Abstract

The creation of embedded systems requires multi-disciplinary methods. The class of embedded systems is a quite heterogeneous class of systems, ranging from small high volume integrated circuits to expensive one-of-a-kind systems, such as electron microscopes or air-traffic controllers. The Embedded Systems Institute has been founded on the assumption that multi-disciplinary methods to create embedded systems can be applied in multiple domains, despite the wide variation in embedded systems over the domains. In this article we discuss this assumption and we give a budget method as an example of a multi-disciplinary multi-domain method. Multi-disciplinary methods are used widely in the industry, but these methods are poorly consolidated and founded. We discuss the required research steps to advance from implicit methods to explicit and founded methods.
This work has been carried out as part of the Boderc project under the responsibility of the Embedded Systems Institute. This project is partially supported by the Netherlands Ministry of Economic Affairs under the Senter TS program. This work is also part of the Gaudi project.

September 1, 2020
status: concept
version: 0.8
Assumptions of the ESI Research Agenda

1. Methods that fulfil multiple objectives exist to create embedded systems.

2. These methods help to speed up the creation process, reduce the risks, and increase the product quality.

3. These methods are generic for multiple market/business domains, application domains and functional domains.

4. These methods build upon the software and electronics technologies, and to a lesser degree these methods build upon the more conventional technologies, such as mechatronics and physics.

5. These methods need an intelligent adaptation to the specific domain.
Domains Mapped on CAFCR

Customer objectives

Application

Functional

Conceptual

Realization

market
business

application

functional

technology

health care
consumer electronics
office
semiconductor equipment
automotive

cardio/vascular
video entertainment
professional document
lithography
car navigation

persistent storage
search/query
wireless communication
image processing
motion control
print, display
workflow

DVD+RW, FLASH
DBMS
bluetooth, WLAN, UWB
MPEG 4
PID control
LCD, plasma, OLED
scheduling
VxWorks, RT-Linux,
Embedded Windows

Do Useful Multi-Domain Methods Exist?

Gerrit Muller

version: 0.8
September 1, 2020
ESRAdomains
Do Useful Multi-Domain Methods Exist?

Gerrit Muller

version: 0.8
September 1, 2020
MDMabstractionHierarchy
Attributes of a method

- a goal
- a decomposition in smaller steps
- possible orders of taking these steps
- visualization(s) or representation(s)
- guidelines
Examples of Methods Applied in Multiple Domains

**Methods successfully applied in multiple domains:**
- key driver model;
- context modeling;
- cost of ownership modeling;
- use cases, worst cases;
- graph representation for logistics purposes (commercial, goods flow, service);
- mapping functions to products and others (QFD);
- interface specification;
- construction decomposition;
- functional decomposition;
- designing with multiple decompositions;
- execution architecture;
- performance modeling;
- micro benchmarking;
- **budget-based design**
- safety, reliability and security analysis, for example FMEA;
- work break down structure;
- integration plan;
- quality checklist;
- story telling

**Domains where these models have been applied:**
- wafersteppers
- health care
- electronics infrastructure projects
- document handling
- consumer electronics
- semiconductors

---

The budget-based design method will be discussed as applied in wafersteppers, health care, and document handling.

So, What are the Problems?

- generic nature of methods
  - need for customization
  - need for highly skilled designers

- lack of description
  - concepts
  - how tos

- lack of education in this type of methods
  - where to learn (graduate, postgraduate, postdoc)?
  - which discipline?

- lack of research (exploration and consolidation)
  - when to apply?
  - what are the limits?
  - what are alternative methods?
  - what are the options for (partial) solutions?

- lack of relation with mono-disciplinary methods
  - how to use the results, f.i. how to transform a construction decomposition into a class decomposition?

- lack of tools?
Goals of Budget Based Design

- to make the design explicit
- to provide a baseline to take decisions
- to specify the requirements for the detailed designs
- to have guidance during integration
- to provide a baseline for verification
- to manage the design margins explicitly
Visualization of Budget Based Design Flow

can be more complex than additions

SRS
\[ t_{boot} = 0.5s, \quad t_{zap} = 0.2s \]

spec

feedback

measurements
new (proto)
system

model

\[ t_{proc} \]
\[ t_{over} \]
\[ t_{disp} \]

form

budget

\[ t_{proc} \quad \begin{array}{c}
10 \\
20 \\
30 \\
5 \\
20 \\
25 \\
55
\end{array} \]

\[ T_{proc} \quad T_{disp} \quad T_{total} \]

Do Useful Multi-Domain Methods Exist?

Gerrit Muller

version: 0.8
September 1, 2020
EAAbudget
## Example: Budget Based Design Flow

<table>
<thead>
<tr>
<th>Step</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A. measure old systems</td>
<td>micro-benchmarks, aggregated functions, applications</td>
</tr>
<tr>
<td>1B. model the performance starting with old systems</td>
<td>flow model and analytical model</td>
</tr>
<tr>
<td>1C. determine requirements for new system</td>
<td>response time or throughput</td>
</tr>
<tr>
<td>2. make a design for the new system</td>
<td>explore design space, estimate and simulate</td>
</tr>
<tr>
<td>3. make a budget for the new system:</td>
<td>models provide the structure measurements and estimates provide initial numbers specification provides bottom line</td>
</tr>
<tr>
<td>4. measure prototypes and new system</td>
<td>micro-benchmarks, aggregated functions, applications profiles, traces</td>
</tr>
<tr>
<td>5. Iterate steps 1B to 4</td>
<td></td>
</tr>
</tbody>
</table>
### memory budget in Mbytes

<table>
<thead>
<tr>
<th></th>
<th>code</th>
<th>obj data</th>
<th>bulk data</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>shared code</td>
<td>11.0</td>
<td></td>
<td></td>
<td>11.0</td>
</tr>
<tr>
<td>User Interface process</td>
<td>0.3</td>
<td>3.0</td>
<td>12.0</td>
<td>15.3</td>
</tr>
<tr>
<td>database server</td>
<td>0.3</td>
<td>3.2</td>
<td>3.0</td>
<td>6.5</td>
</tr>
<tr>
<td>print server</td>
<td>0.3</td>
<td>1.2</td>
<td>9.0</td>
<td>10.5</td>
</tr>
<tr>
<td>optical storage server</td>
<td>0.3</td>
<td>2.0</td>
<td>1.0</td>
<td>3.3</td>
</tr>
<tr>
<td>communication server</td>
<td>0.3</td>
<td>2.0</td>
<td>4.0</td>
<td>6.3</td>
</tr>
<tr>
<td>UNIX commands</td>
<td>0.3</td>
<td>0.2</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>compute server</td>
<td>0.3</td>
<td>0.5</td>
<td>6.0</td>
<td>6.8</td>
</tr>
<tr>
<td>system monitor</td>
<td>0.3</td>
<td>0.5</td>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>application SW total</td>
<td>13.4</td>
<td>12.6</td>
<td>35.0</td>
<td>61.0</td>
</tr>
<tr>
<td>UNIX Solaris 2.x</td>
<td></td>
<td></td>
<td></td>
<td>10.0</td>
</tr>
<tr>
<td>file cache</td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td></td>
<td></td>
<td>74.0</td>
</tr>
</tbody>
</table>
Power Budget Visualization for Document Handler

- Scanner and feeder
- Power supplies
- Procedé
- Paper path
- Finisher
- Paper input module
- UI and control
- Cooling

Legend:
- Physical layout
- Size proportional to power

Do Useful Multi-Domain Methods Exist?

version: 0.8
September 1, 2020
MDMpowerProportions
Alternative Power Visualization

power supplies
cooling
UI and control
paper path
paper input module
finisher
paper
procedé
electrical
power
heat
Research questions

- What are potential applications for budgets?
- What kind of budget is required?
- What is the decomposition to be used?
- How to manage margins?
- How to verify a budget?
- How to use and maintain a budget?
- Does it provide value when a budget is coupled to other design information?
- and many more...
Potential Applications of Budget based design

- resource use (CPU, memory, disk, bus, network)
- timing (response, latency, start up, shutdown)
- productivity (throughput, reliability)
- Image Quality parameters (contrast, SNR, deformation, overlay, DOF)
- cost, space, time
What kind of budget is required?

<table>
<thead>
<tr>
<th>static</th>
<th>dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>typical case</td>
<td>worst case</td>
</tr>
<tr>
<td>global</td>
<td>detailed</td>
</tr>
<tr>
<td>approximate</td>
<td>accurate</td>
</tr>
</tbody>
</table>

is the budget based on wish, empirical data, extrapolation, educated guess, or expectation?
Start Research by Consolidation of Implicit Methods

- Exploration of new ideas
  - solutions for open issues
  - promising alternative methods
  - foundation and formalization
  - alternative application possibilities

- Application of technology
  - Industry as laboratory

- Consolidation of know how
  - case descriptions
  - extract explicit method
  - identify open issues
  - create educational material

Hypothesis

Evaluation

articulate research question

Do Useful Multi-Domain Methods Exist?

version: 0.8
September 1, 2020
MDMtechnologyManagementCycle
Conclusions

1. Multi domain Multi-disciplinary methods research is a huge research field

2. The technology management cycle is a useful framework for multi-domain method research

3. The challenge is to find the right abstraction level to make the method useful