Your Vehicle, A Moving Computer

Kai Huang
Stanford Racing

- 2005 DARPA Grand Challenge: First place
- two quad-core Intel workstation

CMU BOSS

- 2007 DARPA Urban Challenge: First place
- ten 2.16 GHz Core2Duo processors

http://www.tartanracing.org
Automotive Electronics

Source: market and technology study automotive power electronics 2015

Level of dependency

1970
- Electronic Injections
- Check Control
- Speed Control
- Central Locking

1980
- Electronic Gear Control
- Electronic Air Condition
- ASC Anti Slip Control
- ABS
- Telephone
- Seat Heating Control
- Autm. Mirror Dimming

1990
- Navigation System
- CD-Changer
- ACC Adaptive Cruise Control
- Airbags
- DSC Dynamic Stability Control
- Adaptive Gear Control
- Xenon Light
- BMW Assist
- RDS/TMC
- Speech Recognition
- Emergency Call

2000
- ACC Stop&Go
- BFD, ALC, KSG
- 42 voltage
- Internet Portal
- GPRS, UMTS
- Telematics
- Online Services
- BlueTooth
- Car Office
- Local Hazard Warning
- Integrated Safety System
- Steer/Brake-By-Wire
- I-Drive
- Lane Keeping Assist
- Personalization
- Software Update
- Force Feedback Pedal

You name it!

2020

Source: BMW

2/4/2014
Kai.Huang@tum
Brief history of ICT in the Automobile

- Up to ca. 1990, no or minimal use of ICT in the car (with the exception of the radio), control of the energy flow by the driver
- Three threads of development:
  - Controllers for automatic transmissions
  - Electronic fuel injection EFI
  - Antilock Braking System ABS
Brief history of ICT in the Automobile: EFI

- (Mechanical) fuel injection, Introduction in aircraft in Germany in the 1930’s, Bendix Corp. Introduced it for cars in the USA in the beginning of the 50’s
- First cars with EFI: 1958 Chrysler’s sport models D300, Adventurer, D500 and Fury with Bendix Electrojector
- First German car with EFI (Bosch D-Jetronic): VW Type 3 (1600 E), 1967, first Bosch ECU (analog)

http://www.ch300imp.com/bendix_us.htm

2/4/2014 Kai.Huang@tum
Brief history of ICT in the Automobile: ABS

- First presentation of electronic ABS by Mercedes-Benz in 1970
- Introduction in 1978 S-Class
- First digital ECU, basis of digitization of ICT in the car
Characteristics of today’s ICT in the car

- Historically grown structures, mapped to (and clotted into) the development and production processes in the automotive industry
- More or less firm (and static) coupling between (software) function and (hardware) execution unit
- High complexity of the design of new or “overarching” functions (involving more than one execution unit)

→ Concepts for new architectures inevitably needed when additional sets of complex functions are added, e.g., energy/battery management and thermal management for EVs
State of the art

- “Hard wired” architecture with distributed ECUs
- Dedicated bus systems
- Evolutionary grown architecture that is increasingly interconnected
  - Over 70 electronic control units (ECU)
  - Divided into different domains (Chassis, Body, Drivetrain, Infotainment)
  - 5 different communication systems
  - 6 CAN buses (different speed / domains)
  - 22 LIN buses (connecting sensors / actuators)
  - 1 FlexRay bus (Chassis/drive train / motor control)
  - 1 MOST bus (Infotainment/Multimedia)
  - Ethernet (Point to point)
- Complexity of integrating new functions increases dramatically
Complexity Keep Increasing

DENSO's View

Vehicle System Trend
- Standalone
- Network System
- Integrated Vehicle System

Large-scaled Complex!

Next-Generation Automotive Systems
Intelligent Vehicle System + Infrastructure (V2X)

ECU Program size and SW Complexity
Multiple Increase

SW Engineering Trend

Component-based Development
Model-based Development
Platform-based Development
New Advanced...

2/4/2014 Kai.Huang@tum
Value Chain: Mechanics -> Embedded Systems

Data from car manufacturers

**Increasing complexity in automotive electronics**

**Change in the value chain.**
Value creation in cars is increasingly driven by electronics and software.

Source:
- Paul Milbredt, AUDI AG, EFTA 2010
  Switched FlexRay: Increasing the Effective Bandwidth and Safety of FlexRay Networks
- BMW Group, FTF 2010 Orlando
  Energy Saving Strategies in Future Automotive E/E Architectures
Centralized Architecture Reduces Complexity
Required Technology for Centralised ICT

- High performance
- Scalability
- Energy efficiency
- Safety and Reliability
Need a Nvidia GeForce GTX 285 (1G DDR3, 1476MHz) to get 24 frames/second for a 600*480 resolution video
Current Automotive Controllers

Infineon 8 bit, 16 bit, 32 bit chips

Freescale 16 bit, 32 bit chips
What is Needed

- Use the combination of state-of-art Semiconductor techniques to achieve high performance and energy efficiency
- Use customized board to scale the number of chips to use
Scalability Demos
fortiss eCar
Lab Car 1: LEGO E-Corner
Lab Car 2: LEGO
Lab Car 2: Collision Avoidance
TUM Lab Car: Climbing the Tube
Video 5: Mercedes S-class
MISC

- AUTOSAC (http://www.autosar.org/)
- GENIVI (http://www.genivi.org/)
Ford reveals solar-powered car

- Fully charged the car could travel for up to 21 miles powered just on electricity.
- Research from the company suggests that in future the sun could power up to 75% of all trips made by an average user in a solar hybrid vehicle.