FSM of Electronic Control Units Software
Designed following the AUTOSAR Standard

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Agenda

• Context

• AUTOSAR (AUTomotive Open System Architecture )

• Functional Size Measurement with AUTOSAR

• Conclusions & future work
Context: Embedded Systems in cars

• In today’s cars, the use of E/E systems is continuously growing. Modern car prices are highly related to the use of these systems.

• E/E systems are complex systems, composed of ECUs that are interconnected by a network, in which software plays an ever more important role.

• Software reuse and carryover techniques have become inevitable for OEM.
• The AUTOSAR consortium was formally launched in July 2003 by the major automotive companies including automobile manufacturers, suppliers and tool developers.

• Its main objective is to standardize a large number of ECU software modules in order to benefit from the reuse of these modules.

• It also aims to prepare for the increase in functional scope of E/E systems.
AUTomotive Open System Architecture 1

Cooperate on standards

- Standardized application interfaces
- Standardized software architecture
- Standardized configuration processes

Compete on implementation

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AUTomotive Open System Architecture 2

- System engineering approach with a **layered architecture**.

- **Standardization** and distribution of functions.

- Principle of **Reuse** and configuration.

• **Software is widely independent** of Hardware.
• **Time and costs are reduced** due to the simplification of the development processes.
• **Quality and efficiency are enhanced** because of software reuse at OEM and suppliers.
AUTOSAR Meta-Model 1

• SWCs are the main elements of Application Software in AUTOSAR: they contain the functional description of the Software.

• There are two types of SWC: Sensor/Actuator SWC and Application SWC:
  • Application SWCs are defined regardless of hardware architecture and ECU location,
  • Sensor/Actuator SWCs are bound to the ECU to which the sensor/actuator is connected physically.
The internal behavior of a SWC is defined as a set of Runnable entities (or Runnables) which are executed at runtime.

A Runnable represents a portion of the code that will be executed on the target ECU. A Runnable is mapped to an OS (Operation System) task.

Runnables exchange information using inter-Runnables variables.
Communication between SWCs is performed using communication ports. There are two types of ports:

- **sender-receiver:**

- **or client-server:**
A Steer-by-Wire system with AUTOSAR 1

The system provides two main functionalities: rack torque and feedback torque.
Functional Size Measurement 1

• FSM is a powerful tool providing an objective and quantitative base for managing software projects: estimation models, effort models, benchmark models, and quality models...

• The COSMIC ISO 19761 method provides a standardized method for measuring the functional size of software from both the MIS domain and the real-time domain. The COSMIC method is considered a second-generation FSM.
• COSMIC is applicable at both the beginning of the development process, in the requirements specification phase, and at the end of the project, after implementation for benchmarking studies.

• The measurement result corresponds to the functional size of the FUR of the software measured, and is expressed in COSMIC Function Points (or CFP).
A guideline for measuring the functional size of ECU software

The measurement strategy phase

• **Purpose**: To measure the size of the FUR of any system based on its model described following the AUTOSAR standard.

• **Scope of the measurement**: the AUTOSAR Virtual Functional Bus - where communication between SWCs and the environment are specified independently of hardware.
A guideline for measuring the functional size of ECU software 2

- **Level of granularity:** SWC description level of the AUTOSAR architecture - they encapsulates part of the functionality of the Application Software.

- **Functional User:** Each SWC (Application and/or Sensor/Actuator) interacting with the application to be measured is a functional user of that application.
The mapping phase

- **Functional Process**: Runnables are the schedulable parts of SWCs: when triggered, they receive, manipulate, and move data groups.

- **Boundaries**: Exist between any functional user and the Application Software to be measured.

- **Data groups**: AUTOSAR communication modes provide transmission and reception of atomic data elements.
COSMIC data group movements / AUTOSAR
corcepts of data communication

Source/ Destination

SWC -> NVRAM Manager Module
X+R+E
Service request + Service Response
Runnable inside the SWC -> NVRAM Manager Module
X+W+E
Functional size of the steer-by-wire system:
Measurement detail of the Steer Manager SWC

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value</th>
<th>CFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run_Sensor</td>
<td>2E + 2X</td>
<td>4 CFP</td>
</tr>
<tr>
<td>Run_Command</td>
<td>5E + 2X</td>
<td>7 CFP</td>
</tr>
<tr>
<td>Run_InterECU_Wheel</td>
<td>1E + 2X</td>
<td>3 CFP</td>
</tr>
</tbody>
</table>
## Functional size of the steer-by-wire system

<table>
<thead>
<tr>
<th>AUTOSAR SWC</th>
<th>Runnable (COSMIC Functional Process)</th>
<th>Data group movements identified</th>
<th>Functional Process Size (in CFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SteerManager</td>
<td>Run_Sensor</td>
<td>2E + 2X</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Run_Command</td>
<td>5E + 2X</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Run_InterECU_Wheel</td>
<td>1E + 2X</td>
<td>3</td>
</tr>
<tr>
<td>SteerSensor</td>
<td>Run_Acquisition</td>
<td>2E + 1X</td>
<td>3</td>
</tr>
<tr>
<td>SteerActuator</td>
<td>Run_Actuator</td>
<td>1E + 1X</td>
<td>2</td>
</tr>
<tr>
<td>Wheel Manager</td>
<td>Run_Sensor</td>
<td>2E + 2X</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Run_Command</td>
<td>5E + 2X</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Run_InterECU_Steer</td>
<td>1E + 2X</td>
<td>3</td>
</tr>
<tr>
<td>WheelSensor</td>
<td>Run_Acquisition</td>
<td>2E + 1X</td>
<td>3</td>
</tr>
<tr>
<td>WheelActuator</td>
<td>Run_Actuator</td>
<td>1E + 1X</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>38 CFP</strong></td>
</tr>
</tbody>
</table>
Conclusions & Future work

1. We presented a guideline for measuring functional size in accordance with the COSMIC ISO 19761 measurement method for ECU Application Software designed following the AUTOSAR architecture: this is the “How?”...

2. “Why?”: FSM is a potent tool to address some indicator needs early in the software development process in the context of the AUTOSAR standard:

3. Design a Functional Size Measurement procedure in form of a set of rules to follow, in order to correctly measure the functional size of ECU Application Software.

4. Apply our approach to more systems and analyze the measurement results obtained.
Q & A

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