


## About Nanzan University in Mo-Town Nagoya


☞ One of the World Largest Automotive Industry Located around Nagoya


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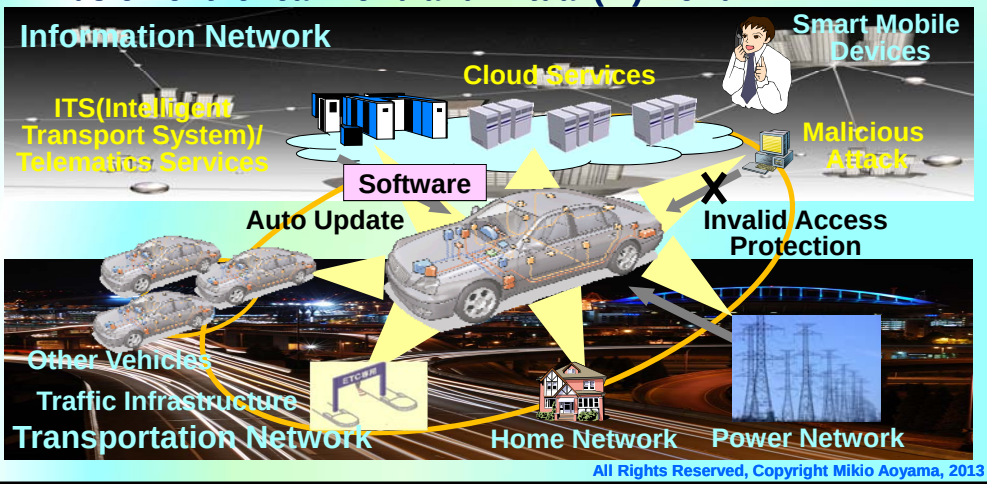
## It's a "Programmable World" ! Convergence of IT and Transportation Technology

☞ Automobile is a vehicle of not only people, but also information (and Power): IT convergence

☞ Fusion of the real-world and virtual (IT) world

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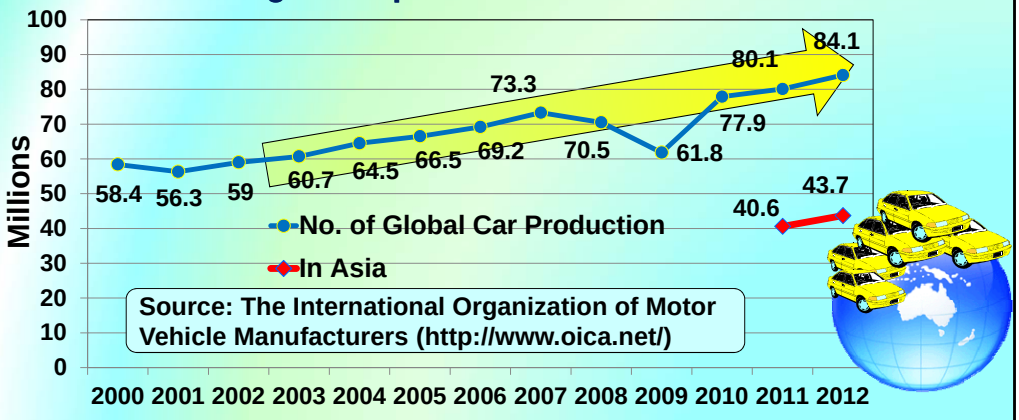
## It's a "Programmable World" ! Automotive is Becoming Ubiquitous

- In 2020, 2 billion cars on the globe
- 84 millions of new cars in 2012, more than 50% in Asia
- Global warming: Transportation accounts 25% of CO2

7,200 cars/45 min.




Reference: D. Sperling and D. Gordon, Two Billion Car: Driving Toward Sustainability, Oxford University Press, 2009.

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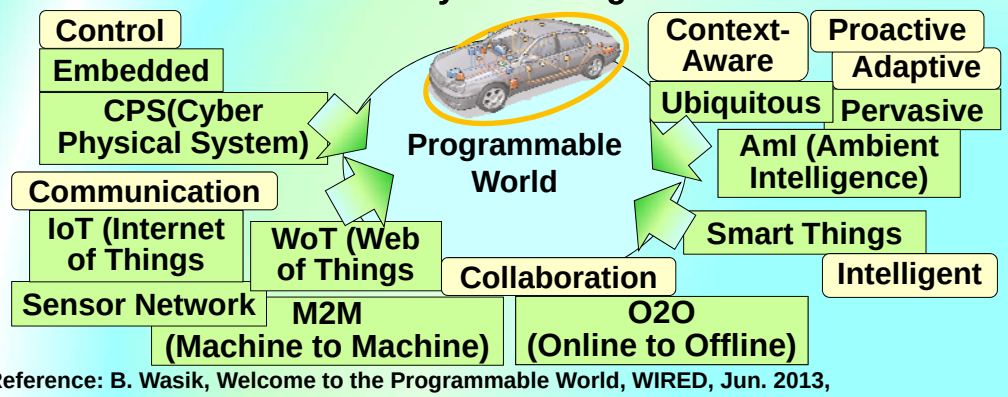
## It's a "Programmable World" ! Convergence of Technologies

- Our world is going to be "Programmable".
  - Every "thing" is smart, and talks each other
- Convergence of diverse approaches and technologies
  - Smarter automobile by IT convergence




Reference: B. Wasik, Welcome to the Programmable World, WIRED, Jun. 2013, pp. 140-147, 180.

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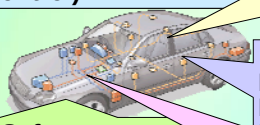
## It's a "Programmable World" ! Programmable Automobile

- Ever Increasing Computers and Size of Software
  - No. of computers (ECU: Electronic Control Unit): 50 ~ 100
  - Size of software: 5 ~ 20 Million LOC (Lined Of Code)

**Engine and Power Train**
ACC (Adaptive Cruise Control)
ECT (Electronic Controlled Transmission)
EFI (Electronic Fuel Injection)
HVC (Hybrid Vehicle Control)

**Comfort and Pleasure**
Back Guide Monitor
Climate Control: Air Conditioner
Door Lock Control, Immobilizer
Power Seat, Power Window
Remote Engine Start (Keyless)



**Communication**
DCM (Data Communication Module)
In-Vehicle Network: CAN, LIN, MOST, FlexRay, TTEthernet
Short Range Wireless: Bluetooth

**Chassis and Safety**
AFS (Adaptive Front-lighting System)
ACS (Active Control Suspension)
ABS (Antilock Brake System)
ESC (Electronic Stability Control)
PCS (Pre-Crash Safety)
TRC (TRaction Control)
VDM (Vehicle Dynamics Management)

**Human Interface and Support**
Car Navigation System
LCD Instrument Panel, Touch Panel,
HUD (Head Up Display), Speech Recognition System, Haptic Interface

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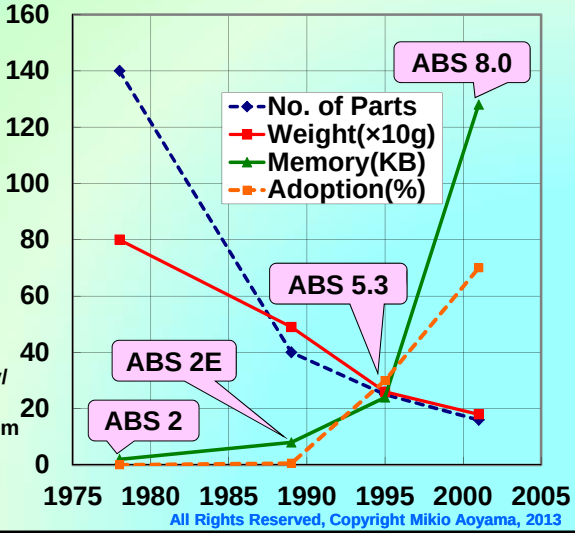
## It's a "Programmable World" ! Ever Increase of Programming: A Case of ABS

- Evolution of ABS (Antilock Braking System)
- 1st Gen (ABS 2): 1978~
  - 8 bit micro controller
- 1.5 Gen (ABS 2E): 1989~
- 2nd Gen (ABS 5.x): 1993~
  - 16 bit micro controller
- 3rd Gen (ABS 8.x): 2001~
  - 32 bit micro controller




References:
Bosch, 25th Bosch ABS Anniversary, http://www.bosch.com/assets/en/company/innovation/theme03.htm.
N. Rittmannsberger, Antilock Braking System and Traction Control, Proc. Int'l Conf. on Transportation Electronics (Convergence 1988), 1988, pp. 195-202.

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## Smarter Automobile by IT Convergence
## Diverse Demand from Society

- Automobile should be better merges to IT society while assuring high safety
- More and advanced IT convergence is necessary

**(2) Safety**
Zero Collision:
Auto Braking and
Collision Avoidance

**(4) Comfort and Pleasure**
Lower Burden of Driving:
Automatic Driving,
Pleasure of Driving Experience,
Comfortable Room

**(1)Environment and Economy**
Zero/Lower Emission and
Fuel Consumption

**(3) Seamless to IT Society**
Fully-Connected to IT Society,
(SNS, IT Services),
IT Support for Driving Experience

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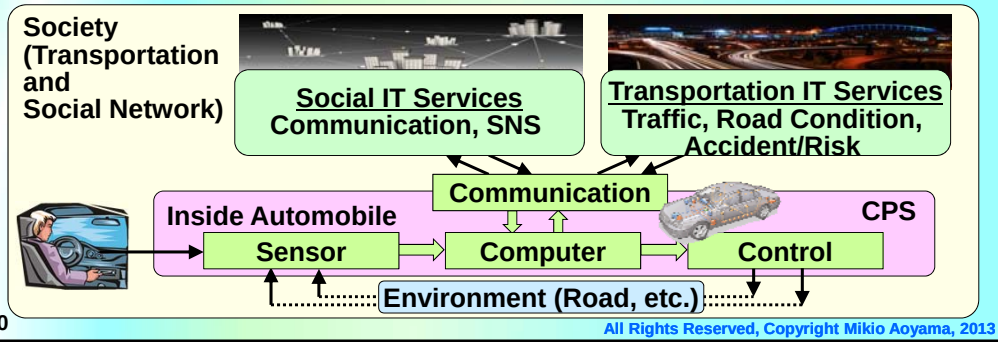
## Smarter Automobile by IT Convergence
## IT Convergence to Automobile and Transportation Network

- IT convergence in an Automobile: CPS (Cyber-Physical System)
  - Sensing, computing, controlling, and communicating
- IT Convergence across Transportation and Social Network
  - Automobile is social actor: Working with transportation and social network for better safety, environment, economy, and experience

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## Smarter Automobile by IT Convergence
## (1) Environment: Evolution for Environment and Economy

- Concerns on global warming
  - Fuel consumption regulation from '20 in Japan: 20.3 Km/L, 24% and 19.6% reduction from '09 and 2015, respectively
- Hybrid engine converging IT, electronics and mechanical eng.
  - HEV: Toyota initiated the development of Prius in '93, and put the first Prius to market in '97, HV accounts 41.9% in '12
  - EV: Mitsubishi i-MiEV and Nissan Leaf in '09 and '10, respectively

Toyota Prius (1997) 3rd Gen (2009) 32.6 Km/L*

Toyota Prius PHV(2012) 57.2~61.0 Km/L* EV Range: 26.4 Km*

Nissan Leaf (2010) EV Range: 200Km*

FCV (Fuel Cell Vehicle)

EV (Electric Vehicle)

PHV (Plug-in HV)

HEV (Hybrid Electric Vehicle)

Combustion (Gasoline, Diesel)

*Note: Performance is Measured with JC 08, A Standard by Japanese Government

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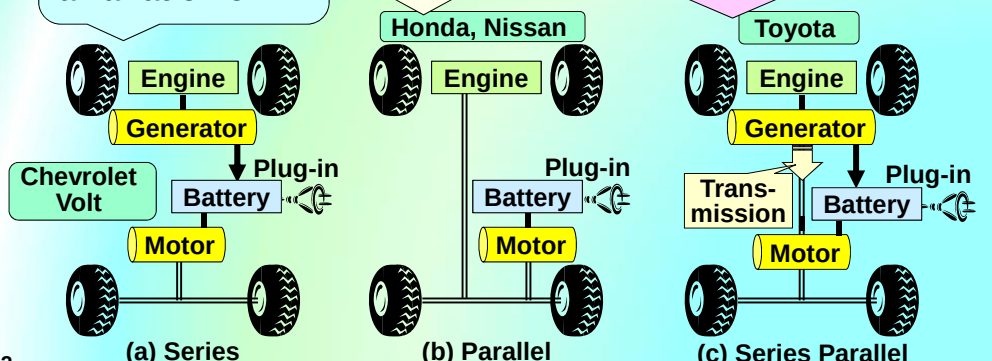
## Smarter Automobile by IT Convergence
## (1) Environment: Three Architectural Styles of HEV

- Three Architectural Styles (Patterns) Based on the Configuration of Engine and Motor

Series: No drive from engine, a variation of EV

Parallel: Both engine and motor drive in parallel

Series-Parallel: combination of engine and motor for drive and generation

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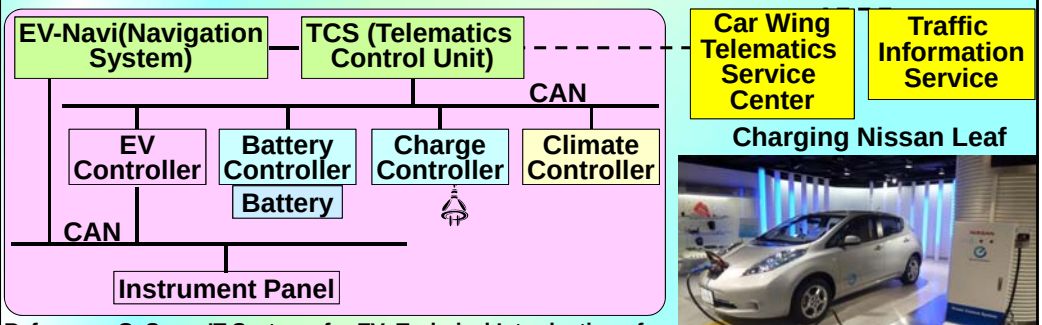
## Smarter Automobile by IT Convergence
## (1) Environment: An Architecture of an EV

- Simple EV control, but working tightly with IT
  - Limited driving range and sparse allocation of charging station
- IT helps to find charging/plug-in station within driving range
  - Estimating the max. range of driving based on remaining battery and traffic condition by data analysis




Charging Nissan Leaf



Reference: G. Sone, IT Systems for EV: Technical Introduction of IT System for Nissan Leaf, Tech. Paper 2011-39-7217, SAE, 2011.

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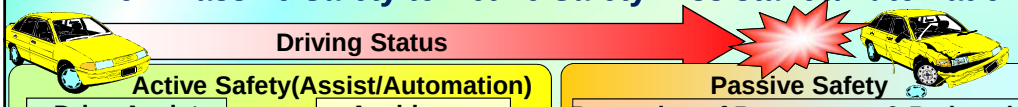
## Smarter Automobile by IT Convergence
## (2) Safety: Active and Passive Safety

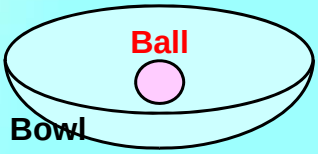
- Safety is Requirements No. 1
- Real-Time Integrated Control by Computer/Software
- From Passive Safety to Active Safety: Assistance/Automation




| Active Safety(Assist/Automation) | | Passive Safety | | |
|---|---|---|---|---|
| Drive Assist | Avoidance | Protection of Passengers & Pedestals | | |
| **Normal Status (Easy to Drive)** | **Critical Status** | **Unable to Avoid Crash** | **At Crash** | **After Crash** |
| VDM(Vehicle Dynamic Management system) | ESC(Electronic Stability Control Including ABS) | PCS(Pre-Crash Safety) | Air-bug | e-Call (emergency Call) |
| ACC(Adaptive Cruise Control) | Warning and Brake Assist | Seatbelt Pre-Tensioner | | Release Door Lock |
| Lane Keeping | Automatic Braking | | | |
| Parking Assist | Automatic Steering | | | |
| 360 Degree Vision | | | | |
| Night Vision | | | | |

## Smarter Automobile by IT Convergence
## (2) Safety: Advanced Safety

- Better Stability by Computer Control
  - Statistics proved reduction of traffic accidents
  - EU, USA, Japan mandated ESC to new models
- ESC(Electronic Stability Control)
  - ABS + TRC(TRaction Control) + stability control
- VDM (Vehicle Dynamics Management system)
  - ESC + engine control + steering control + suspension control
  - Toyota's Implementation: VDIM (Vehicle Dynamic Integrated Management system)
  - Basic principle: "Ball in a bowl"
    - Bowl: Safe maneuver surface

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## Smarter Automobile by IT Convergence
## (2) Safety: Collision Avoidance

- Collision Avoidance by automatic braking
  - Regulation: Works for 1.4 sec. before collision
- Implementation
  - Volvo city safety for obstacles [2008]
    - Works under 30 Km/h, braking under 15 Km/h
    - Sensor: Laser radar
  - Subaru Eyesight V. 2 for obstacles and person [2010]
    - Works at any speed, braking under 60 Km/h
    - Sensor: Stereo camera inside of front window
  - Many car companies will deliver the similar systems
- Next Generation: Collision avoidance by automatic steering

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## Smarter Automobile by IT Convergence
## (3) Seamless to IT Society: Car as Mobile Sensors

- Sensing and collecting big data
  - Traffic: Location, direction(GPS), speed
  - Road condition: Slipping: ABS
  - Weather condition: Rain sensor
- Submitting opinions
  - Point of interests, personal opinions
- Use of big data from "prove" car
  - Recommendation of route: Fuel-efficient, shortest-time
  - Predicting arrival time at destination
  - Warning before accident-prone point and route

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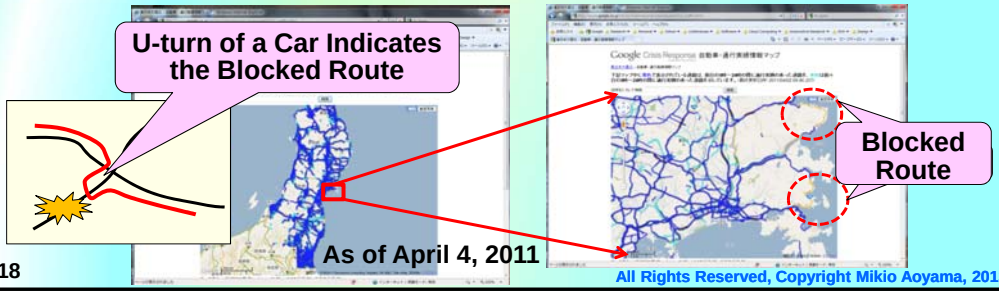
## Smarter Automobile by IT Convergence
## (3) Seamless to IT Society: Collective Intelligence/Big Data

- Helped recovery from 3.11 tsunami disaster
  - Automobile is effective sensor to know trafficable road
- Prove car system developed by HONDA in 2007
- Trafficable Rout Map on the Web
  - After 3.11, HONDA, TOYOTA, NISSAN and Google worked together and provided trafficable route on Google Maps since March 19

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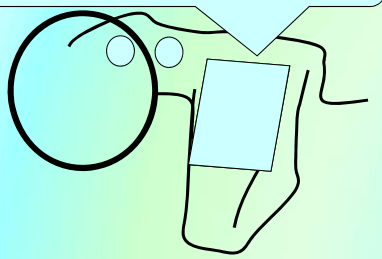
## Smarter Automobile by IT Convergence
## (4) Comfort and Pleasure: Usability and Experience

- Cockpit becomes a "Smartphone"
  - Driving is operating computers
  - Similar to glass cockpit of FBW(Fly-By-Wire) airplane
- Seamless of UI/experience in and out of automobile

Center console of Tesla Model S (EV): 17Inch display



Cockpit of Airbus Fly-By-Wire A320: Joystick

Reference: M. Aoyama, et al., Avionics and IT, Kyoritsu-Suppan, 2001 (In Japanese).

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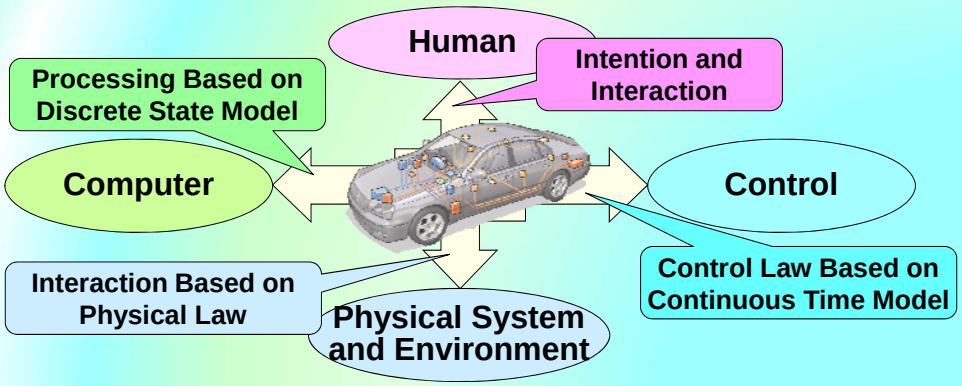
## Challenges for the Future
## Problem Structure

- Assure the Behavioral Integrity between
  - Computer and Control
  - Human and Automobile (Computer, Control and the Physical System and Environment)

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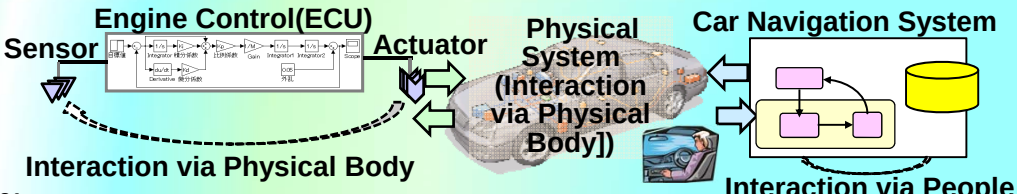
## Challenges for the Future
## Design for Converging Computer and Control

- Collaborative control model of CPS (Cyber Physical System)
  - Computational interaction via physical body
    - Feedback via physical body
  - Global behavior of collaborative control via interactions
    - Continuous-time control and discrete state transition
  - Different architectural principles: SAC and MVC

| SAC (Sensor Actuator Controller) Architecture Pattern<br>Feedback Control on Continuous Time | MVC (Model View Control) Architecture Pattern<br>Behavior of State Transition |
|---|---|

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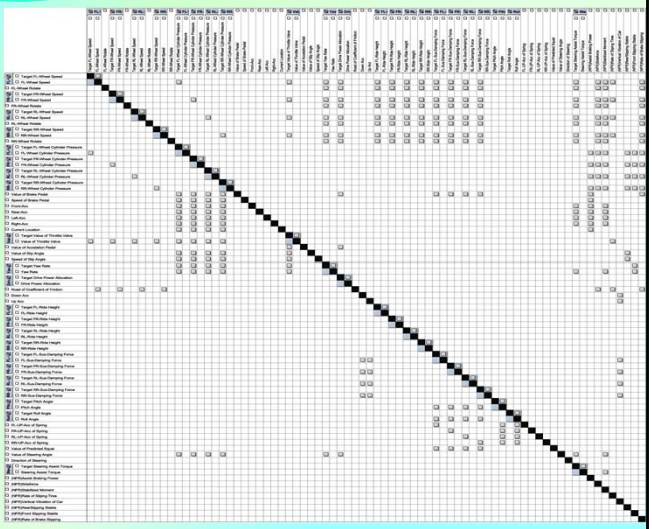
## Challenges for the Future
## Computer and Control: Design for Converging Two Models

- Extended DSM (Design Structure Matrix) of VDM (Vehicle Dynamics Management system)
- Automatic clustering the interactions among components:
  - Computer, sensor, and actuator



Reference: M. Aoyama and H. Tanabe, A Design Methodology for Real-Time Distributed Software Architecture Based on the Behavioral Properties and Its Application to Advanced Automotive Software, Proc. APSEC 2011, IEEE Compute Society, Dec. 2011, pp. 211-217

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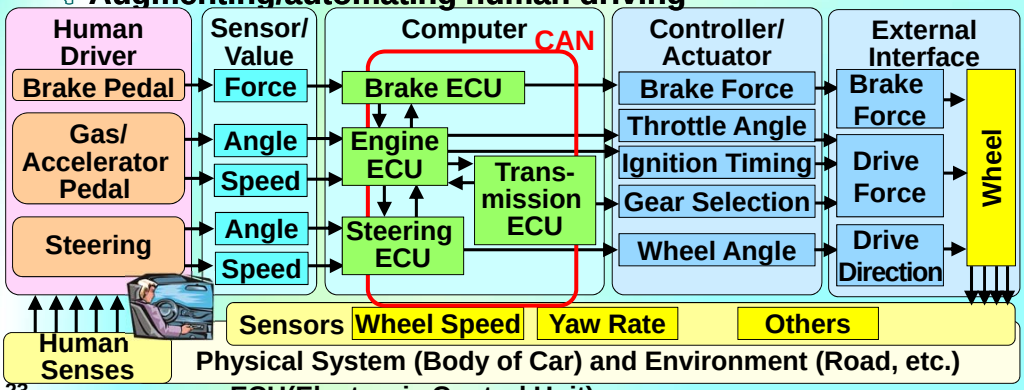
## Challenges for the Future
## Human-Centered and Context-Aware

- Human-in-the-loop: Total integrity including human behavior
  - Extreme complexity due to severe constraints: simple input, human, and, simple output, wheels
  - Augmenting human senses: Camera, radar, and other sensor
  - Augmenting/automating human driving

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## Challenges for the Future
## Dreams Come True: Driver-less and Auto-steering

- Automated driving comes to street
  - Google (Prius, Lexus) [Half Million Miles] and Toyota (Lexus)
  - Some US states allow to driverless car on the street (California, Nevada)
  - US Dep. of transportation allows only for testing [May 2013]
- Automated steering for collision avoidance
  - Under the condition of clearance space available
- Challenges
  - Automation and augmentation (Old wine)
  - Social acceptance for safety
  - Context-aware computing and control

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## Conclusions

- World is becoming "programmable"
- IT convergence to automobile is VERY significant
  - IT convergence inside automobile: Cyber-physical system
  - IT convergence outside automobile: Transport network, social network
- Automobile is a challenging domain for IT convergence engineering
  - Smarter, greener, seamless to IT society
  - Automation and augmentation
- Let's Challenge Together !!

Reference: M. Aoyama, Computing for the Next-Generation Automobile, IEEE Computer, Vol. 45, No. 6, Jun. 2012, pp. 32-37.

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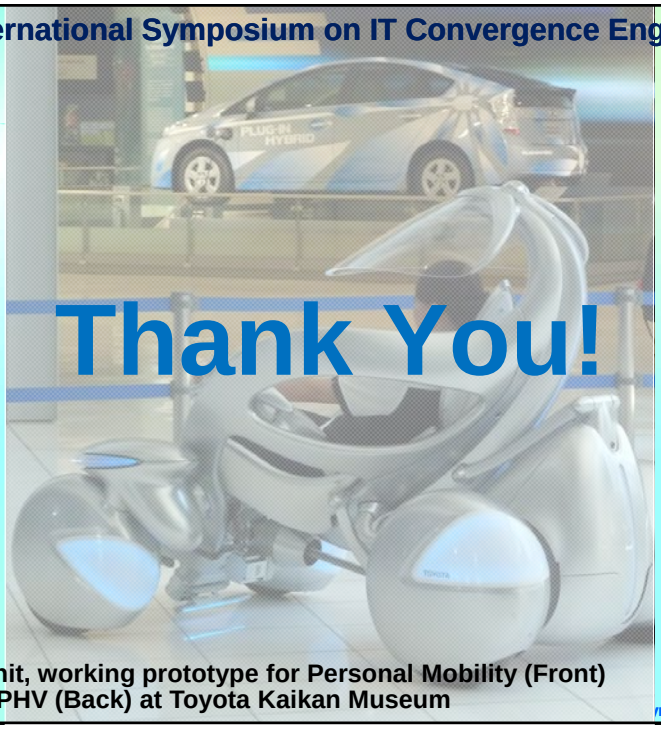
The 5th International Symposium on IT Convergence Engineering



# Thank You!

Toyota i-unit, working prototype for Personal Mobility (Front) and Prius PHV (Back) at Toyota Kaikan Museum

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