Converting Legacy Embedded Control Software to Executable Specifications

Koichi Ueda
TOYOTA MOTOR CORPORATION

Yoshitaka Uematsu
DENSO CORPORATION

Michael Baloh
EMMESKAY INC.
Contents

1. Introduction
2. Motivation
3. Conversion Process
4. Fundamental Process Activities
5. Current Plan and Future Works
6. Conclusions
Contents

1. Introduction
2. Motivation
3. Conversion Process
4. Fundamental Process Activities
5. Current Plan and Future Works
6. Conclusions
Background

Power Train Requirements are becoming increasingly strict.

- Fuel Economy
- Clean Exhaust Gas Emission
- Performance (e.x. Drivability)

Increasing complexity of Engine Control Algorithms

Development process improvement is an urgent issue.

Keywords: Model-Based Development (MBD)
MBD Concept

Virtual World

Engine Performance Specification II

Combination

Validation

Control Software Specification II

Controller Model

Engine Model

SI LS

Rapid Prot. ECU

HILS

Real World

Engine (Engine, Actuators, Sensors)

Combination

Validation

Controller (Hardware, Software)
MBD Process

Requirements & Constraints → Validation → Control System (Engine + ECU)

System design → System Specification

System Specification → Control design

Control design → Control Software Specification

Control Software Specification → Verification → C-code

C-code → Legacy C-code

Automatic Code Generation

Verification

Combination

Integration
Major Activities in MBD

- Model-Based Control
- Model-Based Calibration
- Model-Based Verification & Validation
- Rapid Modeling
- Executable Specification
- Automatic Code Generation (ACG)

TOYOTA and DENSO have already deployed an ACG environment using Real-Time Workshop Embedded Coder® for advanced and mass production development.


Focus: Executable Specification
Contents

1. Introduction
2. Motivation
3. Conversion Process
4. Fundamental Process Activities
5. Current Plan and Future Works
6. Conclusions
Executable Specification

- MBD Application to power train control ECU software


- Advanced development
- Production development

Deployment of Simulink® models as production specifications

20 to 30 % of development period have been reduced.

(Executable Specification + ACG)

NOTE: Executable specifications are applied to roughly 10 % of engine control algorithms.
Motivation

In order to shift to MBD entirely (i.e., further improvements in productivity), we started a project to convert documented legacy control algorithms into executable specifications.
Expectation

Converted Controller Models

Development in the virtual world
- Control algorithms can be explored using controller models and plant models.

Maintenance
- MBD process can be adopted for the maintenance of legacy control algorithms.

Other Activities
- Controller models enable re-architecting the control modules software efficiently.
Contents

1. Introduction

2. Motivation

3. Conversion Process

4. Fundamental Process Activities

5. Current Plan and Future Works

6. Conclusions
Key Considerations

- Correct models
- Uniform quality
- Readable models
- Uniform appearance of models
- Efficient conversion methodology

Key to success: - Structured Process
- Automation
Basic Idea of Conversion

"Legacy Embedded Software"

C-code

Conversion

Simulink Model

Documents

"Properties for Parameters"
"Compiler Configurations"
"Style Guidelines"
"Conversion Rules" etc.

"Executable Specification"

Additional Information
Key Features of Process

- Structured process
- Parallel works
- Automation throughout the process
- Continuous improvement ("Kaizen")

Similar to "Assembly Line"

This process is very efficient while delivering good quality.
Contents

1. Introduction
2. Motivation
3. Conversion Process
4. Fundamental Process Activities
5. Current Plan and Future Works
6. Conclusions
Model Implementation

Target models and modeling
- Correct
- Readable
- Uniform
- Efficient

- Automation scripts
- Custom block sets
- Style guidelines
- Style checkers

Process rules and Trained engineers
Quality Control

Guarantee of the model quality

- Correct
- Readable
- Uniform
- Efficient

“numerical correctness”
“functional accuracy”
“adherence to style guidelines”

- Verification technologies
- Peer review

Process rules and Trained engineers

Start
C-code
Architecture Extraction
Model Implementation
Test Vector Generation
Verification & Peer Review
Product Release
Simulink Model
Meaningful test vectors must be found efficiently.

- TVG is constructed from automatic data generation and manual activity.
- Automatic generation of static signal step tests is used.
- Original coverage metrics are applied.
- TVG continues until coverage requirements are met.
Contents

1. Introduction
2. Motivation
3. Conversion Process
4. Fundamental Process Activities
5. Current Plan and Future Works
6. Conclusions
Current Plan

Aim: Two times increase of productivity

with other activities in MBD

Engine control algorithm specifications

Documented spec.

Model implemented spec.

Current

After several years

0

100%
Future Works

- Continuous improvement of the conversion process
  efficient and practical verification tools environment

- Large scale modeling
  practical environment, style guidelines

- Integrated development environment
  tool chain enhancement
Conclusions

- Due to further improvements in productivity, TOYOTA started a project to convert documented legacy algorithms into executable specifications.

- Adherence to a structured process is one of the key enablers for the successful execution of this project.

- The result of this project will bring about great improvements to the power train control system development process in TOYOTA.
Thank you for your attention!