

CTR



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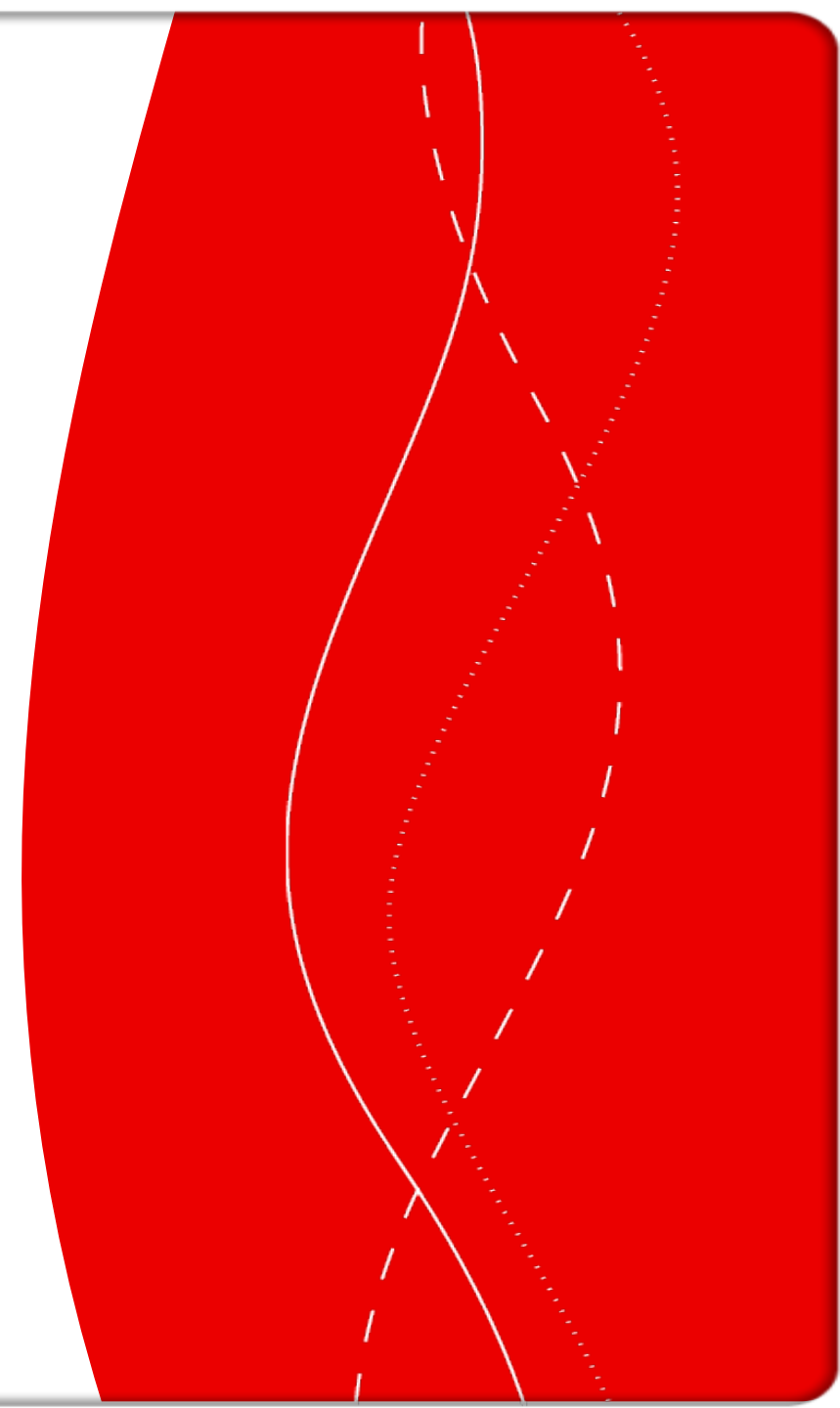
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LINKÖPINGS UNIVERSITET

**Trafiksimulering av självkörande fordon –
hur kan osäkerheter gällande kör-
beteende och heterogenitet hanteras**

CTR-dagen 2018, Stockholm

Johan Olstam



Agenda

- What is an automated vehicle?
- Challenges for traffic simulations of CAVs
- A way to deal with heterogeneity of CAV behavior
- A way to deal with uncertainties w.r.t. evolution of CAVs

Large expectations, but deployment of automated vehicles

- will not develop in a perfectly **linear transition** phase to 100% penetration,
- will require **sharing roads** among diversely equipped road users (probably for a long time),
- will be the result of **technological** progress, **market** development, **regulation**, and urban mobility **policy** making.
- has the **potential/risk** to increase travel demand, vehicle miles travelled, ...
- ... OR to provide the basis for a **fundamental shift** in urban mobility (shared, safer, cleaner, more personalized, more space-efficient)

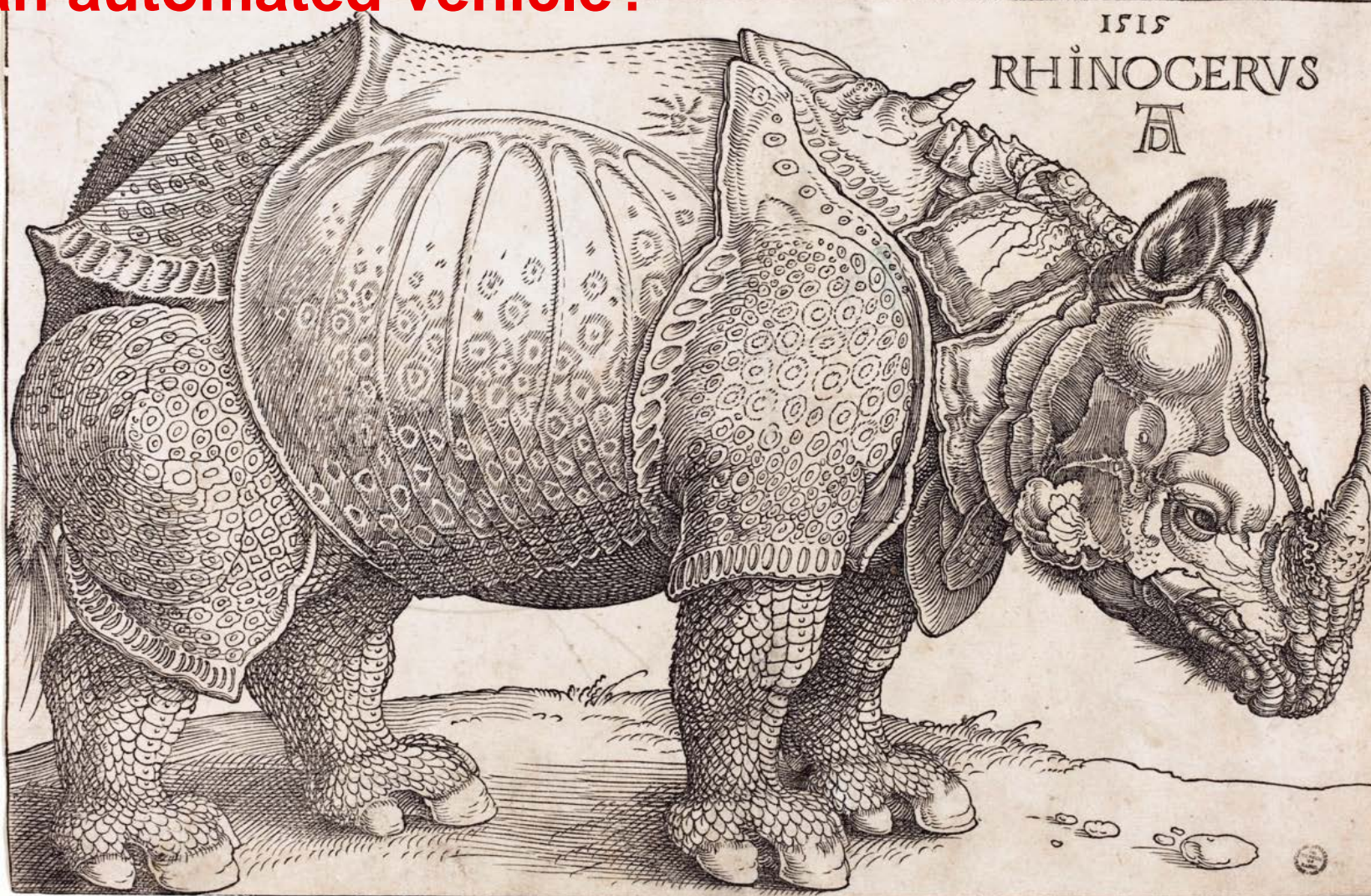


Classification of automated vehicles

SAE level	Short description
0 – No automation	Full-time performance by a human
1 – Driver Assistance	Assistance system of either steering or acceleration/deceleration
2 – Partial Automation	Automation of some parts of the driving task
3 – Conditional Automation	Self driving but driver responsible and required to intervene if necessary
4 – High Automation	Self driving in some environment – driver not responsible
5 – Full Automation	Self driving everywhere

Nach Christus gepurt. 1513. Jar. Abt. i. May. Hat man dem großmectigen Kunig von Portugall Emannell gen Lysabona pracht auß India/ein sollich lebendig Thier. Das nennen sie Rhinocerus. Das ist hye mit aller seiner gest. ale Abcondertset. Es hat ein farb wie ein gespreckelte Schildkrot. Vnd ist vß dicken Schalen vberlegt fast fest. Vnd ist in der groß als der Helffandte Aber nydertrechtiger von paynen/vnd fast weh afftig. Es hat ein scharff starck Horn vorn auff der nase/Das begyndt es albeg zu wezen wo es bey staynen ist. Das drossig Thier ist des Helff fang todt feynde. Der Helffandte furcht es fast vbel/dann wo es In ankunde/so laufft In das Thier mit dem kopff zwischen dye sordern payn/vnd reyst den Helffandte vnden am pauch auff In würrt In dem nager schmit mit dem Horn das Thier In die geyren. In der Helffandte nichts kan thun. Sie sagen auch das der Rhinocerus Schnell/ fraydig vnd Listig sey.

What is an automated vehicle?



Challenges for traffic simulation of CAVs

- Limited data on first generation CAVs
- No data on future CAVs
- Transition towards full automation will be long



Large uncertainties w.r.t.

- Driving behaviour of CAVs
- Evolution of CAV technology and penetration rates
- Behaviour of other road users in response to CAVs

Hierarchical specification of CAV driving behaviour

The level of automation is specified in three steps:

- **AV class**
 - Basic
 - Intermediate
 - Advanced
- **Driving logic** (for different road environments)
 - Rail-safe
 - Cautious
 - Normal
 - All-knowing
- **Functions**
 - ACC
 - Lane keep assistance
 - Jam assistance
 - Etc.

Connectivity levels

- **Exchange of data for vehicle information functions:**
 - Data on the network, the state of the network and the environment of the network.
 - Data to service providers (e.g. vehicle position, state of the vehicle).
- **Exchange of data for vehicle communication functions:**
 - Communication between specific vehicles or specific roadside devices (V2V and V2I or via the Internet).
 - Enables better estimations the behaviour of neighbouring vehicles (e.g. indicating a lane change)
 - Enables better estimations of current or future state of a traffic sign (traffic light, variable speed limits).
- **Exchange of data for vehicle cooperating functions:**
 - Enables AVs to cooperate with other AVs or traffic control devices.
 - Cooperation includes merging, lane changing and the forming of platoons.

AV classes

- **Basic:**
 - SD only in one directional traffic with physical separation to active modes.
 - No dedicated devices for vehicle communication and cooperating functions.
- **Intermediate:**
 - SD in structured traffic.
 - May have dedicated devices for vehicle communication and cooperating functions, but are not depended on them.
- **Advanced:**
 - SD in most environments
 - Will have dedicated devices for vehicle communication and cooperating functions, but are not depended on them.

All three prioritize safety, but the more advanced able to safely drive more offensively than the less advanced.

Driving logics

- **Rail-safe:** Based on the switch principle. Follows pre-defined path.
- **Cautious:** Require large gaps; slows down every time its sensors can have blind angles.
- **Normal:** Similar to an average human driver but with the augmented (and/or diminished) perception due to sensors.
- **All-knowing:** Perfect perception and prediction of the behaviour of other road users. Capable of aggressive whenever is needed, without causing accidents.

Stages of coexistence

- **Introductory:**
 - Majority of vehicles still conventional cars.
 - Automated driving significantly constrained by limitations (real or perceived) in the technology.
- **Established:**
 - Automated driving established as an important mode in some areas.
 - Conventional driving still dominates some areas due to limitations (real or perceived) in the technology.
- **Prevalent:**
 - Automated driving is the norm,
 - but conventional driving is still present.

Example driving logics for cars

Vehicle type: Car			
Road type	Driving logic: Rail-Safe (RS), Cautious (C), Normal (N), All-Knowing (AK), Manual (M)		
	Basic	Intermediate	Advanced
Motorway	C	N	AK
Arterial	C	C / N	AK
Urban street	M	C	N
Shared space	M	RS / M	C

Example of penetration rates & shares

	AV penetration	Basic AV share	Intermediate AV share	Advanced AV share
Introductory	10-40	70-100	0-30	
Established	30-70	0-20	80-100	0-10
Prevalent	60-90		20-80	20-80

Conclusions

- Simulations of CAVs requires sensitivity analysis
- Simulations of the 100% CAV case is interesting as reference...
- ...but the transition period will probably be long
- Simulations of AVs for the transition period should consider correlation between penetration rate and level of automation



Mostphotos