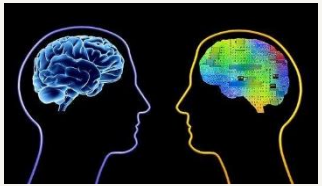
中国自动化学会 — 车辆控制与智能化专业委员会（CAA TC on VCI）





Automated Driving: From Cognitive Intelligence to Parallel Intelligence

自动驾驶：从认知智能到平行智能

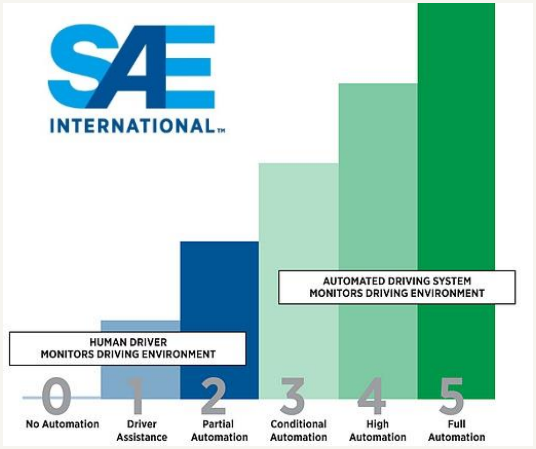
曹东璞
英国克兰菲尔德大学驾驶员认知与自动驾驶实验室主任
王飞跃
中科院自动化所复杂系统管理与控制国家重点实验室主任

2017年6月25日于长春

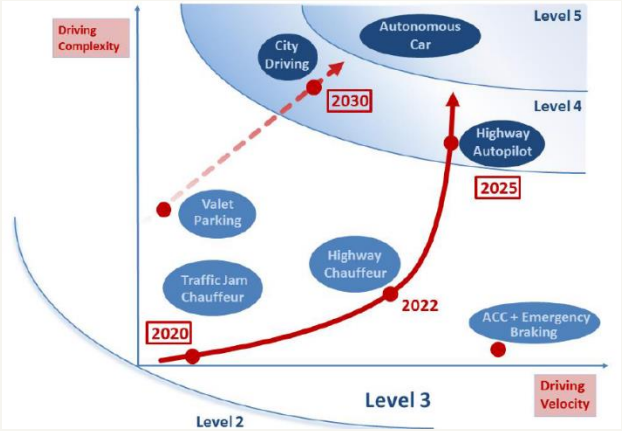
Outline (大纲)

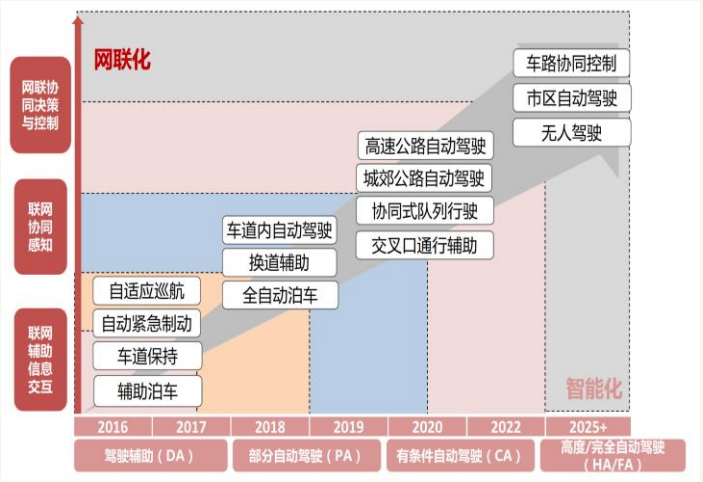
- Intro & roadmaps
- Automated driving: cognitive intelligence
  - Framework of CACDM
  - Selected recent/on-going research activities
- Automated driving: parallel intelligence
  - Framework of parallel driving
  - Selected recent/on-going research activities
- Welcome to IEEE IV'2018

Vehicle automation: definitions & roadmaps (US, EU, China)

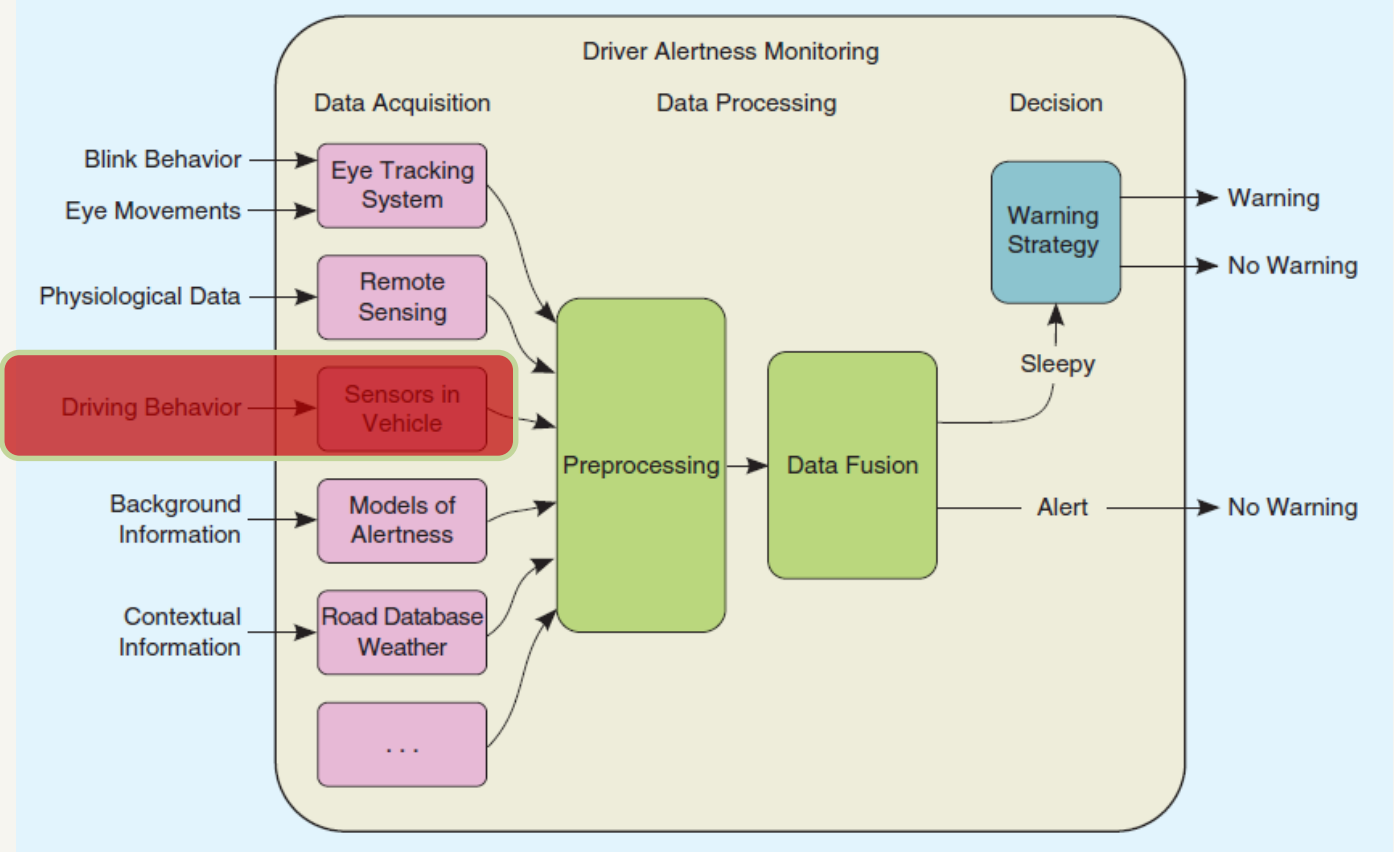


- By 2020: L3 at low speeds or less complex driving scenarios;
- By 2025: L4 on motorways;
- By 2030: L4 in cities (urban driving).





Current ADAS technologies for future? E.g.



Input information depends on the level of automated driving (e.g., typically no driving behavior info for L2 and L3 automation).

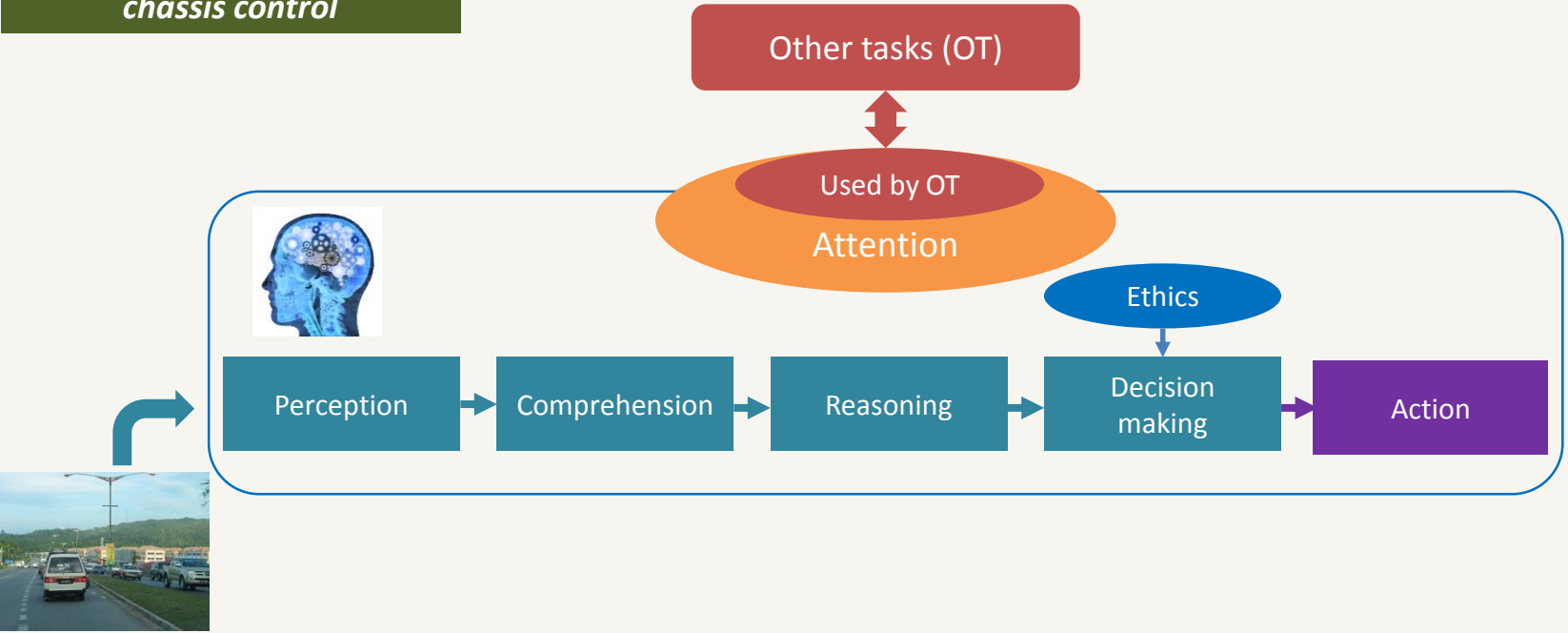
How to achieve a desirable driver-automation collaboration for L1~L3 automation?

Collaborative augmented cognition and decision making (CACDM) for driver-automation collaboration

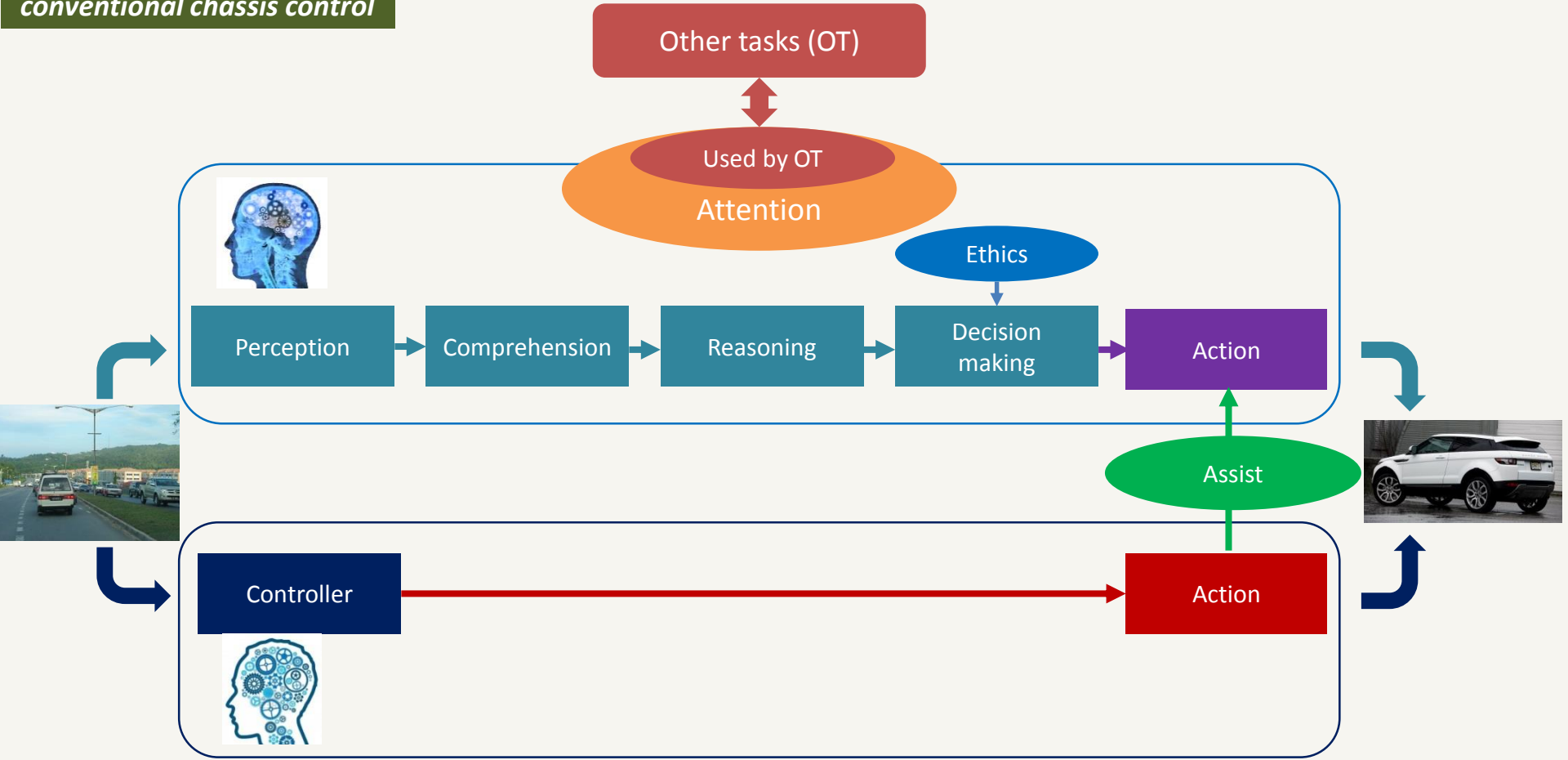
Cognition ??

Using "information processing" approach to simplify

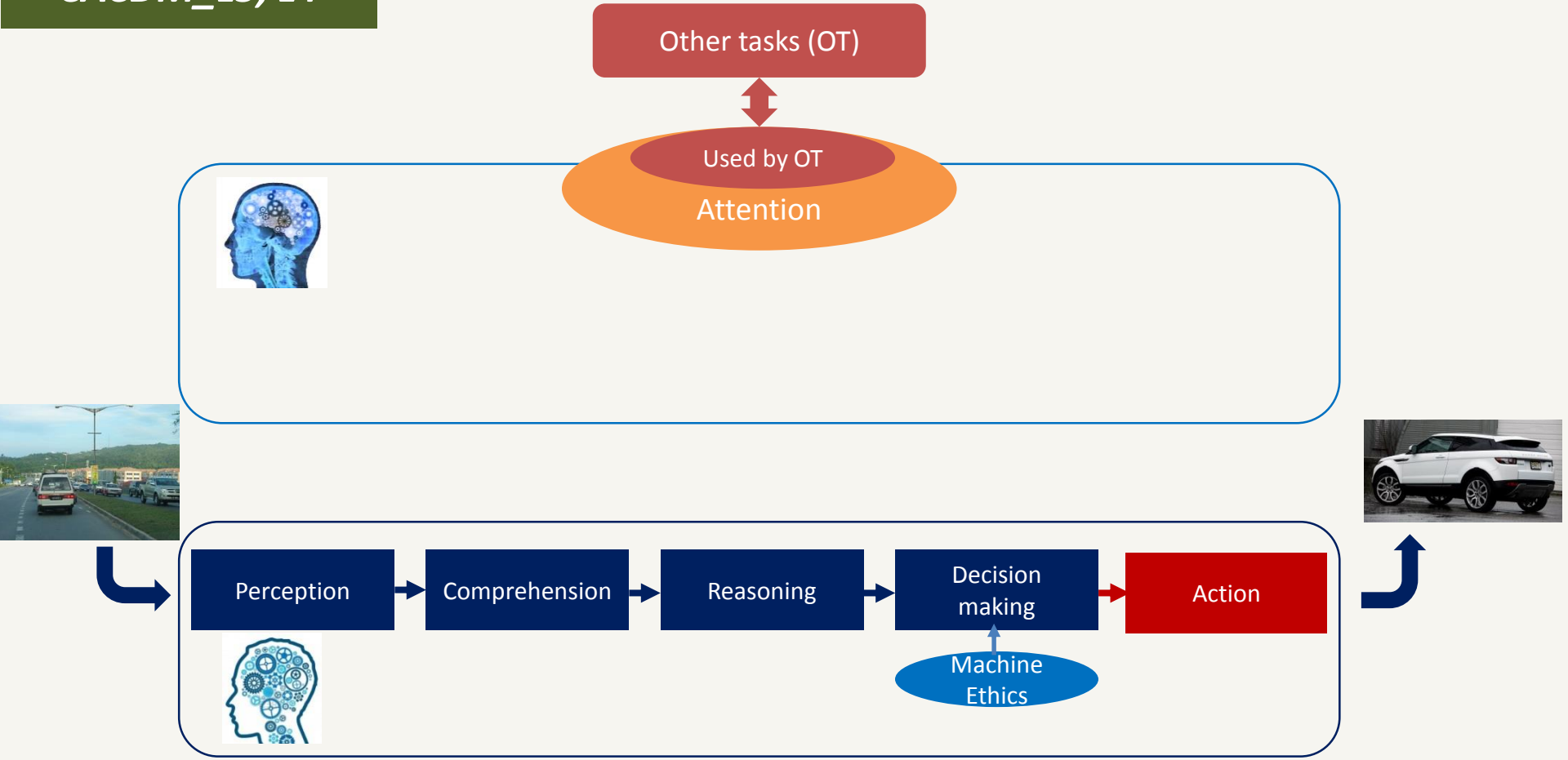
CACDM_L0_no conventional chassis control



CACDM_L0_with conventional chassis control

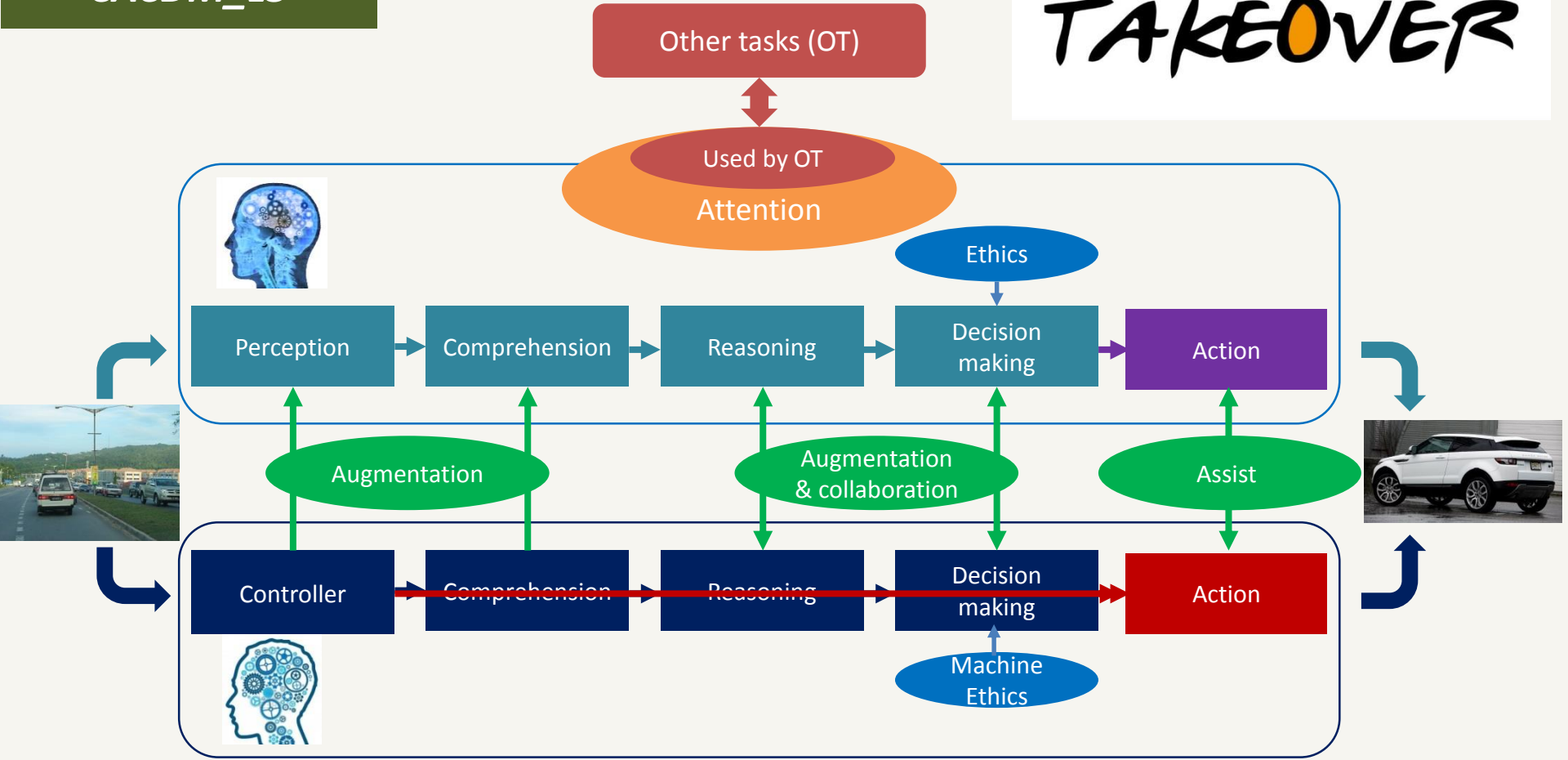


CACDM_L5, L4


Other tasks (OT)
Used by OT
Attention
Perception
Comprehension
Reasoning
Decision making
Action
Machine Ethics

CACDM_L3

TAKEOVER



Task switching in cognitive psychology

134 Review TRENDS in Cognitive Sciences Vol.7 No.3 March 2003

Task switching

Stephen Monsell

Performance measures:
response time (RT) and error rate

Switch costs

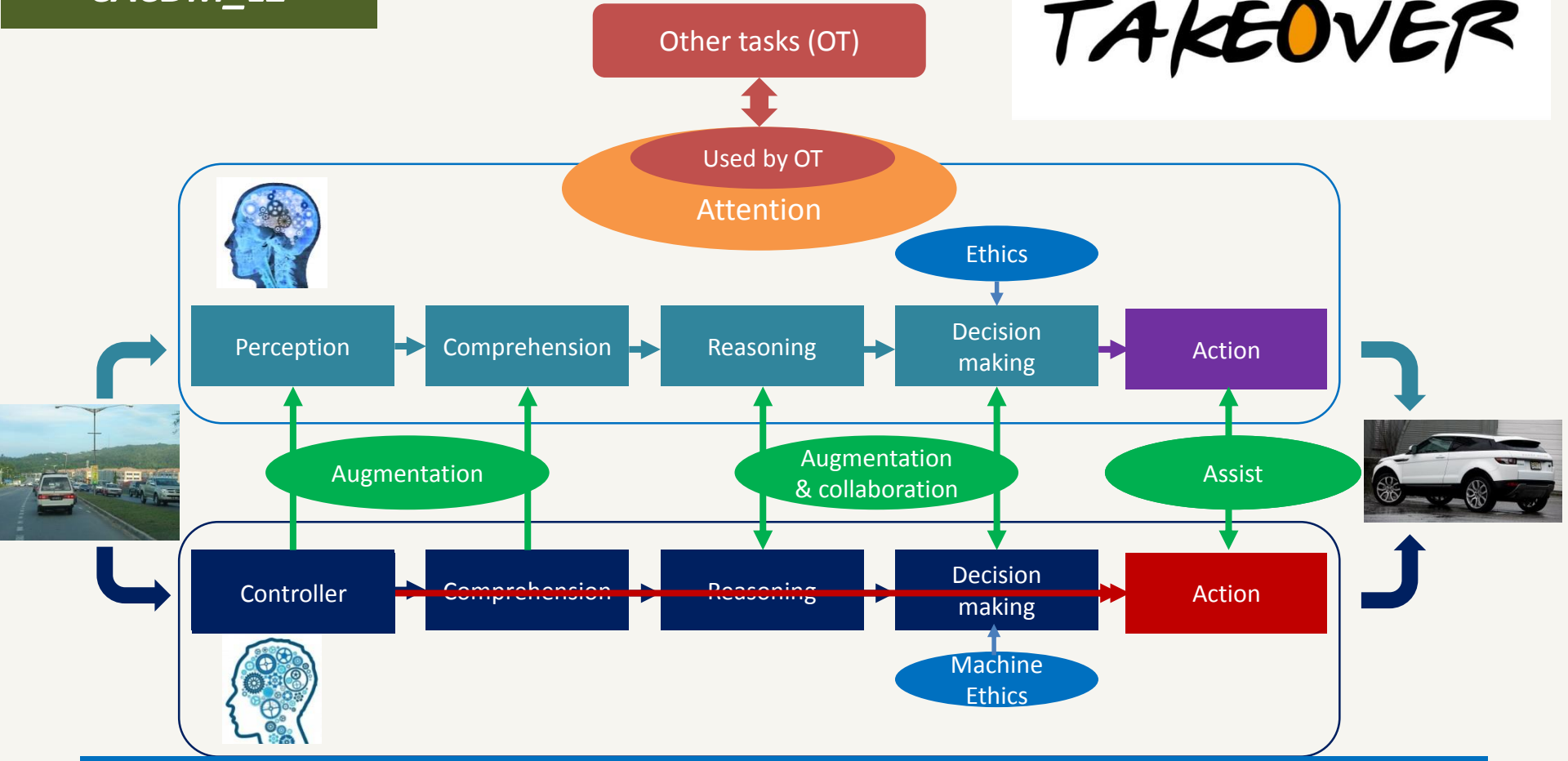
I
- Previous task disengagement (attention disengaging)

II
- Task reconfiguration (task preparation)

III
- Task engagement (attention engaging)

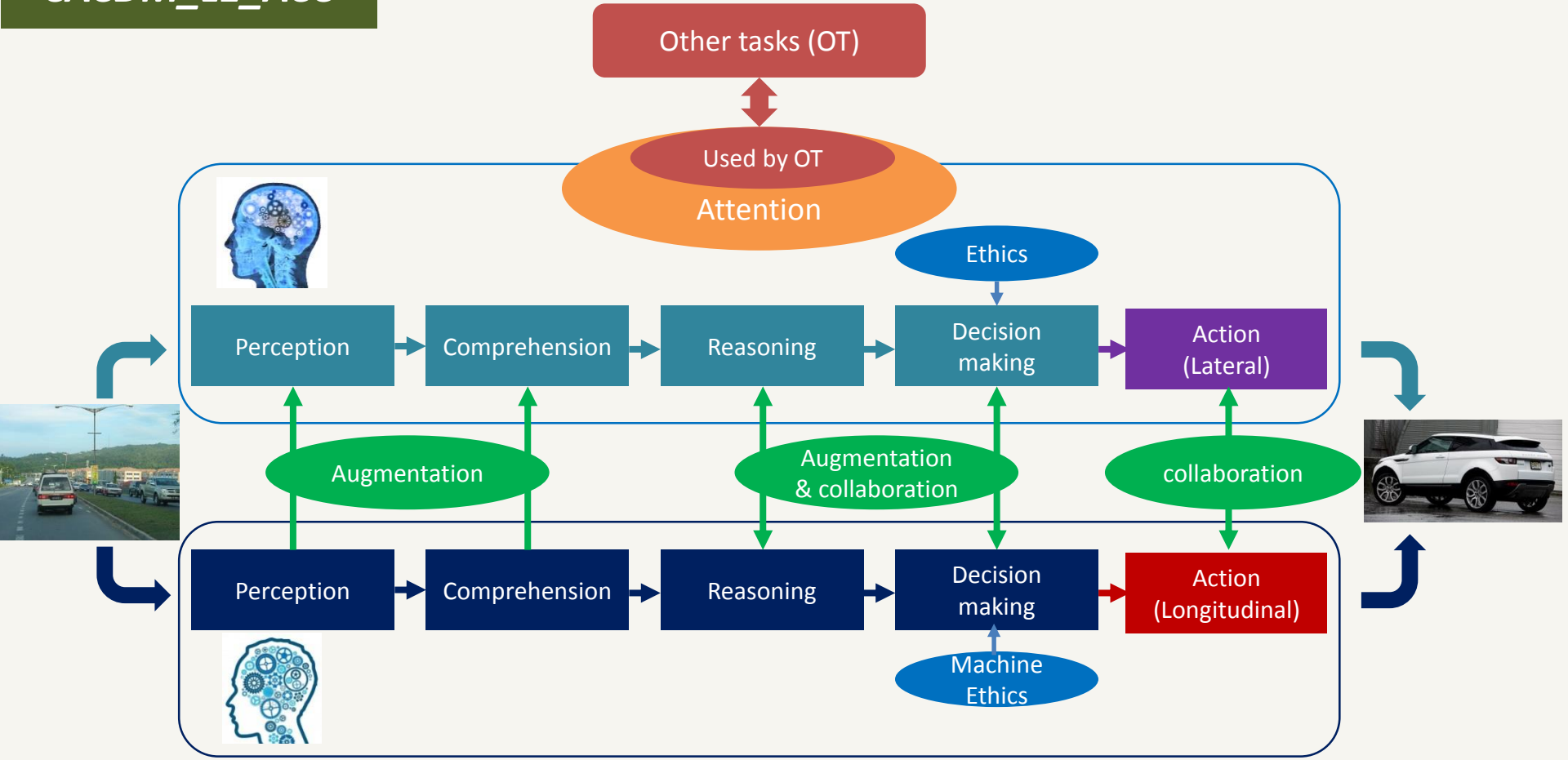
CACDM_L2

TAKEOVER

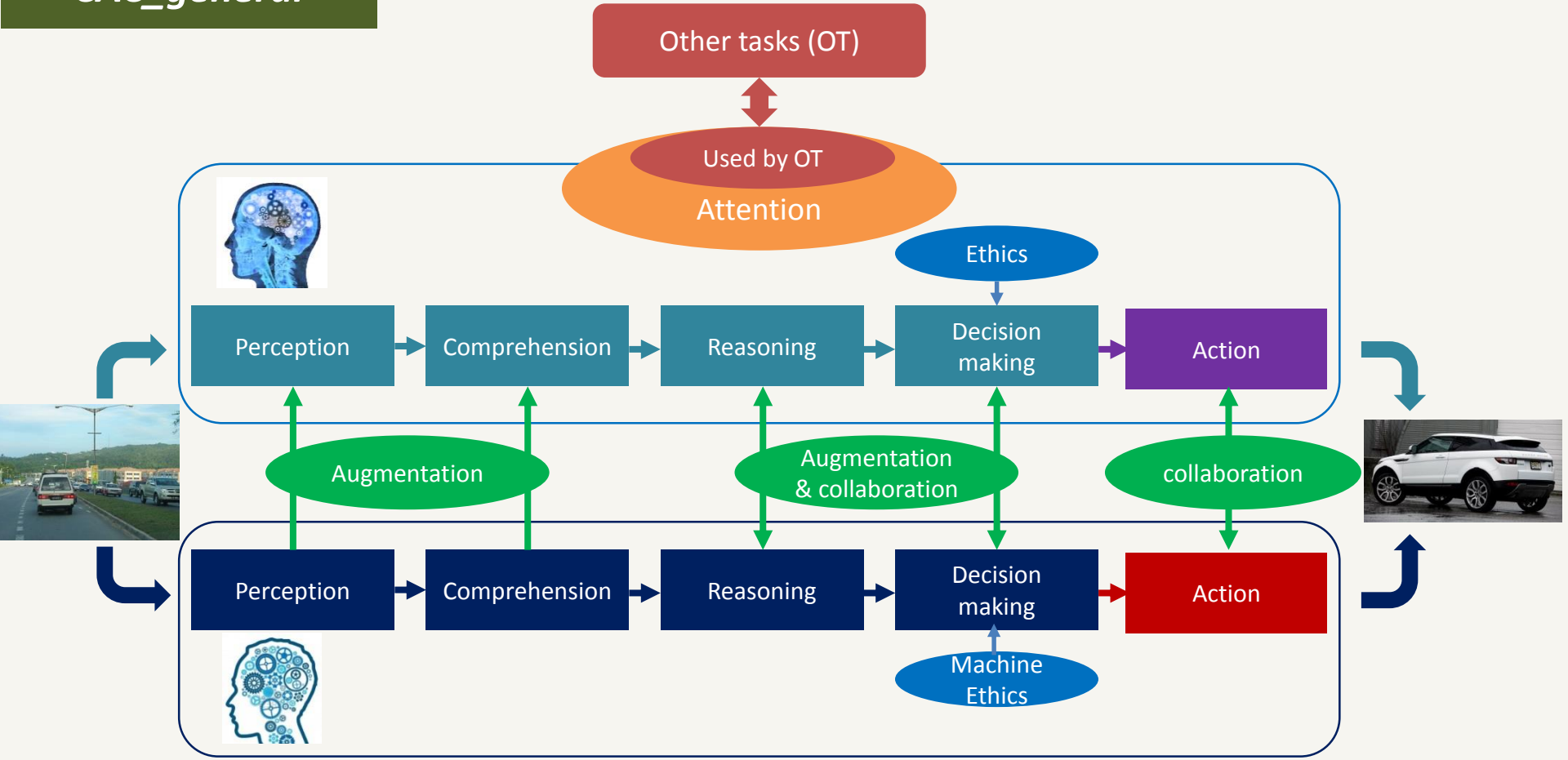


Driver-Collision Avoidance System Collaboration: joint decision making & shared control

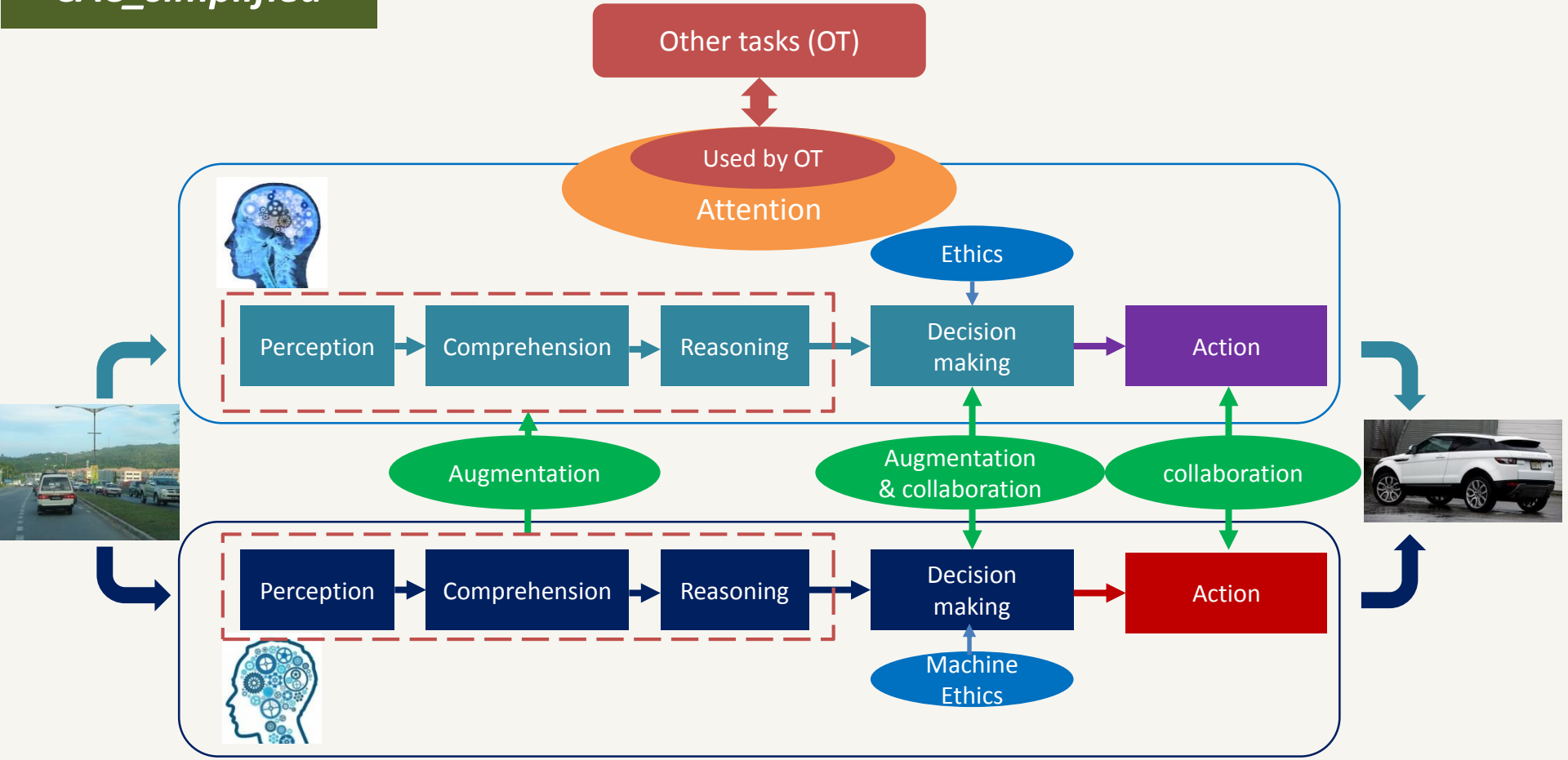
CACDM_L1_ACC


Other tasks (OT)
Used by OT
Attention
Ethics
Perception
Comprehension
Reasoning
Decision making
Action (Lateral)
Augmentation
Augmentation & collaboration
collaboration
Perception
Comprehension
Reasoning
Decision making
Action (Longitudinal)
Machine Ethics

CAC_general


Other tasks (OT)
Used by OT
Attention
Ethics
Perception
Comprehension
Reasoning
Decision making
Action
Augmentation
Augmentation & collaboration
collaboration
Perception
Comprehension
Reasoning
Decision making
Action
Machine Ethics

CAC_simplified



CACDM

Perception → Comprehension → Reasoning

Augmentation

Perception → Comprehension → Reasoning

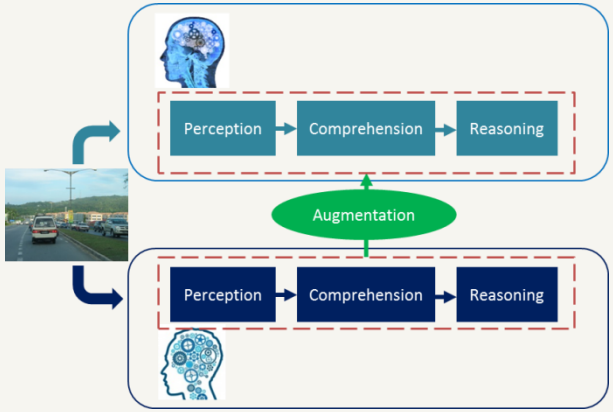
Augmented reality

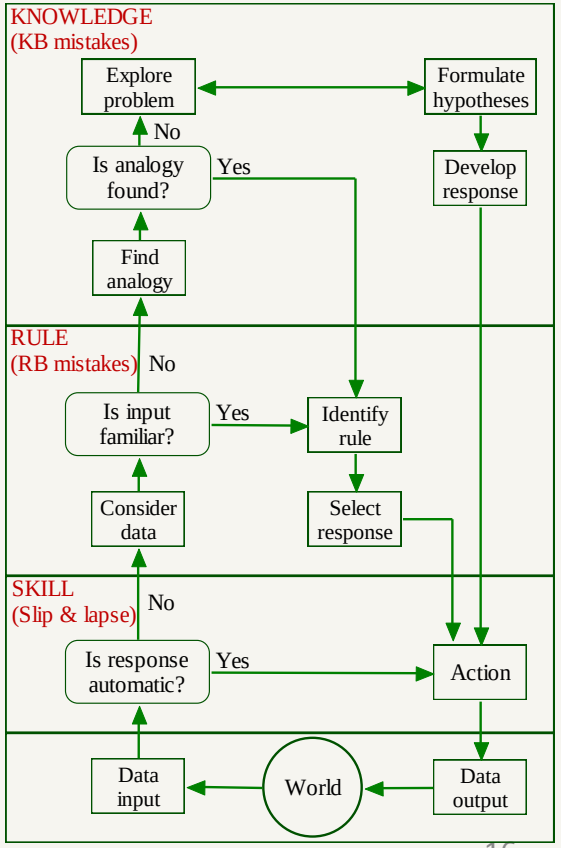
Driver Challenges in Perception and Attention

Perception	Attention
• Registration	• Driver Distraction
• Depth Perception	• Clutter & Occlusion
• Focus Distance	• Over-Reliance
• Color Blending	
• Visual Acuity	

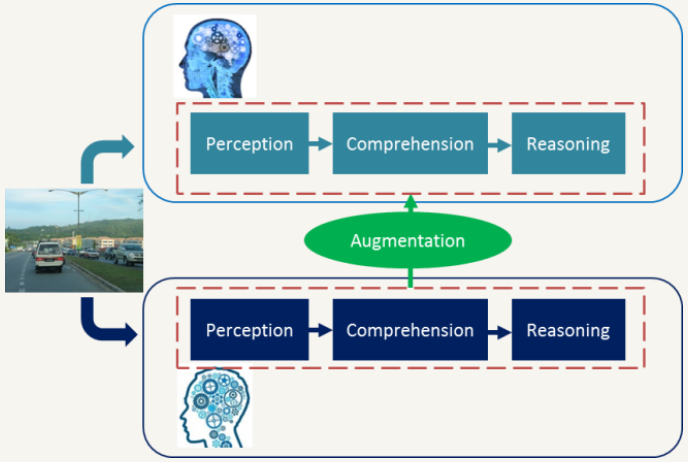
CACDM

Where to see when driving?

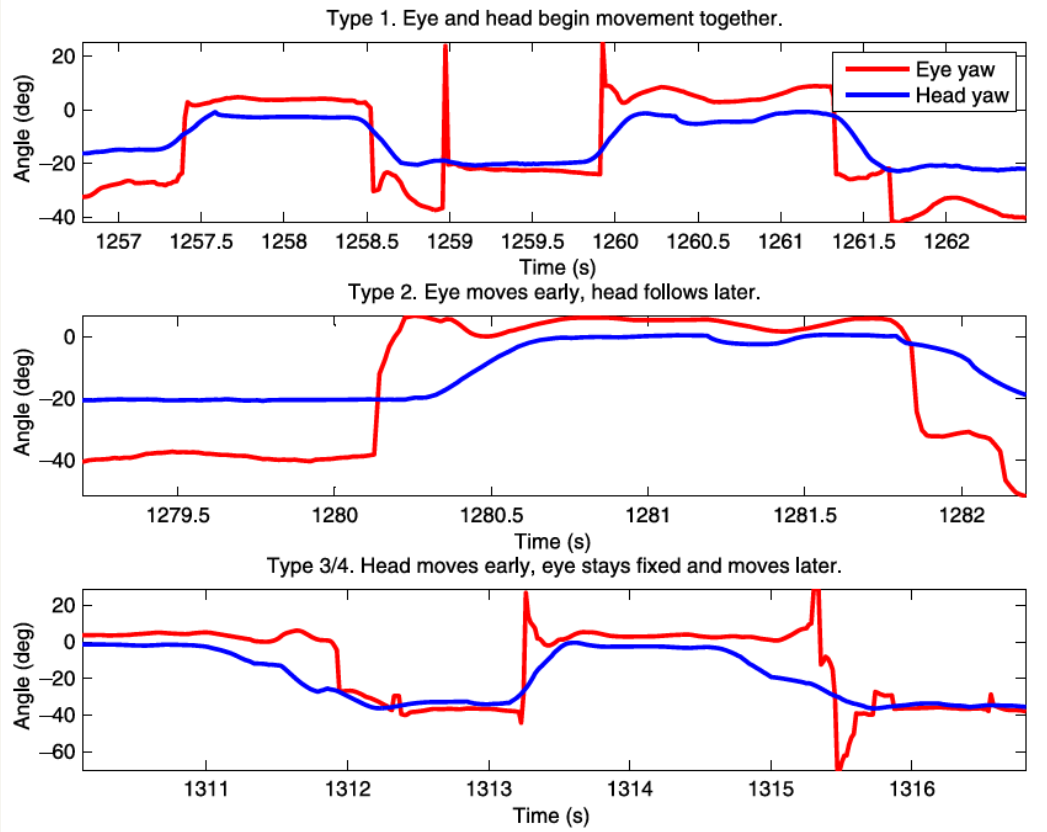




CACDM



Eye-head or eye-head-steering coordination and dynamics



J of Vision, 2012

CACDM

Eye-head or eye-head-steering coordination and dynamics

Fig. 4. A snapshot of the software developed for the proposed head tracking system

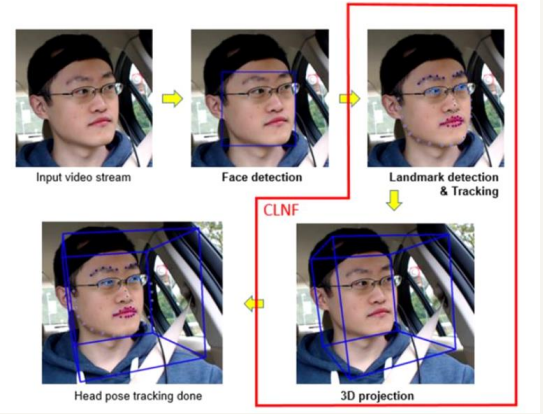
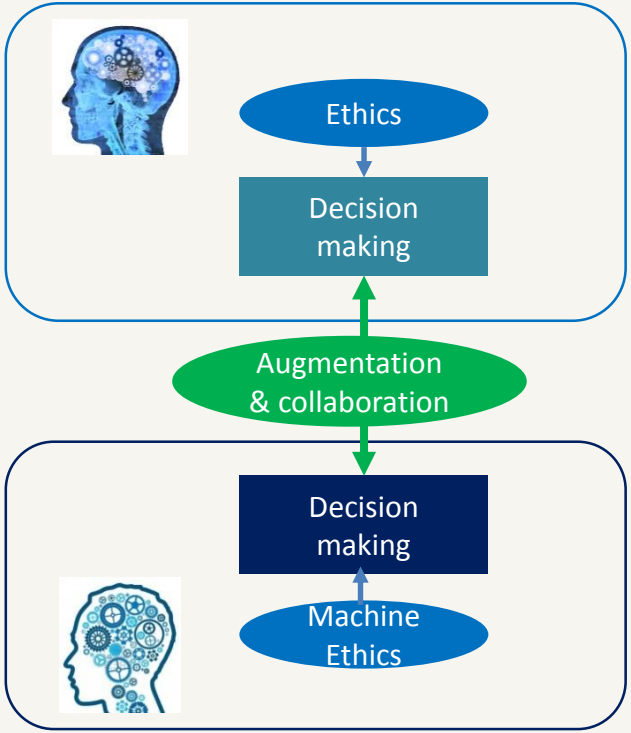
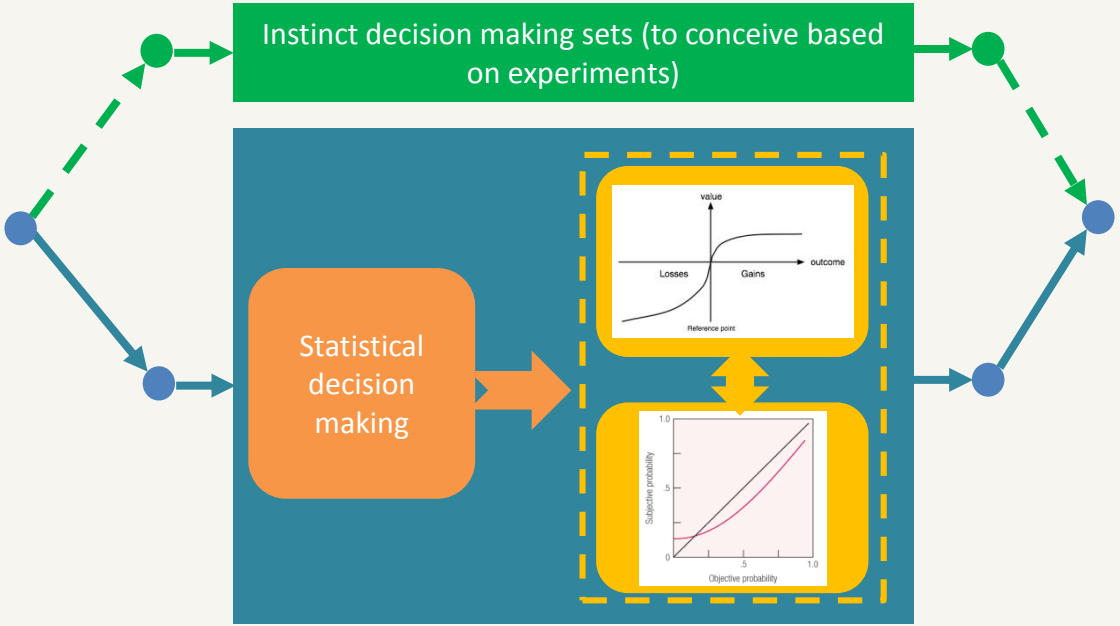


Fig. 9. The LED Indicator used for synchronisation between two tracking systems. Left: Off, Right: On.

CACDM



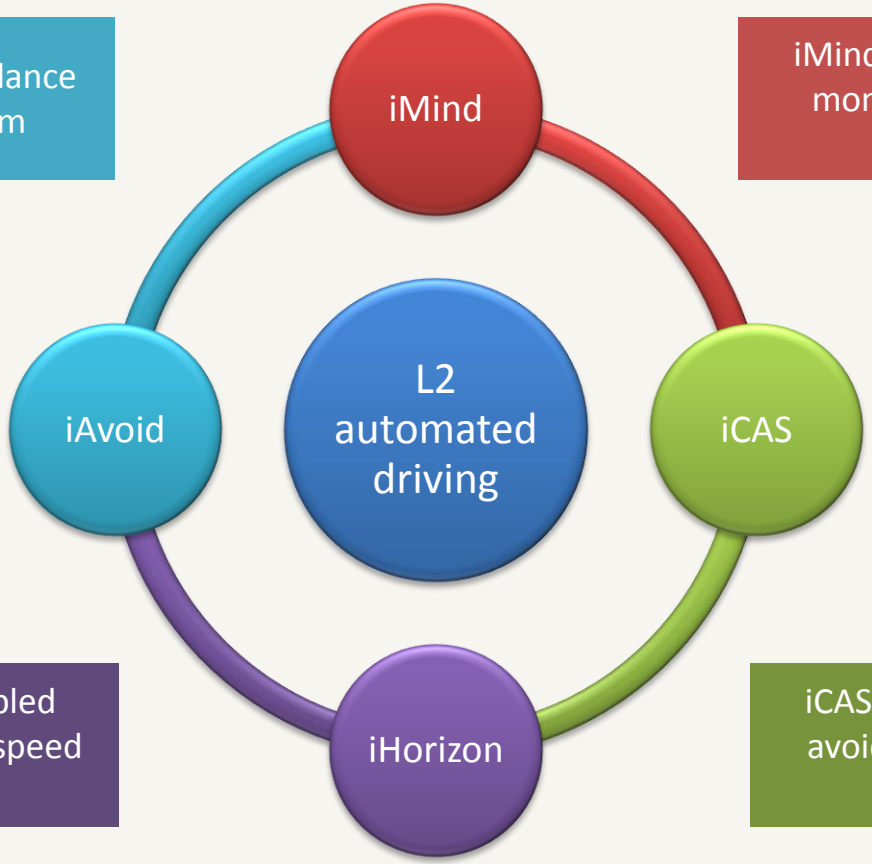
For human driver driving decision making, a dual-process model integrating statistical decision theory and personalized ‘subjective utility’ and ‘subjective probability’ can be used.



二级自动驾驶4i安全智驾系统

iAvoid: Vehicle collision avoidance capacity monitoring system

iMind: Driver mind-on-the-road monitoring system for level-2 automated driving



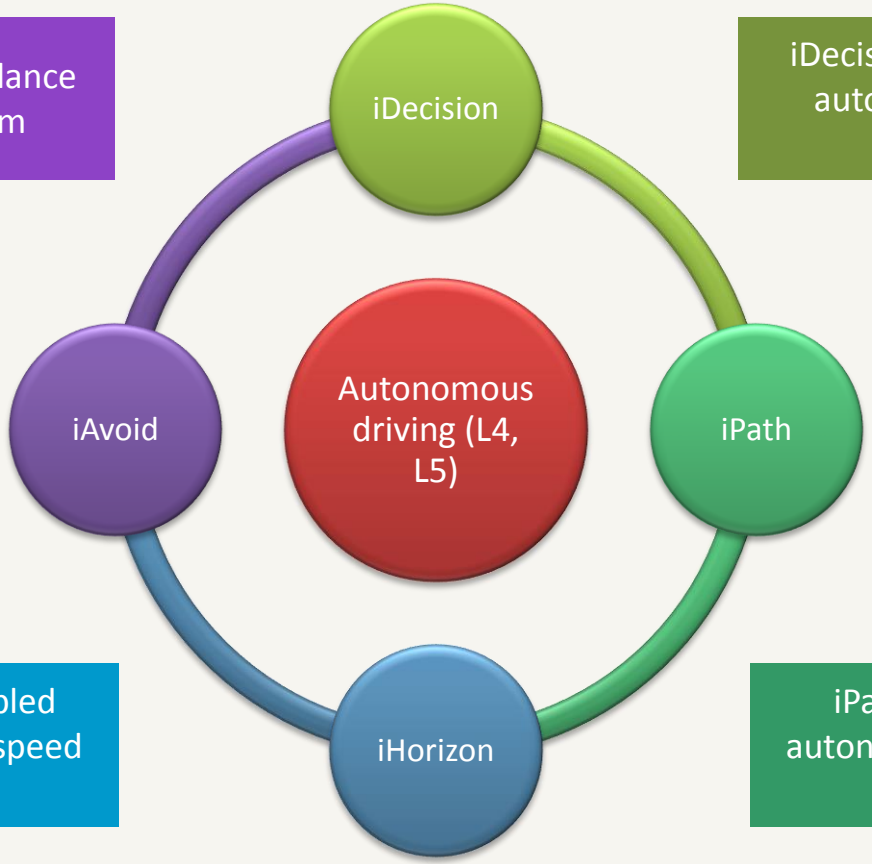
iHorizon: Driving-style enabled short- and long-term future speed prediction system

iCAS: Intelligent driver-collision-avoidance-system collaboration system

自主驾驶4i安全智驾系统

iAvoid: Vehicle collision avoidance capacity monitoring system

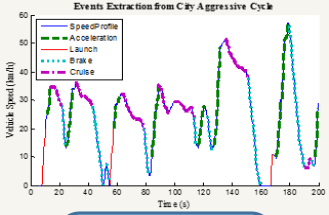
iDecision: Intelligent human-like autonomous driving decision making system

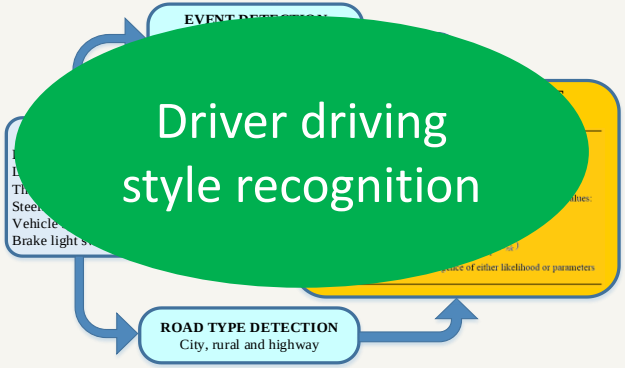


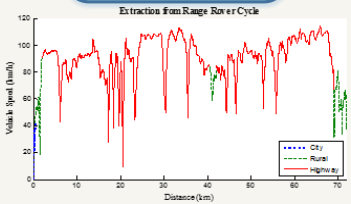
iHorizon: Driving-style enabled short- and long-term future speed prediction

iPath: Intelligent human-like autonomous driving path planning system

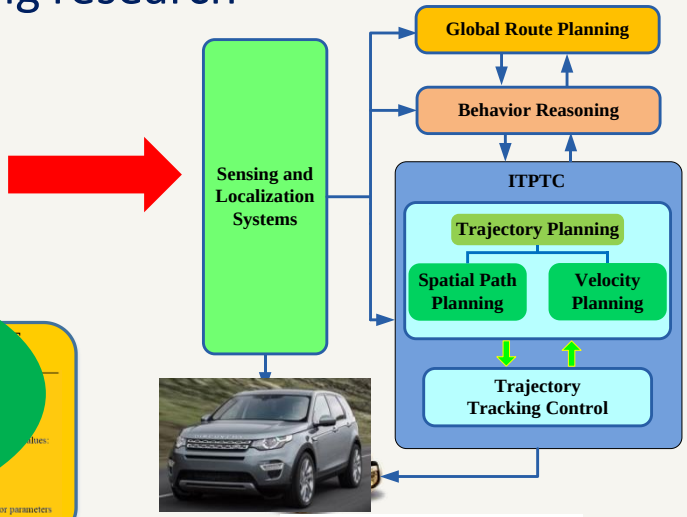
iPath: recent and on-going research

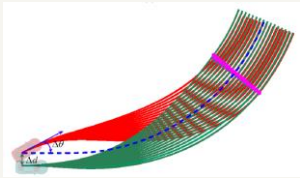


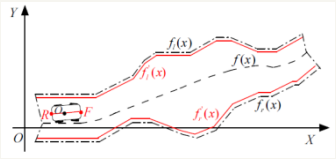


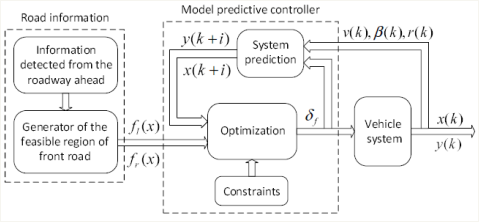


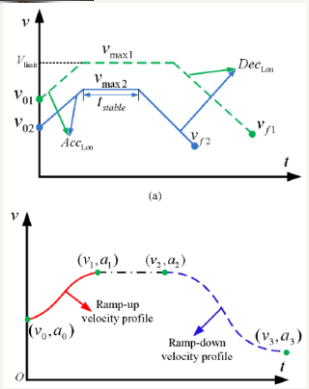
Driver driving style recognition

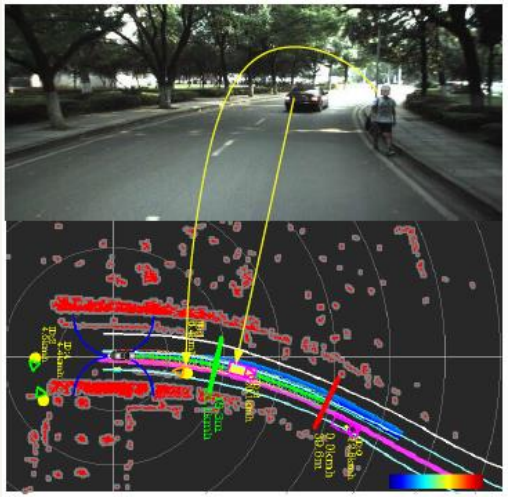








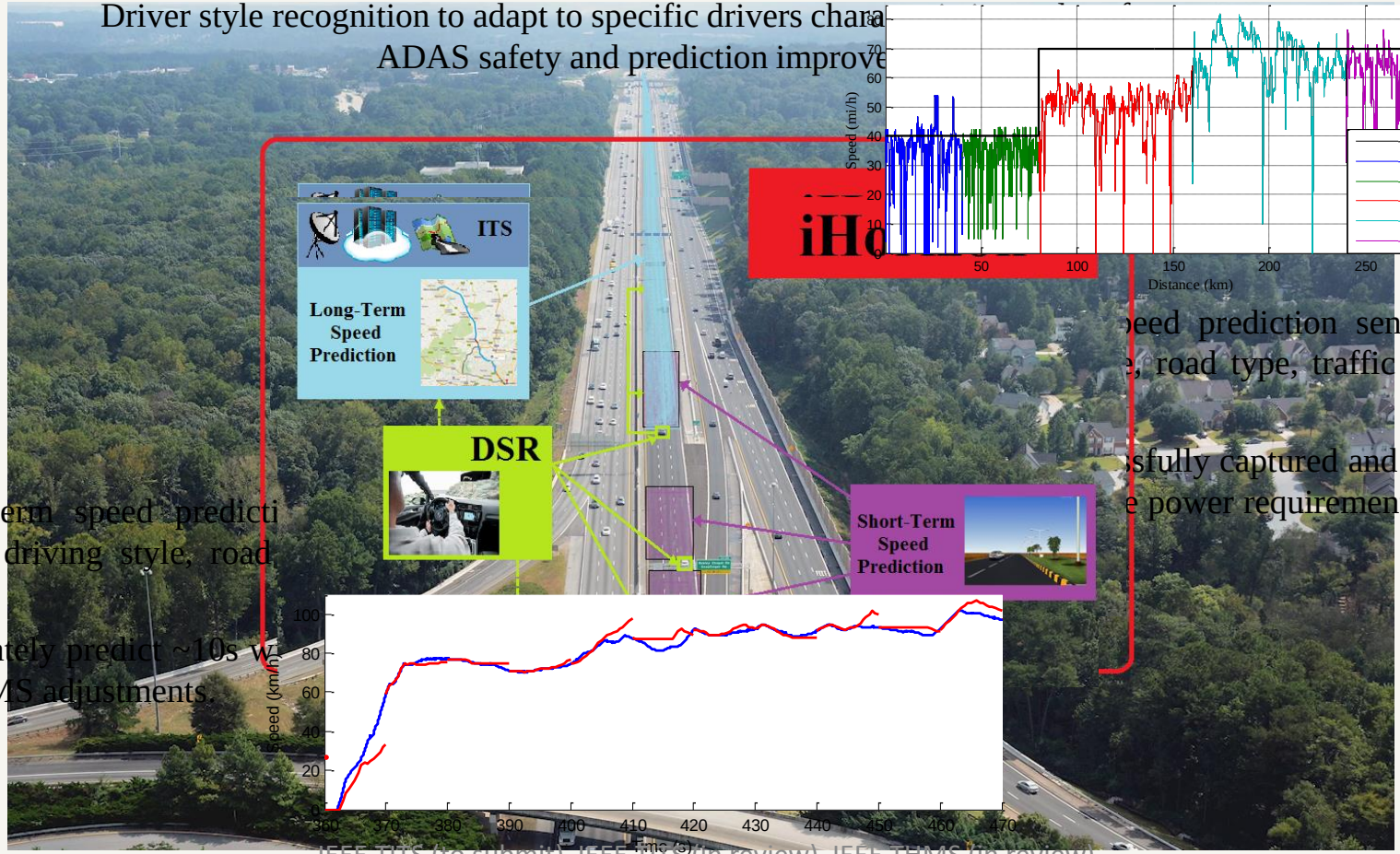




IEEE/ASME TMECH (2016), MSSP (2015), IEEE TITS (in review), IEEE THMS (in review), Mechatronics (in review)

iHorizon: recent and on-going research

Driver style recognition to adapt to specific drivers chara
ADAS safety and prediction improve



eed prediction sensitive
, road type, traffic level

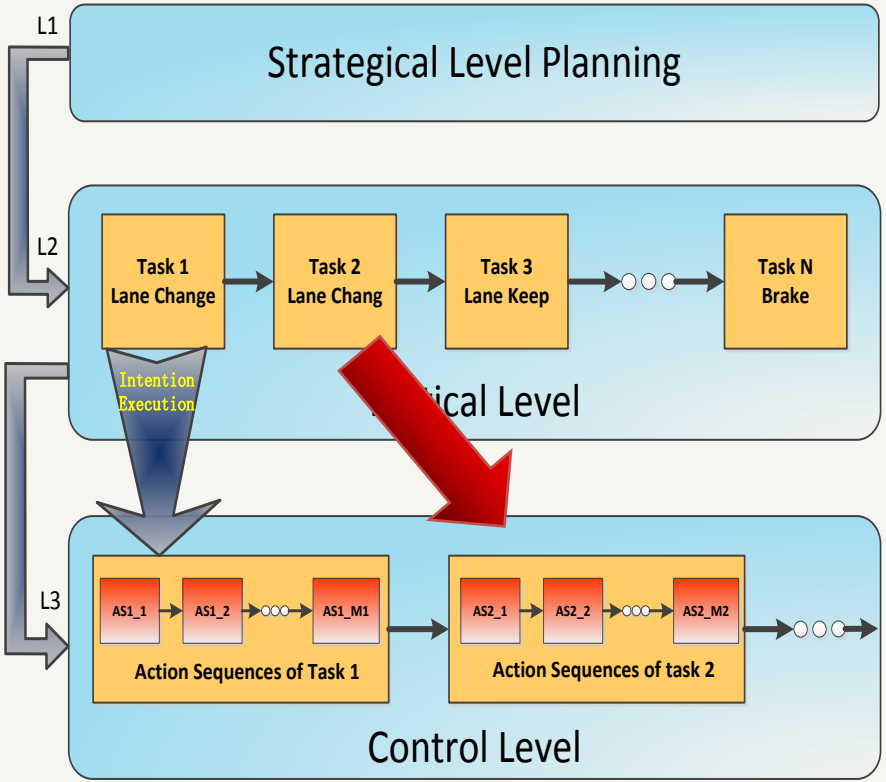
sfully captured and good
e power requirements per

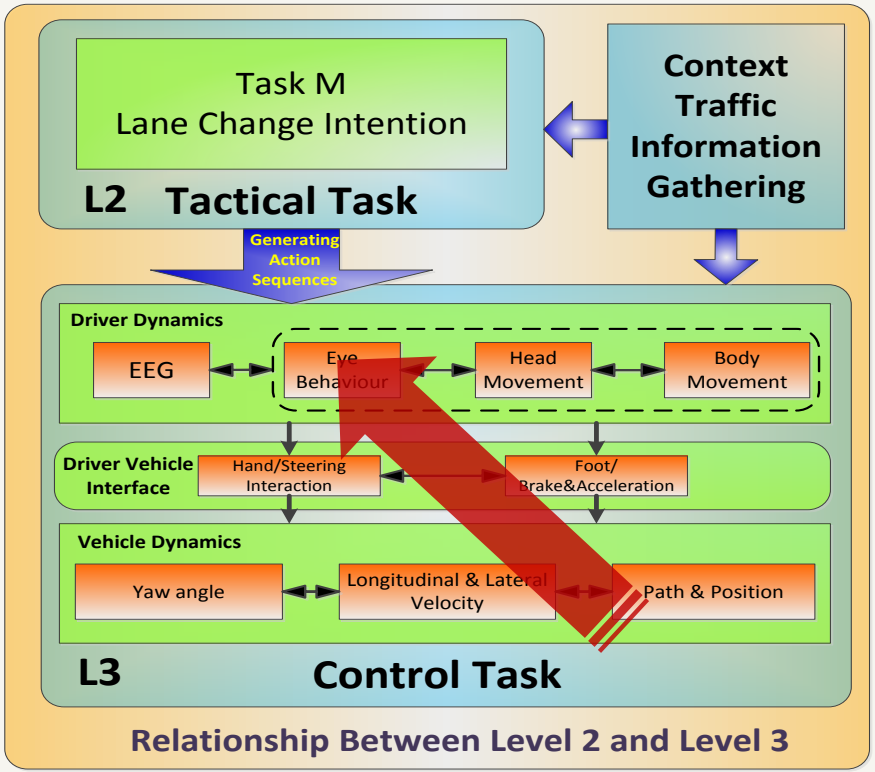
Short-term speed predicti
driver driving style, road
level.

Accurately predict ~10s w
and EMS adjustments.

IEEE TITS (to submit), IEEE TITS (in review), IEEE THMS (in review)

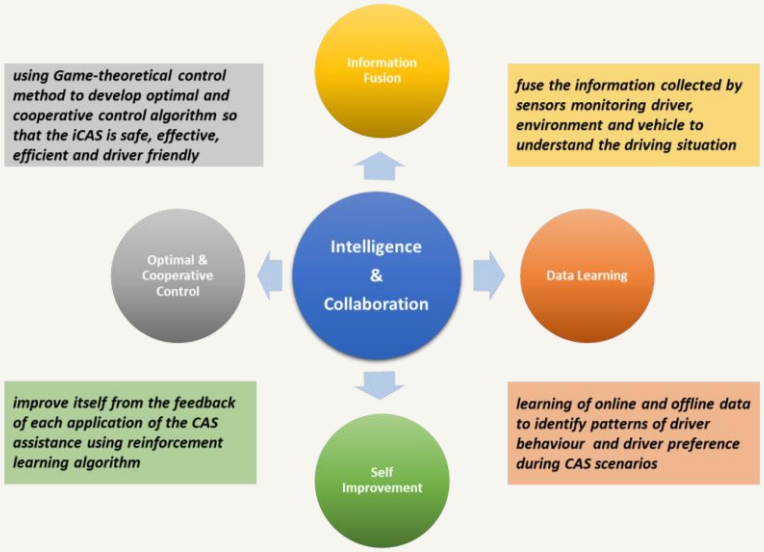
iMind and iDecision: recent and on-going research





Multiple papers published or submitted.

iAvoid and iCAS: recent and on-going research

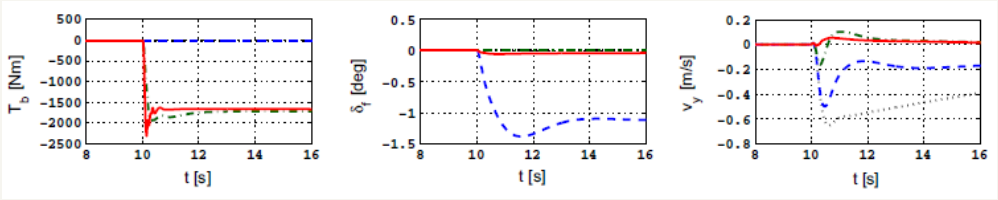


Information Fusion： 实时获得交通环境信息、车辆状态信息、以及驾驶员信息，通过信息融合，明确iCAS所处的工作环境。

Data Learning： 分析和学习线上和线下数据（传感器历史数据、其他途径获取的交通信息数据、驾驶员行为及偏好数据等）分析得到驾驶员的行为特征和CAS工况下的辅助偏好等。

Self Improvement： 使用reinforcement learning等算法，iCAS能够从每次工作后得到的反馈中分析辅助效果，提升工作性能。

Optimal and Cooperative Control： 基于类似Game-theoretical Control等的方法，设计iCAS的最优协同控制器；iCAS能够在与驾驶员合作的同时达到CAS工况下的最优控制。



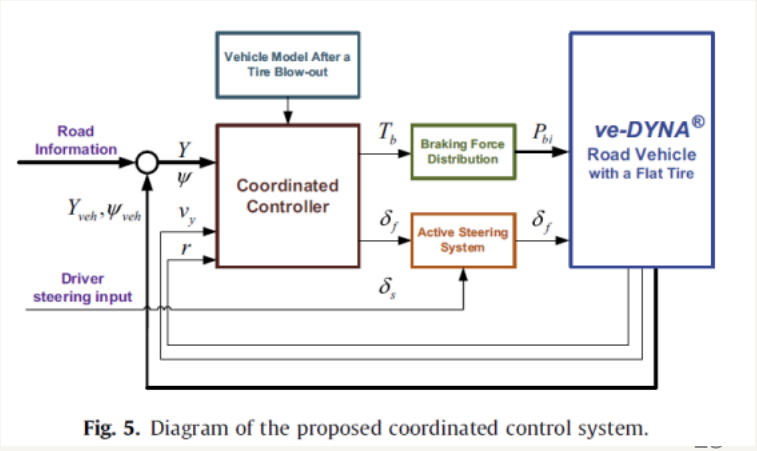
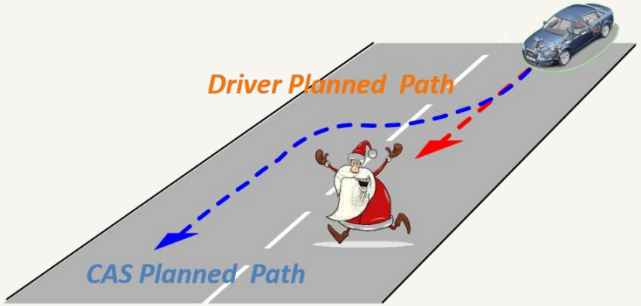
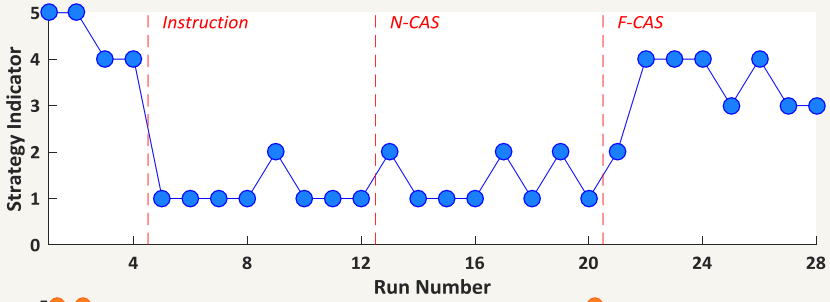


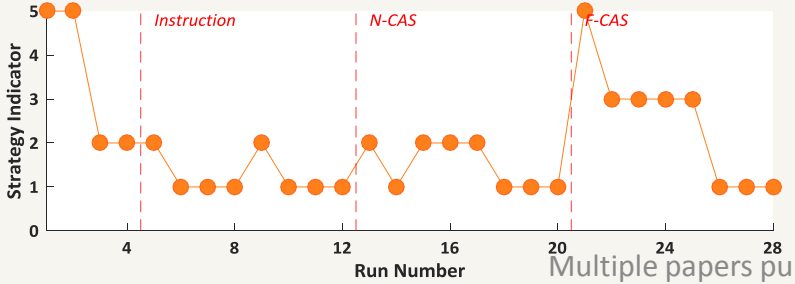
Fig. 5. Diagram of the proposed coordinated control system.

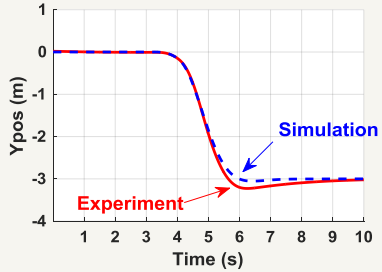
Multiple papers published or submitted.

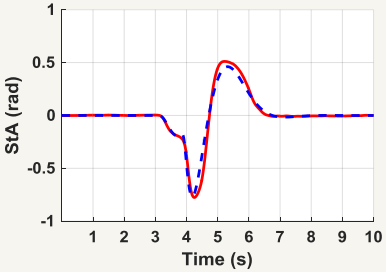
iAvoid and iCAS: recent and on-going research

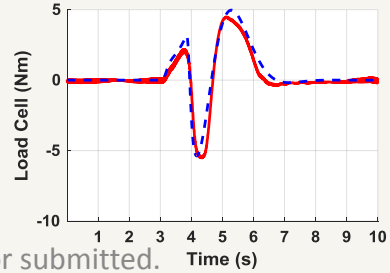


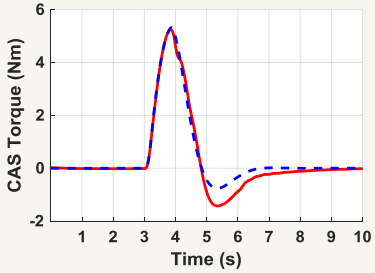








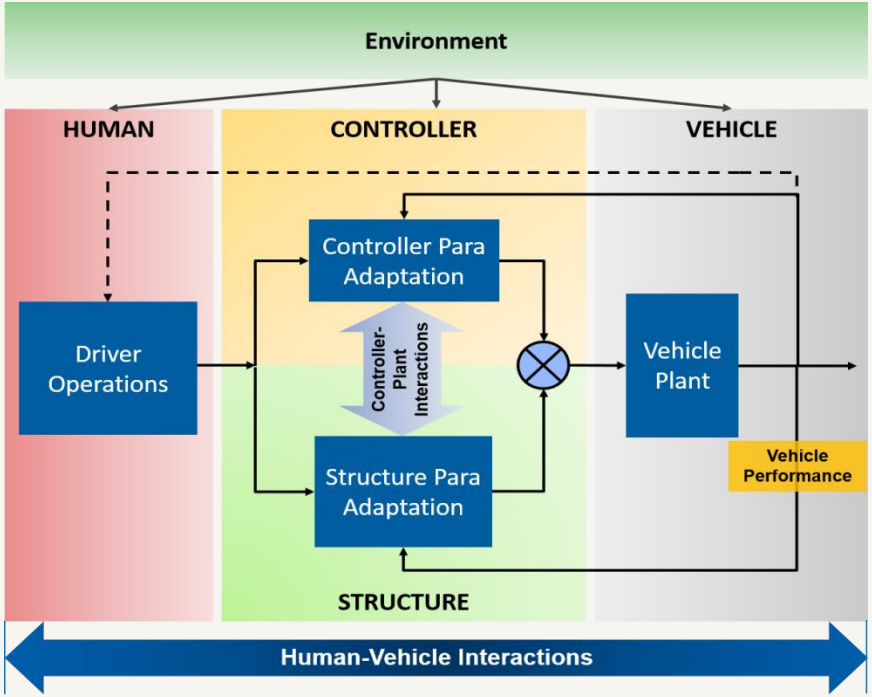




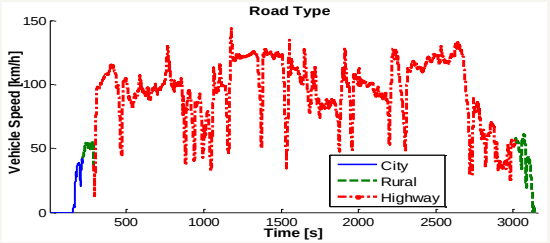
Multiple papers published or submitted.

D-CPS: driver-cyber-physical systems (D-CPS) research

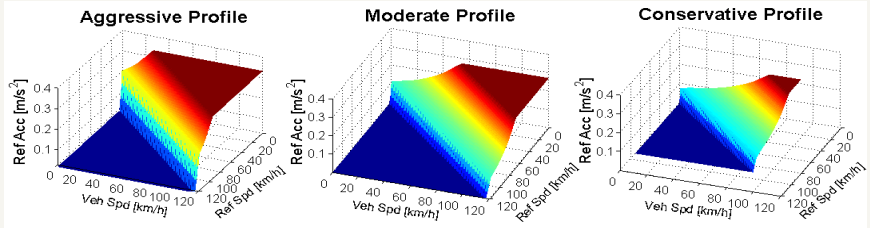
Driving-Style-Aware Design Optimization of Automated EV



- An automated electric vehicle is a typical example of driver-cyber-physics system (**D-CPS**);
- **Goal: Co-design optimization of the physical and controller parameters of an automated electric vehicle for different driving styles**.



Driving style recognition and vehicle test validation

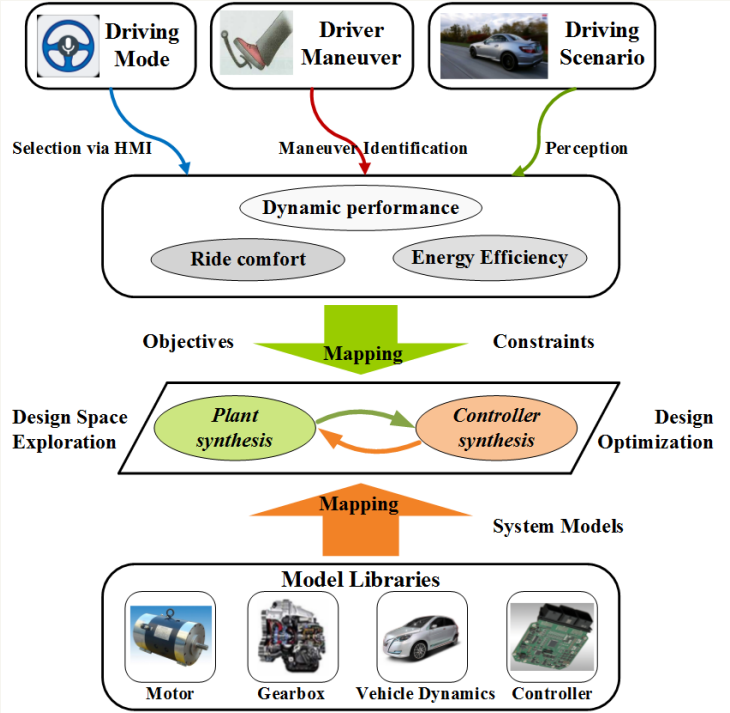


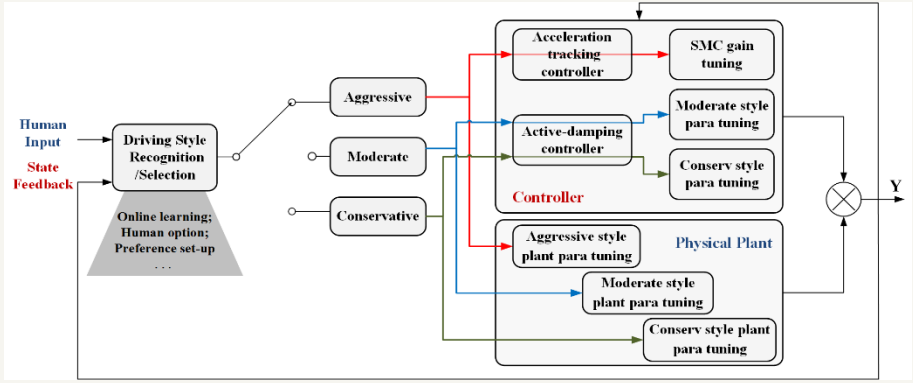
Development of reference profiles based on driving features

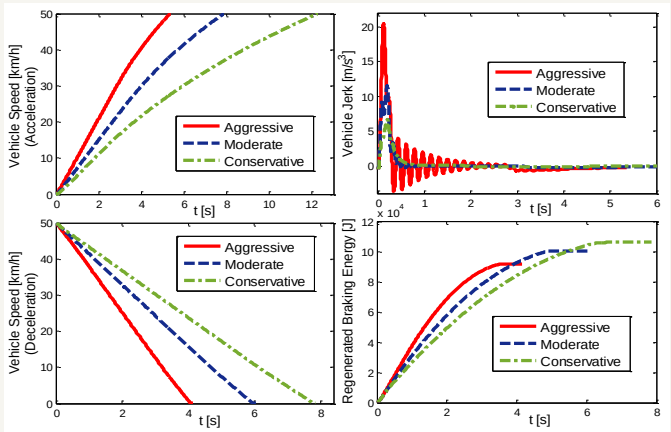
Multiple papers published or submitted.

D-CPS: driver-cyber-physical systems (D-CPS) research

CPS-Based Co-Design Optimization Framework

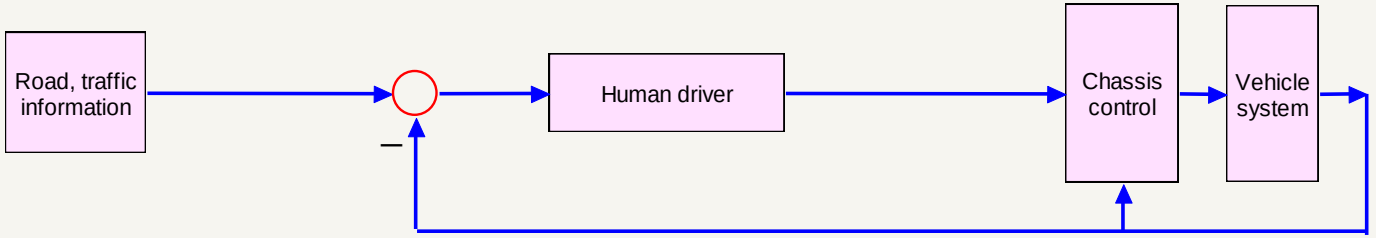




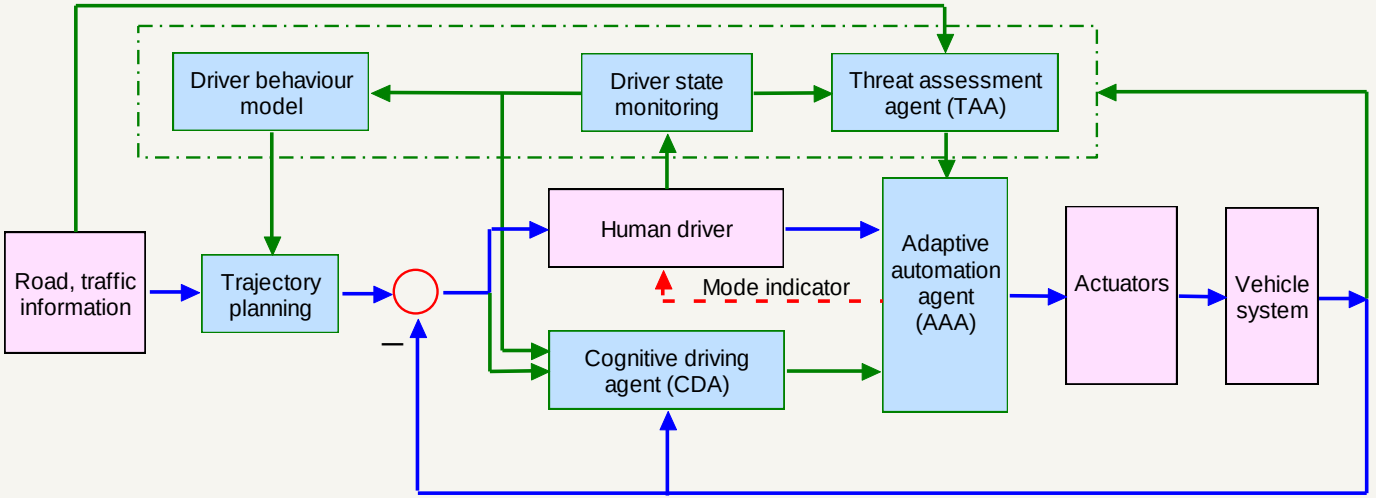


Multiple papers published or submitted.

On-going research activities: driver-automation collaboration

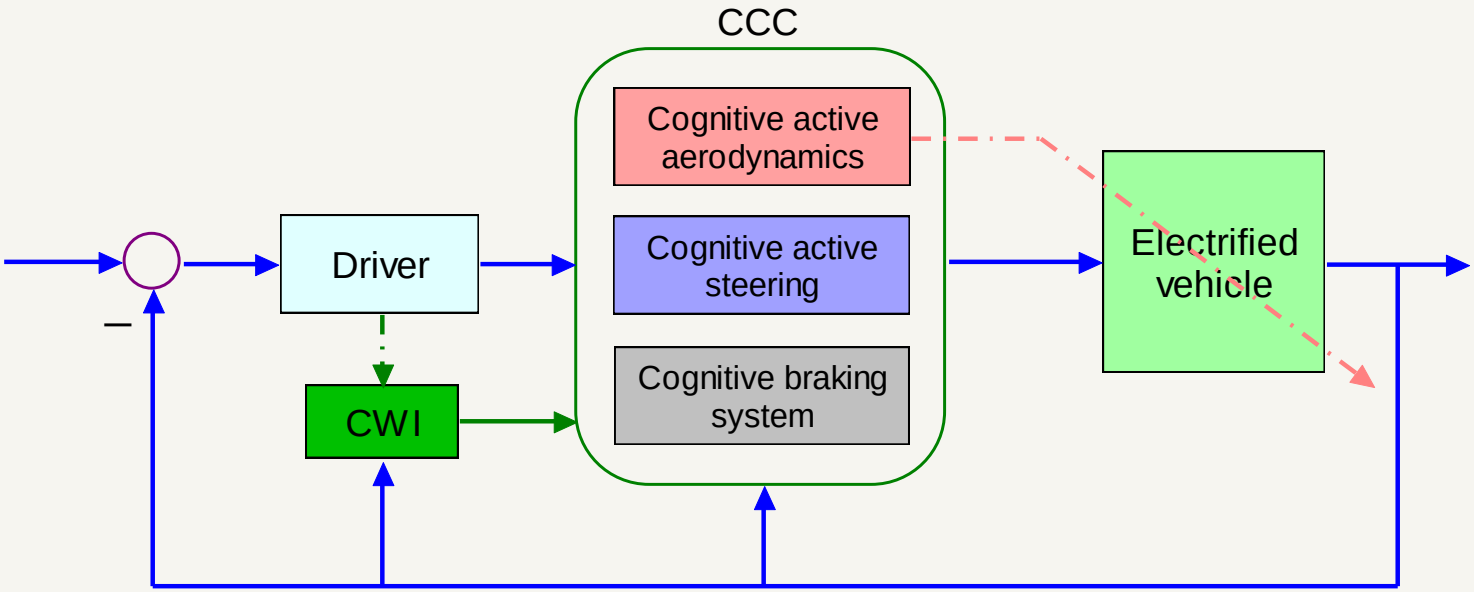


(a) Conventional vehicle dynamics control

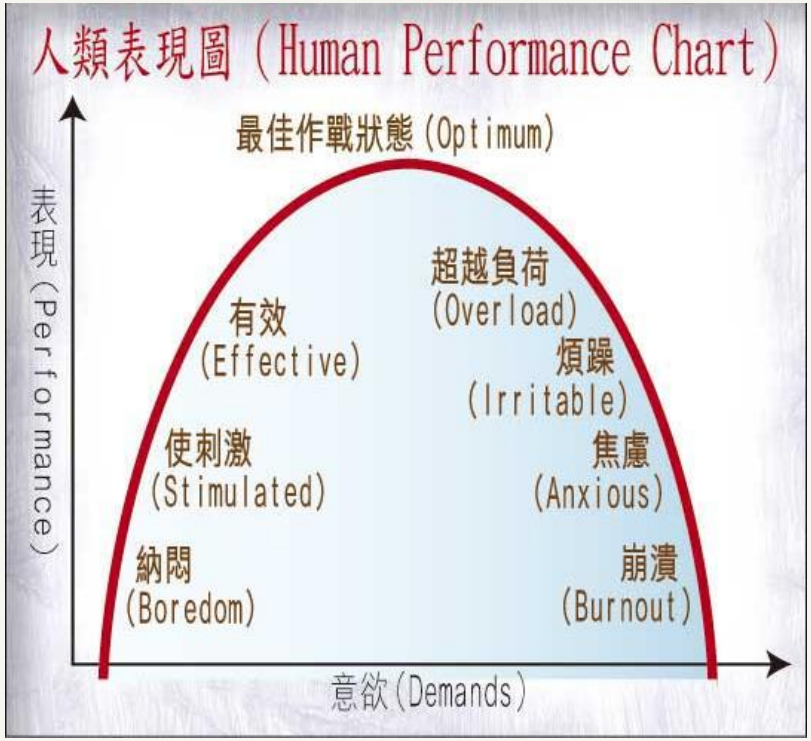


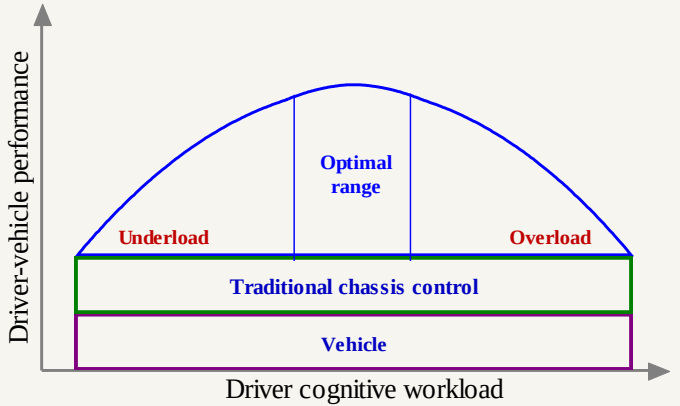
(b) Proposed new driver-automation collaboration

On-going research activities: cognitive chassis control (CCC)

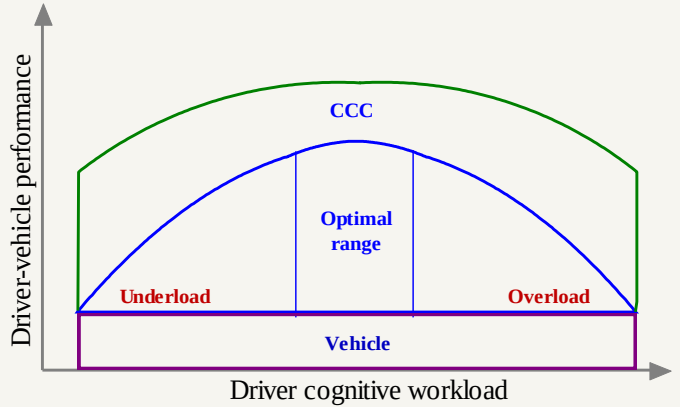


On-going research activities: cognitive chassis control (CCC)



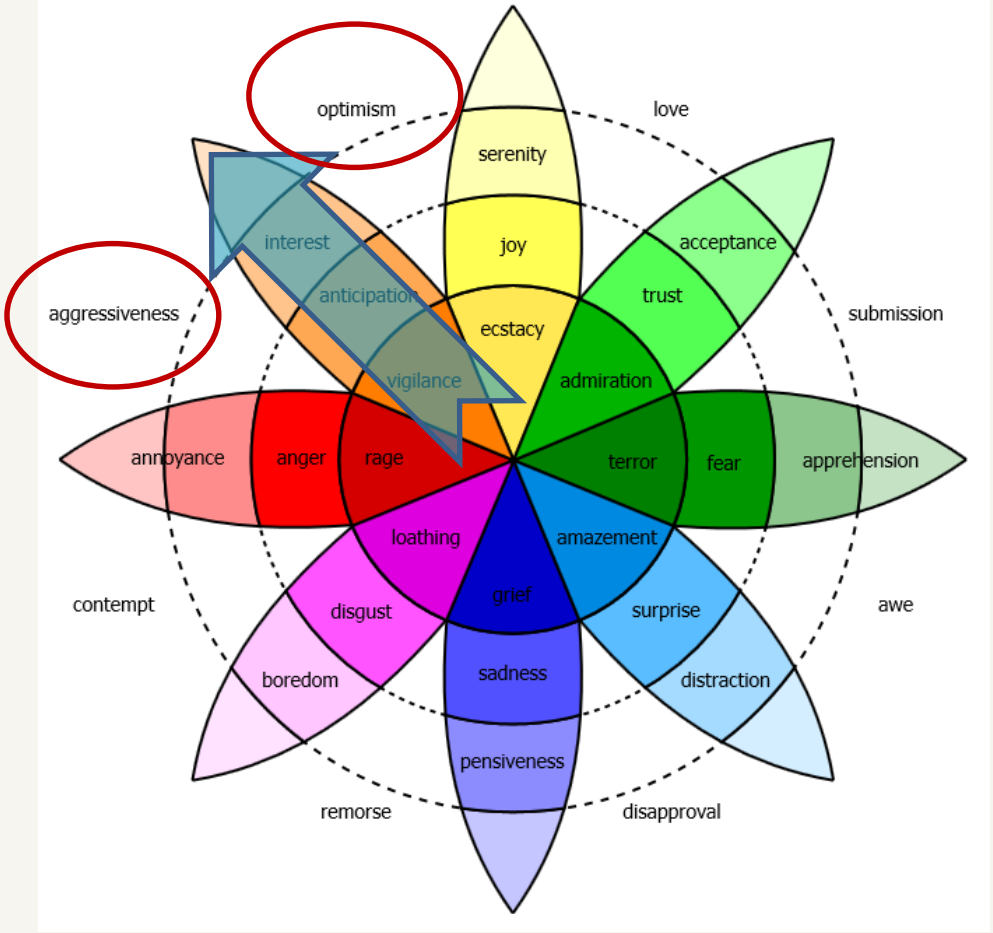


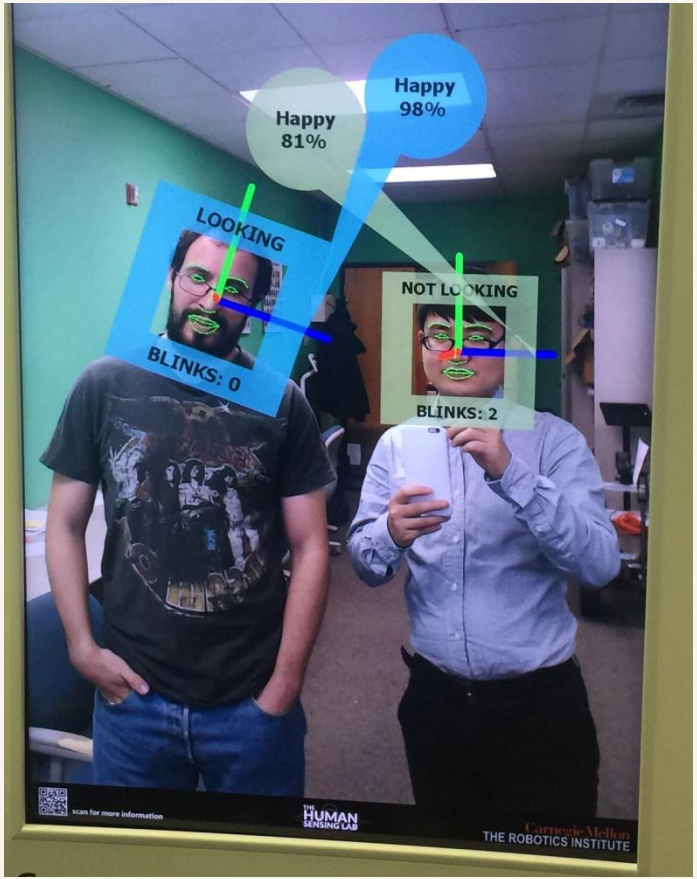
(a)



(b)

On-going research activities: cognitive chassis control (CCC)

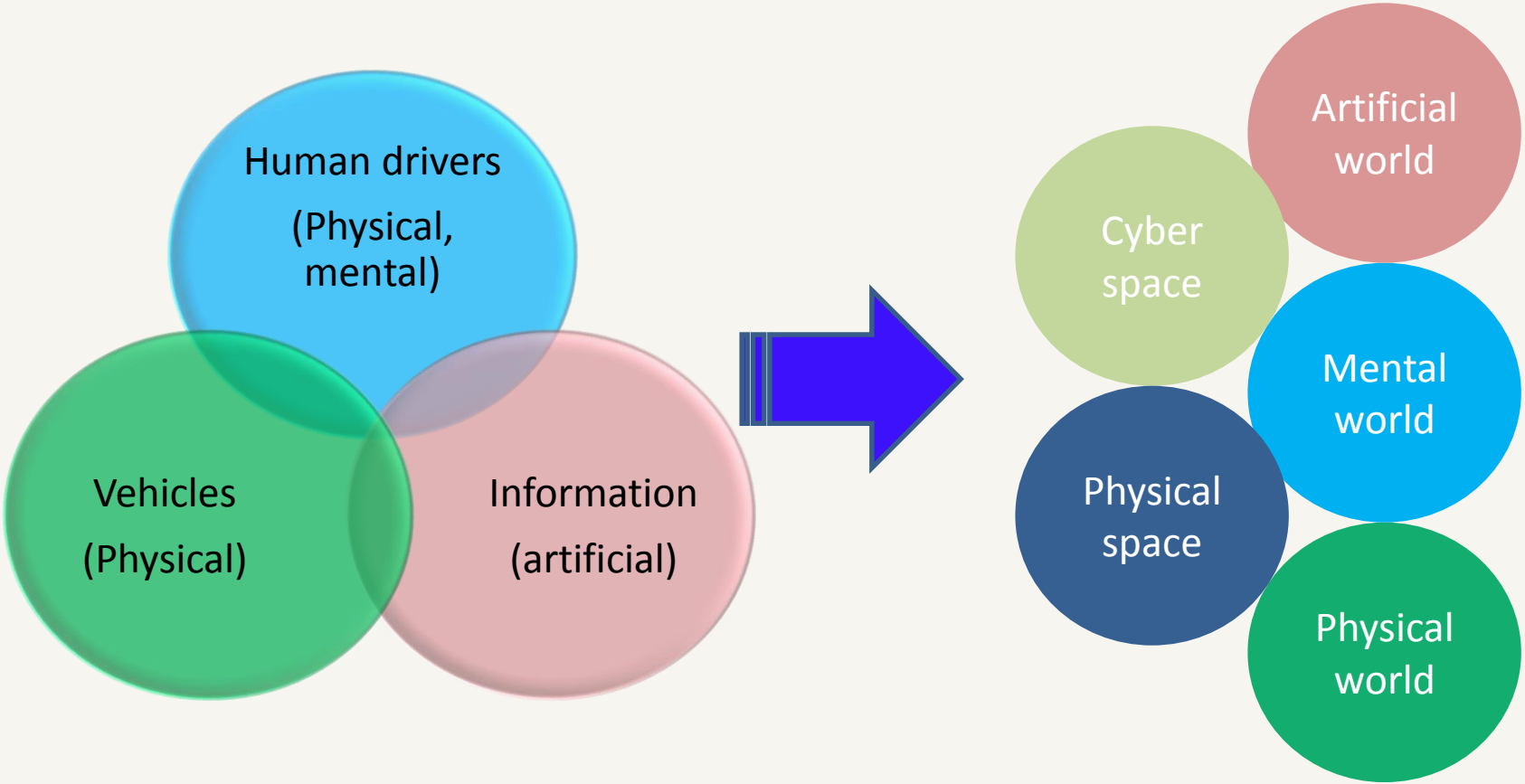




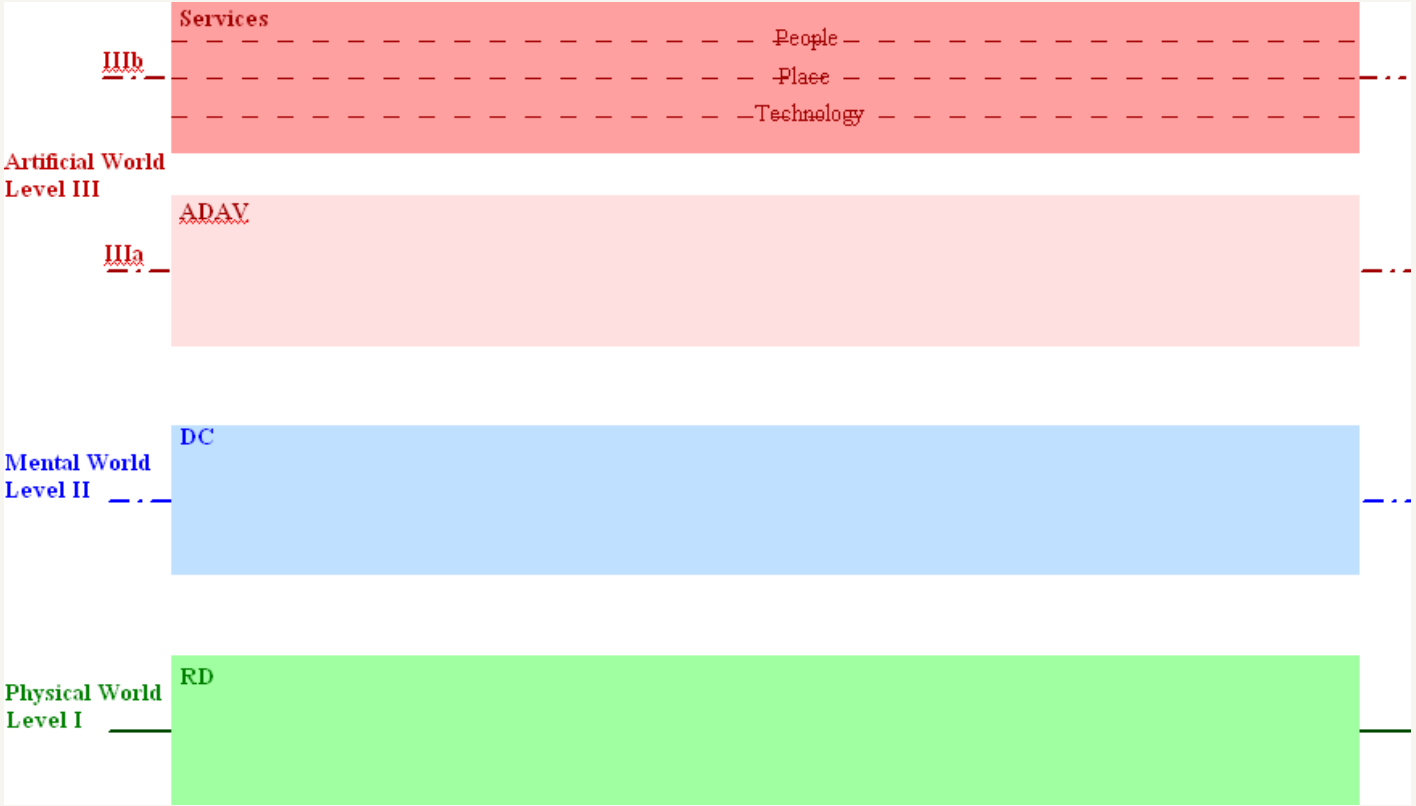
Outline (大纲)

- Intro & roadmaps
- Automated driving: cognitive intelligence
  - Framework of CACDM
  - Selected recent/on-going research activities
- Automated driving: parallel intelligence
  - Framework of parallel driving
  - Selected recent/on-going research activities
- Welcome to IEEE IV'2018

Cyber-physical-social systems (CPSS) based parallel driving

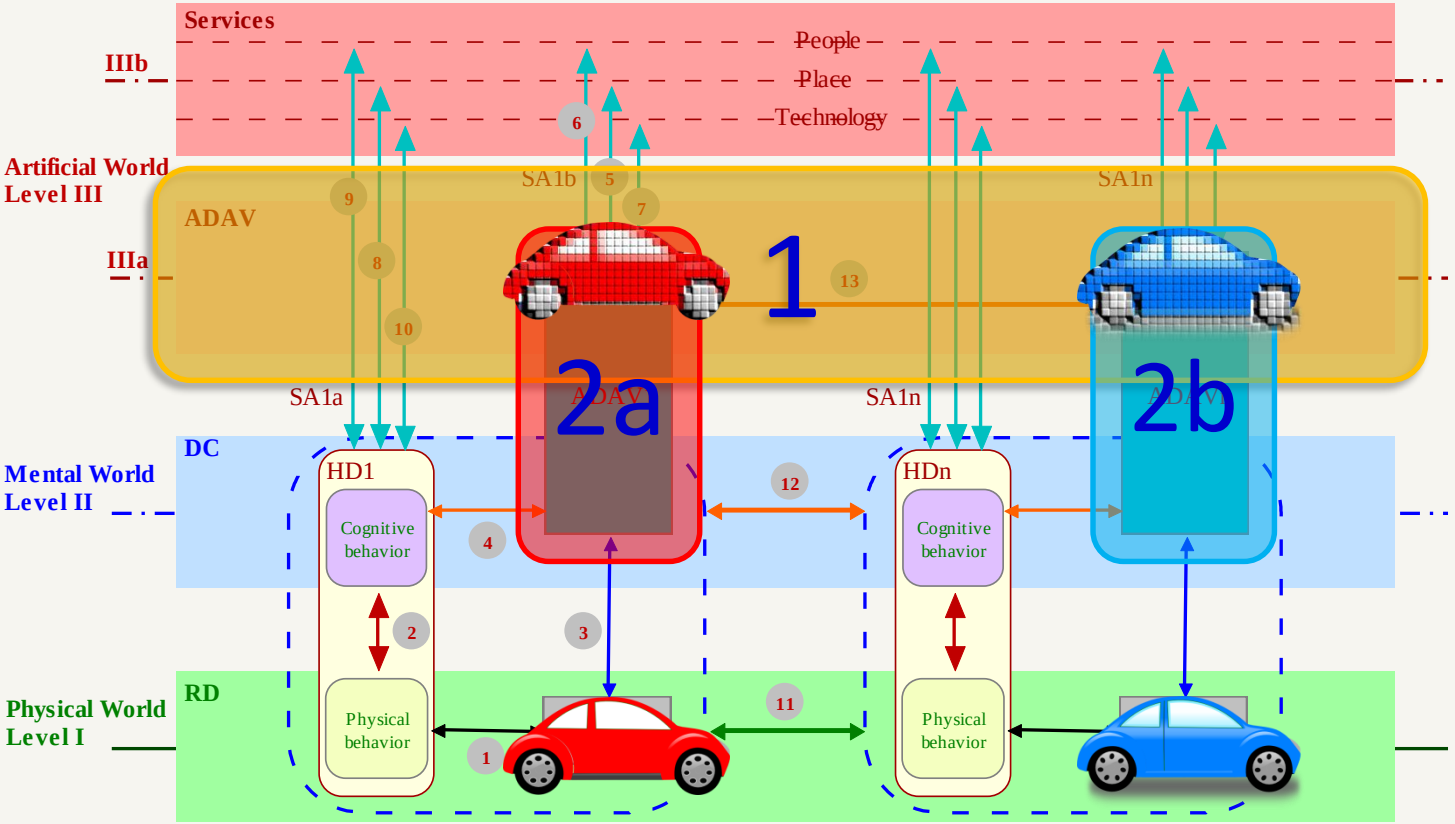


Parallel driving: parallel layout



DC: driver cognition; CPSS Services: people (social web), place (geo web), technology (sensors, IoT, etc); ADAV: artificial driver and artificial vehicle; RD: real driving.

Parallel driving: technology framework



Parallel driving: underlying theories

第 43 卷 第 1 期 自 动 化 学 报 Vol. 43, No. 1
2017 年 1 月 ACTA AUTOMATICA SINICA January, 2017

平行学习 — 机器学习的一个新型理论框架

李 力 [1] 林懿伦 [2,3]

摘 要 本文提出了一种新的机器学习理论框架. 该框
义的人工系统从大数据提取有效数据, 如何结合预测学
领域面临的重要问题进行了特别设计.

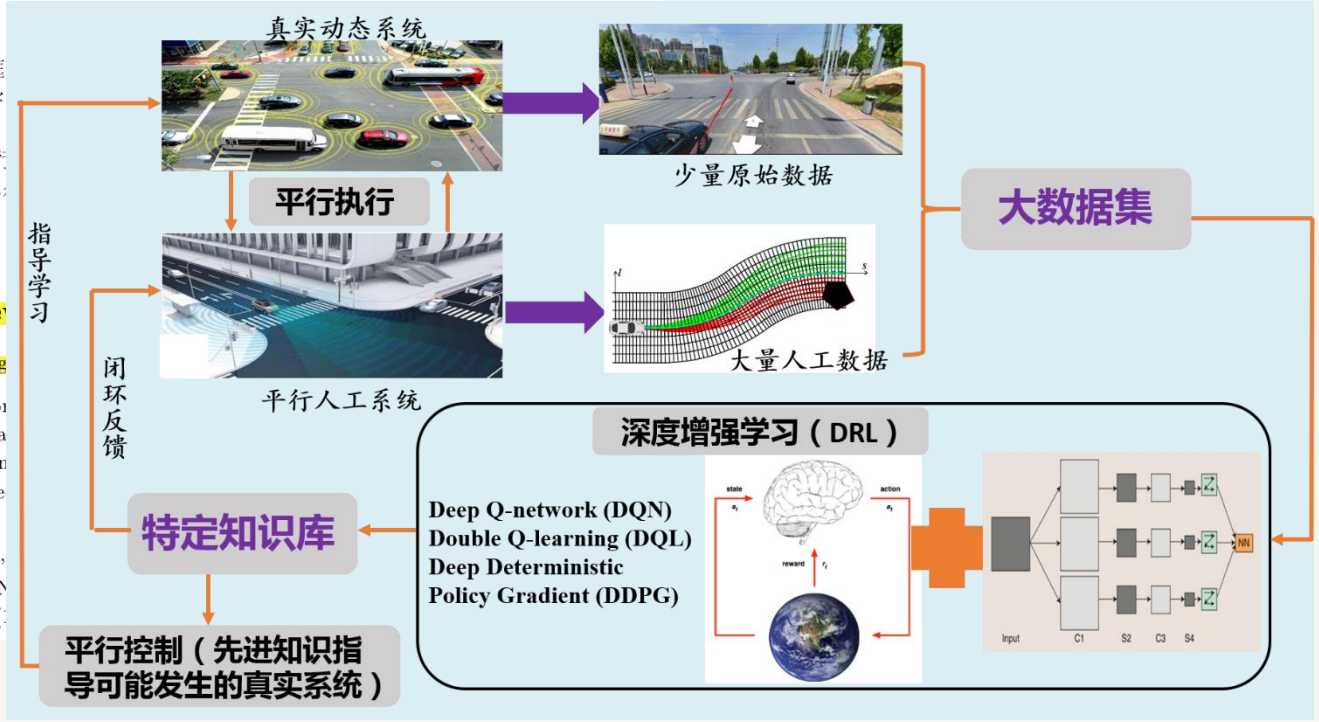
关键词 机器学习, 人工智能, 平行学习, 平行智能, 平行
引用格式 李力, 林懿伦, 曹东璞, 郑南宁, 王飞跃. 平
1−8
DOI 10.16383/j.aas.2017.y000001

Parallel Learning — A Ne

LI Li[1] LIN Yi-Lun[2,3] CAO Dong

Abstract In this paper, we propose a new framewo
and inherits many elements from various existing ma
with some important problems in the machine learn
software defined artificial systems, combination of pre
to prescriptive learning.

Key words Machine learning, artificial intelligence,
Citation Li Li, Lin Yi-Lun, Cao Dong-Pu, Zheng N
machine learning. *Acta Automatica Sinica*, 2017, **43**(



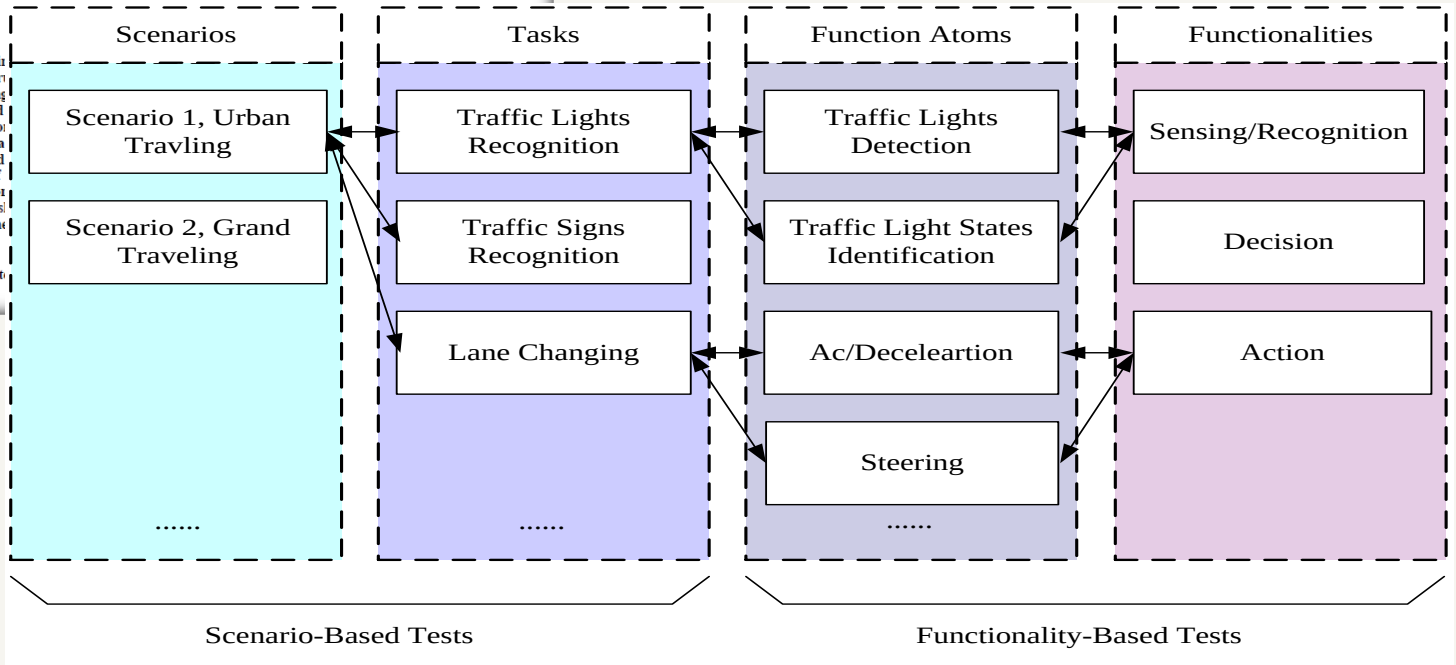
Parallel driving: testing and assessment **approach A**

Intelligence Testing for Autonomous Vehicles: A New Approach

Li Li, *Senior Member, IEEE*, Wu-Ling Huang, Yuehu Liu, Nan-Ning Zheng, *Fellow, IEEE*, Fei-Yue Wang, *Fellow, IEEE*

Abstract— In this paper, we study how to test the in an autonomous vehicle. Comprehensive testing is cr vehicle manufactories and customers. Existing testing can be categorized into two kinds: scenario-based functionality-based testing. We first discuss the shor these two kinds of approaches, and then propose a framework to combine the benefits of them. Based semantic diagram definition for the intelligence of vehicles, we explain how to design task for autonor testing and how to evaluate test results. Experiments s new approach provides a quantitative way to test the of an autonomous vehicle.

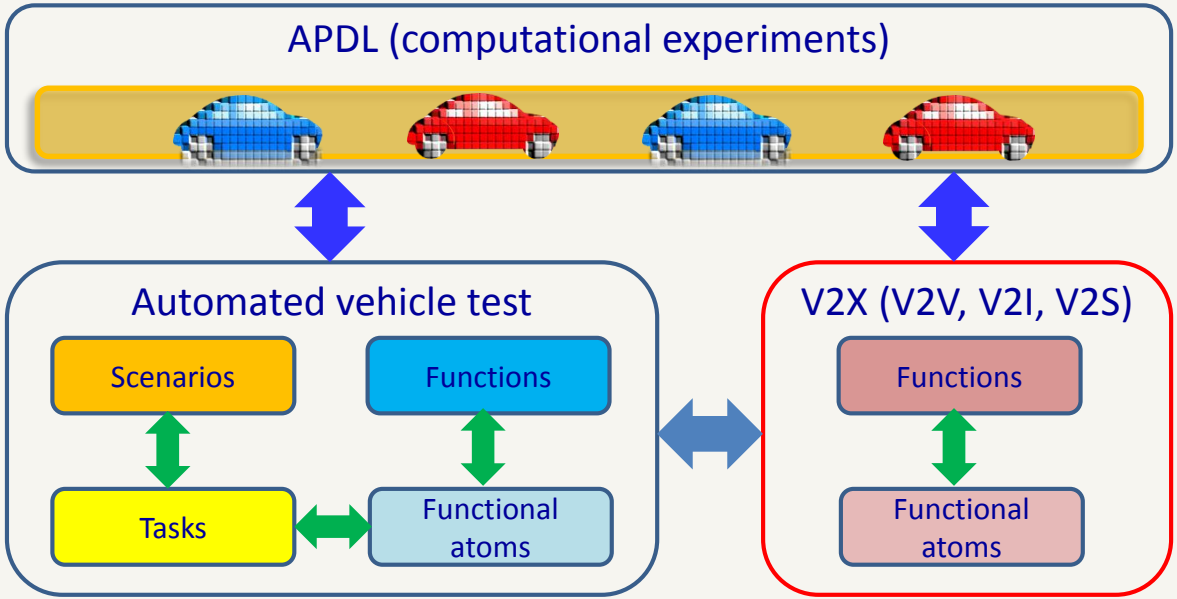
Index Terms— Autonomous vehicles, intelligence t

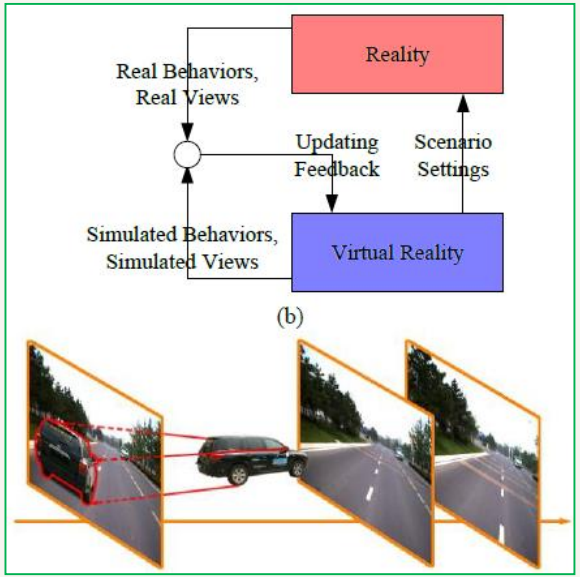


Parallel driving: testing and assessment **approach A**

Three independent and also interacting modules:

- Automated vehicle: hybrid scenario-/functionality-based test
- V2X (V2V, V2I, V2S): functionality-based test
- Artificial parallel driving layer (APDL): computational experiments

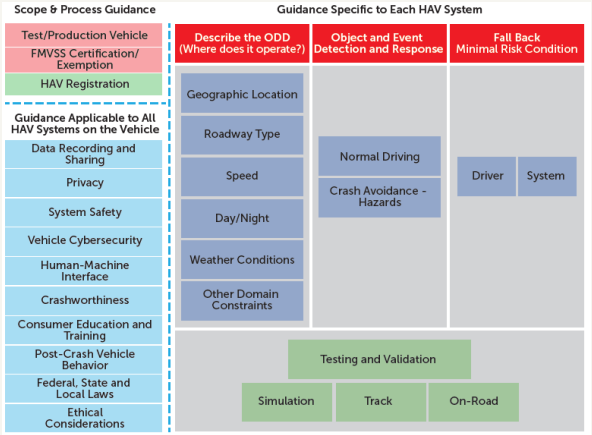




IEEE TIV (2016)

Parallel driving: testing and assessment **approach B**

美国自动驾驶政策指南（09/2016）



Levels of Automation	SAE Levels 3, 4, 5 (HAVs)	SAE Level 2
Safety Assessment Letter to NHTSA	***Yes***	***Yes***
C. Cross-Cutting Areas	***Fully***	***Partially***
C.1.Data Recording and Sharing	Yes	Yes
C.2 Privacy	Yes	Yes
C.3 System Safety	Yes	Yes
C.4 Vehicle Cybersecurity	Yes	Yes
C.5 Human Machine Interface	Yes	Yes
C.6 Crashworthiness	Yes	Yes
C.7 Consumer Education and Training	Yes	Yes
C.8 Registration and Certification	Yes	Yes
C.9 Post-Crash System Behavior	Yes	Yes
C.10 Federal, State and Local Laws	Yes	Clarify to driver
C.11 Ethical Considerations	Yes	Yes
F. Automation Function[47]	***Fully***	***Partially***
F.1 Operational Design Domain	Yes	No
F.2 Object and Event Detection and Response	Yes	No
F.3 Fall Back (Minimal Risk Condition)	Yes	No
F.4 Validation Methods	Yes	Yes

Safety assessment letter required for 15 areas:

Cross-cutting areas:

- Data recording and sharing
- Privacy
- System safety
- Vehicle cybersecurity
- Human machine interface
- Crashworthiness
- Consumer education and training
- Registration and certification
- Post-crash behavior
- Federal, state and local laws
- Ethical considerations

Automation function areas:

- Operational design domain (ODD)
- Object and event detection and response (OEDR)
- Fall back (minimal risk condition)
- Validation methods

Parallel driving: testing and assessment **approach B**

Safety assessment letter

APDL Computational Experiments Report:
- Driving scenarios
- Mileages
- Performance metric and performance responses
- Accidents
- .....

V2X Functionality Report:
- Communication network
- Infrastructure intelligence
- V2V specific
- V2I specific
- V2S specific
- .....

Cross-cutting areas (with V2X):
- Data recording and sharing
- Privacy
- System safety
- Vehicle cybersecurity
- Human machine interface
- Crashworthiness
- Consumer education and training
- Registration and certification
- Post-crash behavior
- Federal, state and local laws
- Ethical considerations

Automation function areas (with V2X):
- Operational design domain (ODD)
- Object and event detection and response (OEDR)
- Fall back (minimal risk condition)
- Validation methods

Benefits assessment letter

Driving energy efficiency areas:
- Energy consumption
- Emissions
- Energy regeneration
- Vehicle/powertrain/battery health
- Validation methods
- .....

Driving comfort areas:
- Ride quality (objective & subjective)
- Handling quality (objective & subjective)
- In-vehicle-task-based comfort (subjective)
- .....

Traffic efficiency report:
- Performance metric and performance responses
- Validation methods
- .....

Large scale transportation management report

Parallel driving: testing and assessment **hybrid approach**

Safety assessment letter

APDL Computational Experiments Report:
- Driving scenarios
- Mileages
- Performance metric and performance responses
- Accidents
- .....

V2X Functionality Report:
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- V2V specific
- V2I specific
- V2S specific
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Cross-cutting areas (with V2X):
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- Consumer education and training
- Registration and certification
- Post-crash behavior
- Federal, state and local laws
- Ethical considerations

Automation function areas (with V2X):
- Operational design domain (ODD)
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- Fall back (minimal risk condition)
- Validation methods

Benefits assessment letter

Driving energy efficiency areas:
- Energy consumption
- Emissions
- Energy regeneration
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- .....

Large scale transportation management report

Driving comfort areas:
- Ride quality (objective & subjective)
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- .....

Traffic efficiency report:
- Performance metric & performance responses
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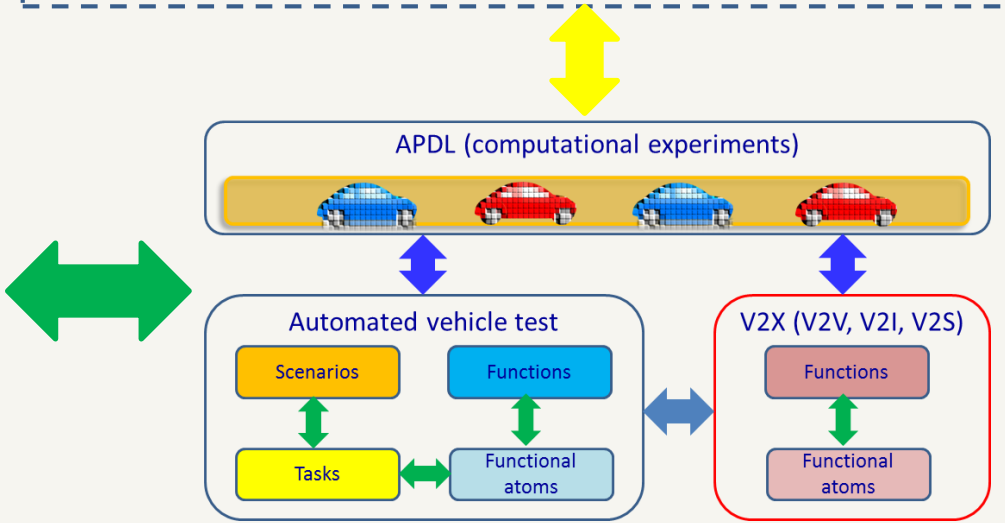
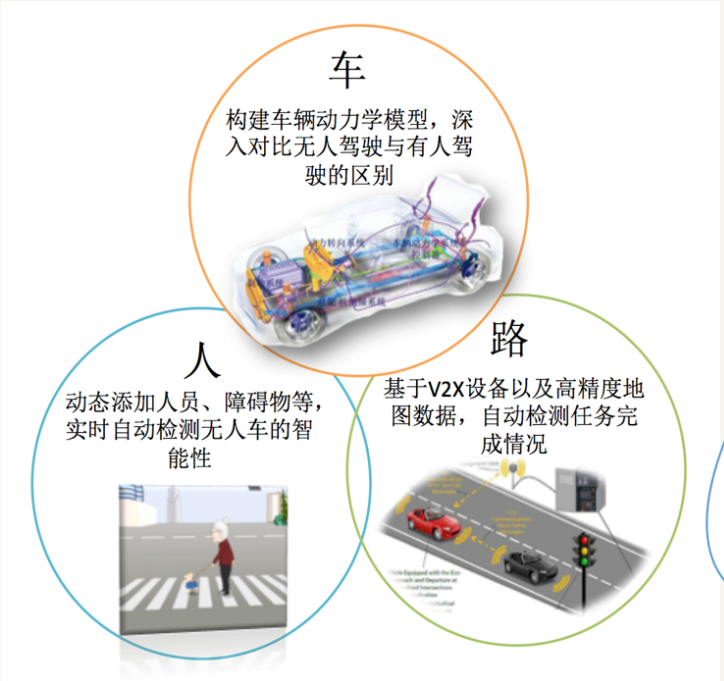
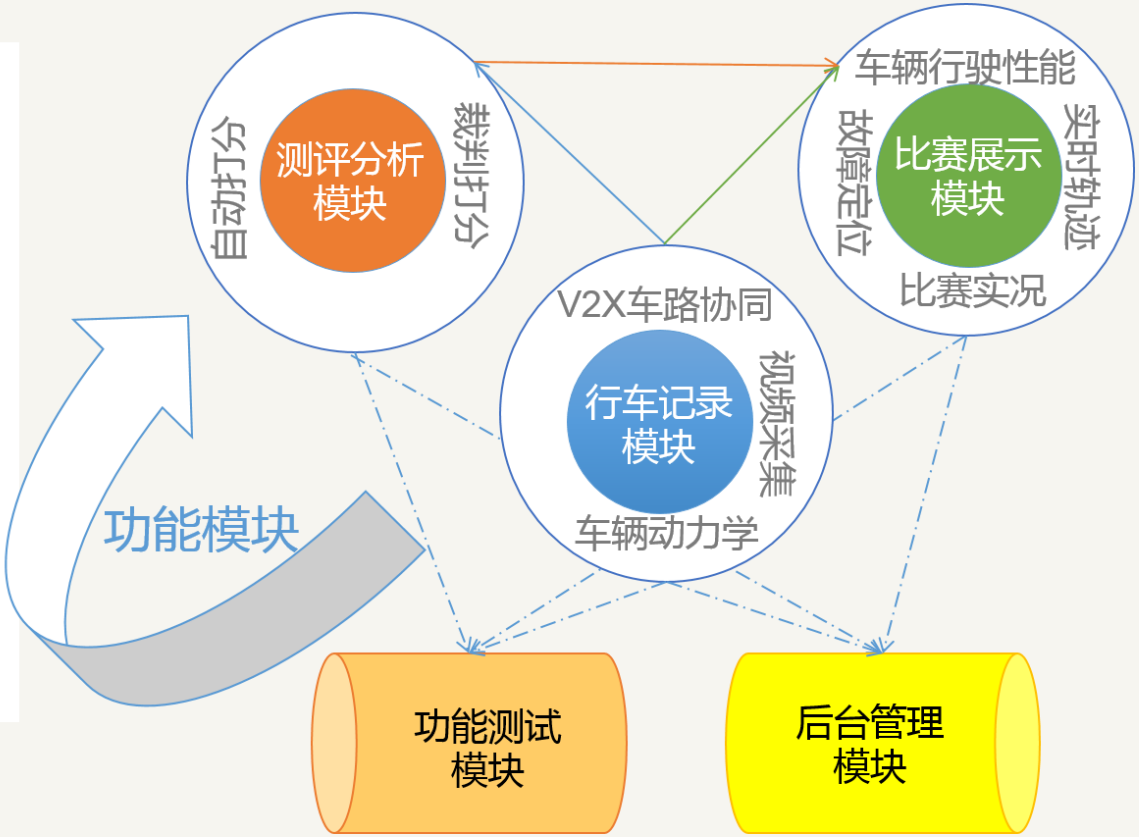


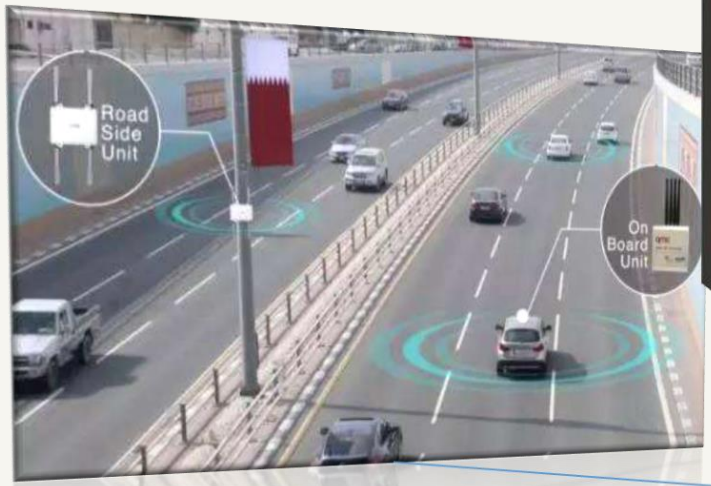
Parallel driving: testing and assessment

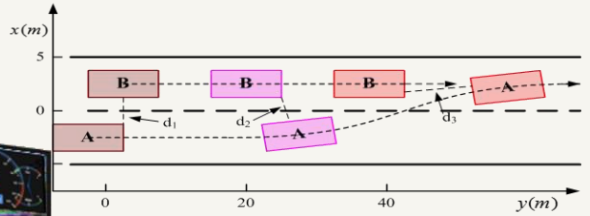


车-路-人 闭环测试与验证



Parallel driving: testing and assessment





车辆动力学模型实时评测性能

- 基于V2X余高精度地图自动打分
- 跟车裁判APP打分
- 实时上传并且展示比赛盛况
- 发生故障远程定位

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The 29th IEEE Intelligent Vehicles Symposium (IEEE IV'18)

June 26 – July 1, 2018， Changshu, Suzhou, China

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- **Prof. Li Li**, Tsinghua University, China
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谢谢大家！