Model Based Design in Automation

Ashraf Zarur
Tetra Pak
Focused on our customers

We specialise in providing customers with complete solutions for the processing, packaging and distribution of food products.
Present in more than 175 countries and operations in all continents

Carton packaging material, millions of packs
179,888

Distribution machines
1,425

Packaging machines
484

Processing units
1,847
Tetra Pak development set up

- Company is split into:
  - Market companies
  - Platforms based on package formats
  - Central organization which focuses on technologies

- Developments are made in each part.
- The following presentation is the result of a platform development.
Background
Difficulties in the Packaging industry

- Customers buy platforms to build on
- Platform is maintained for decades
- Local modifications are made on site
- Integration into plant systems
Difficulties in the Packaging industry

Complexity creates the need for high quality software design

► All customer lines are unique
► Machines must support a myriad of packages
  - different materials
  - volumes
  - formats
► Machines support different configurations
► Higher line capacities requires smarter solutions for managing the increased mechanical strain
Traditional workflow
1. Functions are modeled using UML

2. UML is translated to PLC logic according to standards

3. Function is tested on the machine or simulation. Issues are found and function is updated

4. Model in UML is updated according to changes made during tests
Workflow
Traditional non-model based development

IEC-61131-3 Programming languages

- Ladder Logic
- Sequential Function Charts
- Structured text
Workflow

Traditional non-Model Based Design issues

► Current UML tool is non-interactive and supports limited code generation
► No testing capabilities
► As production line capacities are increased, complexity increases
► We need more simulation and early prototyping
  → Faster development
  → Shorter time to market
Model Based Design roll out
Established workflow in mechanical design

Mechanical design

- CAD drawings designed in PTC Creo (formerly Pro Engineer)
- Early simulations/Rapid prototyping using CAD tools
  - Supports finite element analysis for, flow-, stress- and thermaldynamic simulation using Creo, Abaqus and Ansys
Model Based Design roll out

New workflow combining Mechanics, Mechanics, Motion and Software

Simulation and analysis of concept

- CAD drawings are imported to MATLAB/Simulink
  - Using SimMechanics Link with PTC Creo
- Advanced simulations, contact modeling
- Algorithm prototyping
- Forces, Accelerations, Inertias and trajectories found
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New workflow combining Mechanics, Motion and Software

Motion and actuator design

► Forces, Accelerations, Inertia and trajectories are to dimension motors; Servo drives, Frequency drives, AC/DC-stepper motors

► Motion is designed to minimize accelerations and input to tuning for minimizing vibrations
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Software design workflow

1. Functions are modelled in Simulink/Stateflow
2. Code is generated to PLC logic
3. Function is tested on the machine or simulation.
4. Once issues have been found changes are applied in Simulink/Stateflow
Software Verification and Validation possibilities

► **Coverage reports**
  - Helps find dead logic and design error and generates reports, no such capabilities exist today in any target system

► **Test cases**
  - Design verifier helps generate test cases that are quite random in nature with different coverage goals; e.g. Decision coverage, Condition coverage, etc.
  - Manual tests cases are separately developed to cover use cases and intended applications

Code which has not been executed
Model Based Design roll out

Impressions from initial projects

- Concepts and improvements tested at an early stage
- Dimensioning of actuators has proved promising
- Since code is generated instead of manually translated
- Features of the MATLAB and Simulink greatly simplifies development
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Summary - Issues and future needs

► No debugging together with our specific target system.
► Lack of readability of generated code affecting field service
► Simulated torques and dynamics from CAD drawings are not matching mechanics 100% BUT relative improvements are reliable
► Design Verifier tests are useful but must be manually augmented
► Generated code MUST be tested in the target environment
Semi - Model Based Design roll out
Semi Model Based Approach
Other use cases and additional values

- **Pure discrete event functions**
  Libraries managing State machines, sequences and module coordination

- **Mathematical libraries and calculations**
  Common calculations and deployed analysis

- **Hardware libraries**
  Abstraction of hardware components such as Frequency drives and IOs
Semi - Model Based Design roll out

Pure discrete event functions and state machines

Results – Stateflow vs. UML state machine
Semi Model Based Approach
Other use cases and additional values

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Libraries managing State machines, sequences and module coordination

Mathematical libraries and calculations
Common calculations and deployed analysis

Hardware libraries
Abstraction of hardware components such as Frequency drives and IOs
Semi - Model Based Design roll out

Common calculations

For functions that are more mathematical in nature we found that results are often more readable and easily tested than our original functions
Semi Model Based Approach
Other use cases and additional values

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Hardware libraries
Abstraction of hardware components such as Frequency drives and IOs
Semi - Model Based Design roll out

Abstractions of hardware components

Why

► Code reuse is more easily achieved
► Prerequisite for Model Based Design rollout
Model Based Design roll out

Workflow – Abstractions of hardware components

► Frequency inverter library
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Test environments

► We have found that often test harnesses are more efficient when making a separate function block simulating the hardware interaction
► This function block is then also generated and used to drive tests in the target systems for subsystem tests
Summary
Model based design roll out

Summary

► So far only a limited deployment of Model Based Design has been achieved for smaller functions and pieces of overall software
► To be able to fully roll out Model Based Design as a development practice debugging capability and visualization of state diagrams is needed.
The major advantages include:

- Easier testing and verification with coverage reports
- Advantages in algorithm development
- Easily integrated workflow in V-model
- Step change in early prototyping using Virtual Engineering