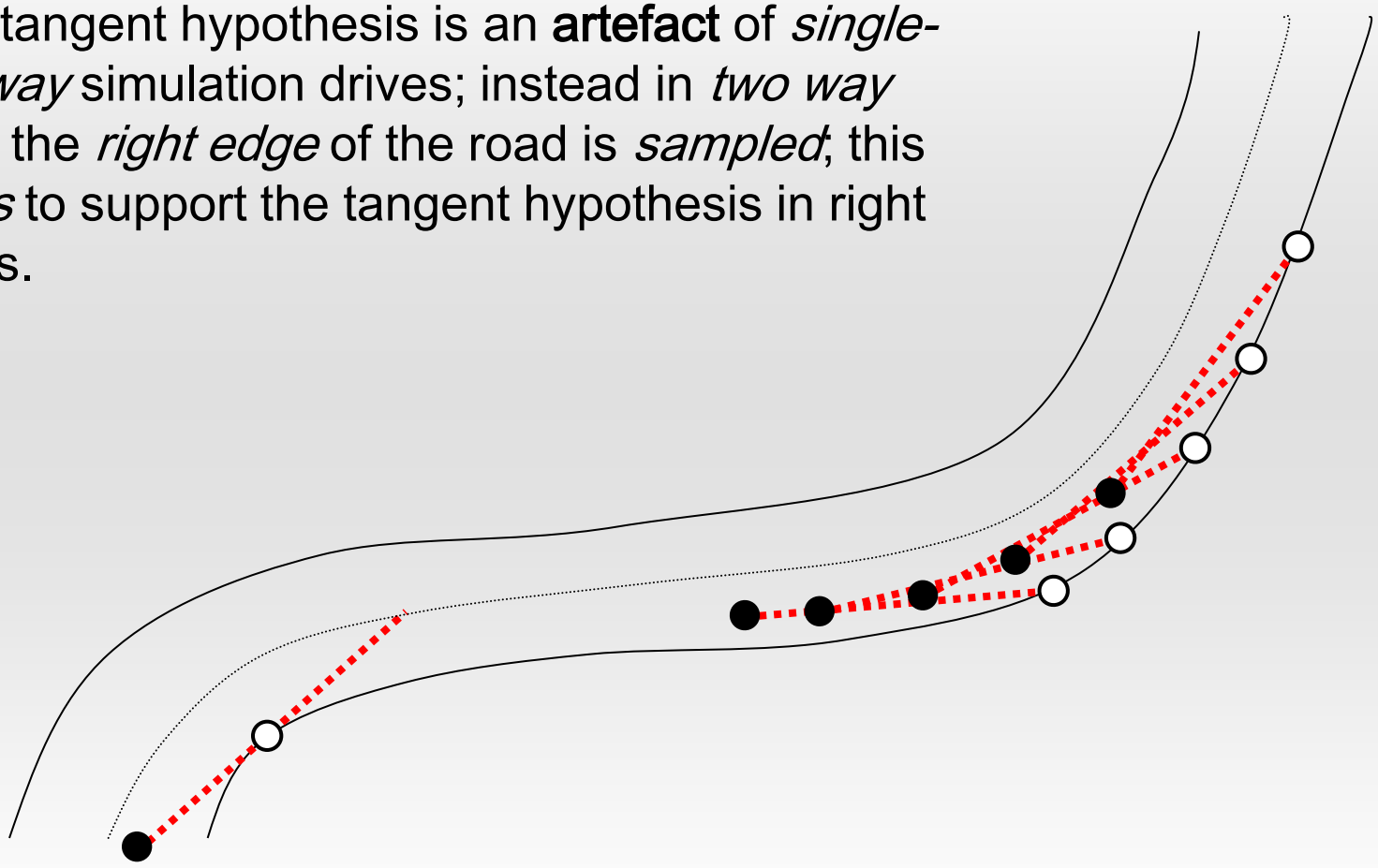
Right Edge Sampling Hypothesis

(two way roads; z.B. Ekernstraße, OL)

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.



DLR-Simulation Run

Outline

- **Motivation**
  - **IMOST skill hierarchy**
- **Control Models of Human Driving**
  - **Kondo, 1953**
  - **Donges, 1978**
  - **Salvucci & Gray, 2004**
- **PRO and CONTRA Salvucci & Gray 2-Point Model**
  - **PRO**
    - Contours of Eye Fixations (LAND, 1994, 1995, 1998)
    - Tangent Point Gaze Fixations in Left-hand Bends (Chattington, 2007)
    - Experiment with Observation Slits (LAND)
  - **CONTRA**
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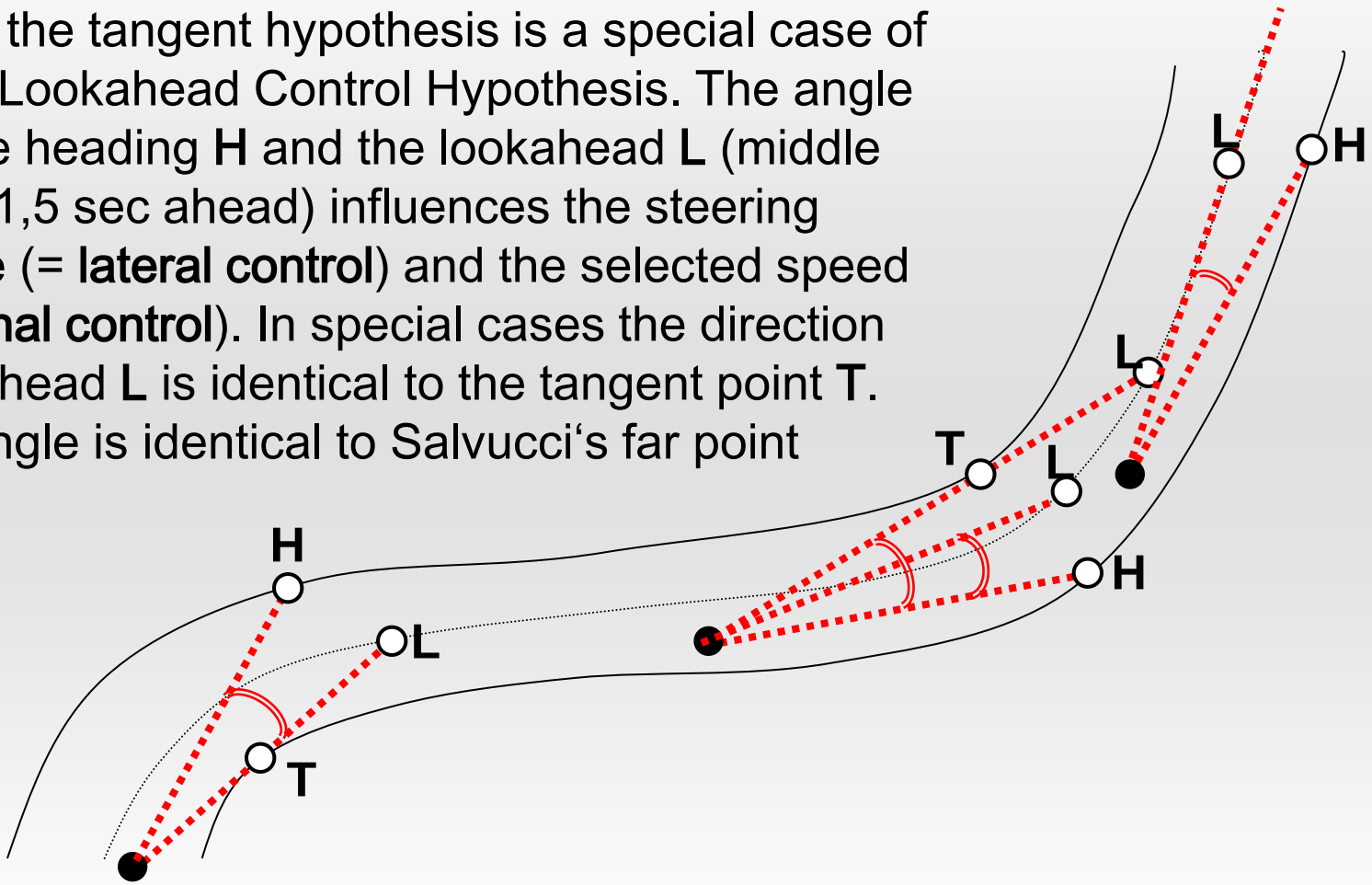
Integrative Hypothesis: Moving Lookahead Control

(two way roads; z.B. Ekernstraße, OL)

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 (= **lateral control**) and the selected speed (= **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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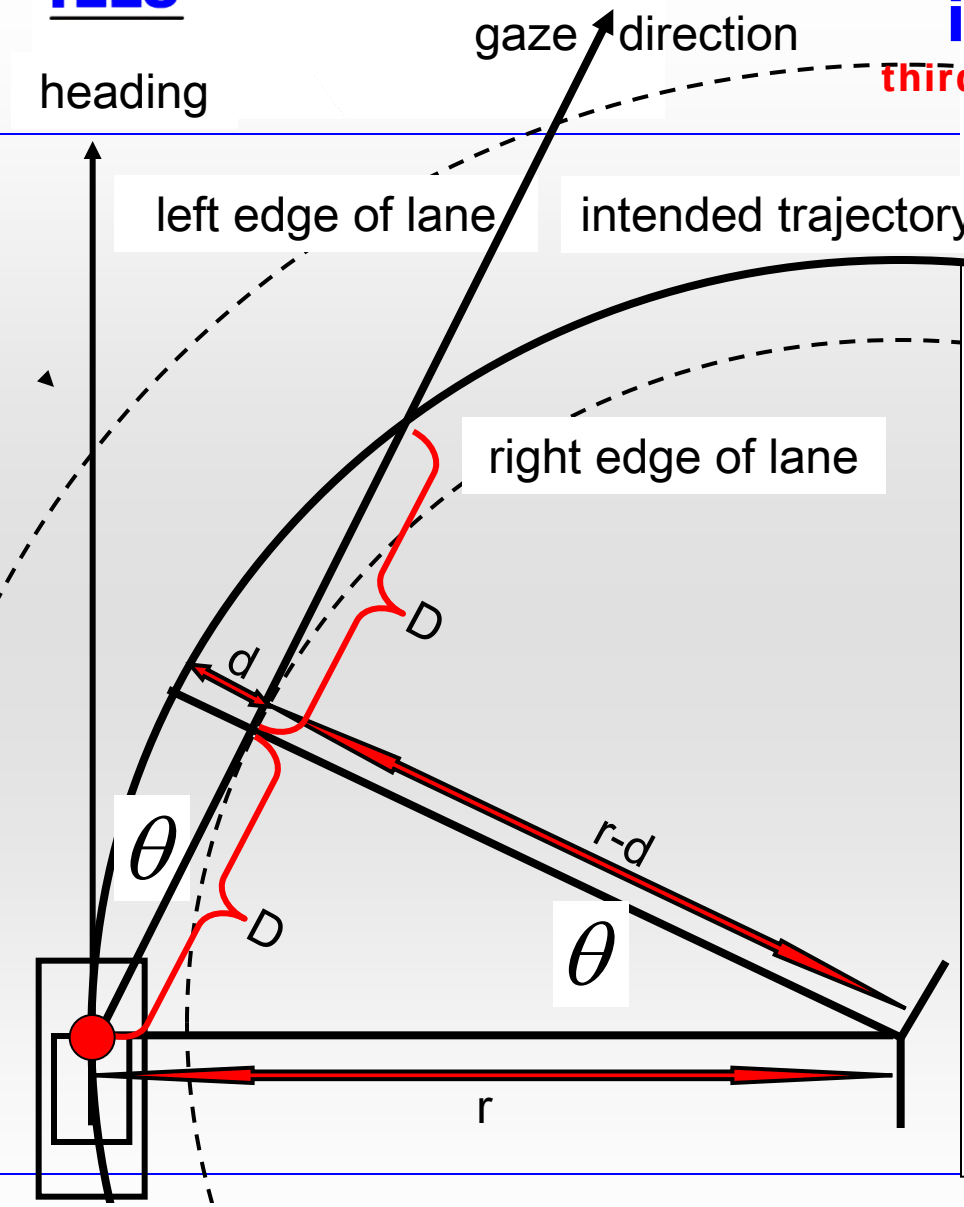
Estimation of Curvature in Tangent Point Steering

third alternative proposal to Land, 1998, p.168



Möbus, Hübner & Garbe, 2007

secant of circle segment

$\Rightarrow$ estimation of curvature of car's intended track

$$2D = 2\sqrt{2dr - d^2}$$

$$D^2 + d^2 = 2dr \Rightarrow r = \frac{D^2 + d^2}{2d}$$

$$\frac{1}{r} = \frac{2d}{D^2 + d^2} < \frac{2d}{D^2} < \frac{2d}{D} = \alpha \cdot \frac{d}{D}$$

$$\frac{1}{r} < \alpha \cdot \frac{d}{D} = \alpha \cdot \frac{\text{intendedCar'sDistanceToRightLane}}{\text{distanceToTangentPoint}}$$

$$\frac{1}{r} \approx \frac{d}{D} = \frac{\text{intendedCar'sDistanceToRightLane}}{\text{distanceToTangentPoint}}$$

$\approx$ estimation of curvature of car's intended track

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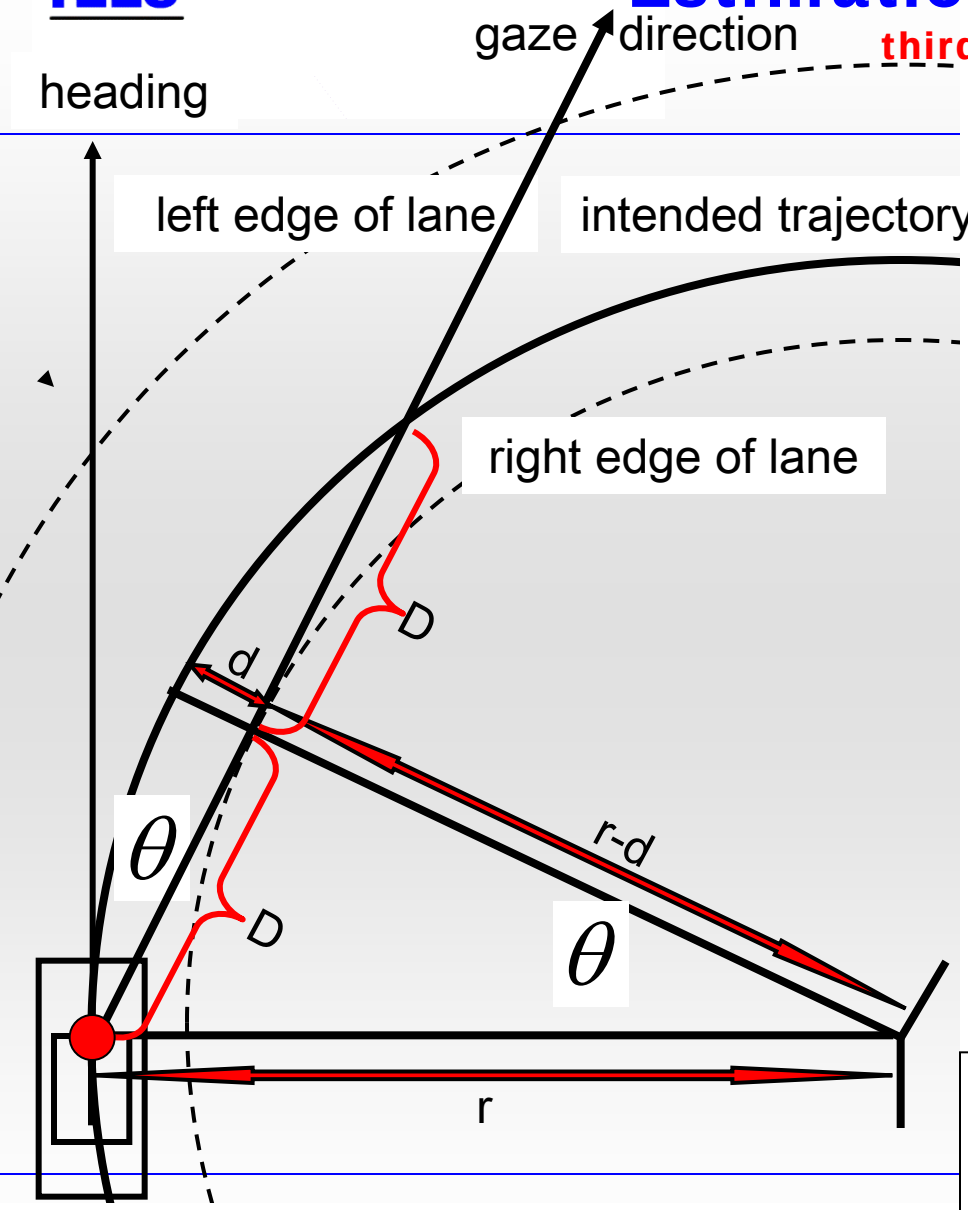
Estimation of Curvature: Ausholen

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 …