university of groningen

Areti Ampatzoglou
areti.ampatzoglou@rug.nl
University of Groningen
The Netherlands

The perception of TD in the Embedded Systems Domain

An Industrial Case Study

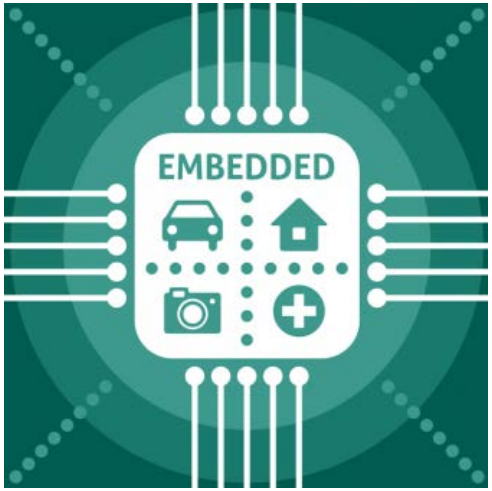
Areti Ampatzoglou, Apostolos Ampatzoglou, University of Groningen,
Alexander Chatzigeorgiou, Paris Avgeriou, University of Macedonia,
Pekka Abrahamsson, Antonio Martini, National Technical University of Norway,
Uwe Zdun, Kari Systa Chalmers University of Technology,
University of Vienna,
Technical University of Tampere

university of groningen

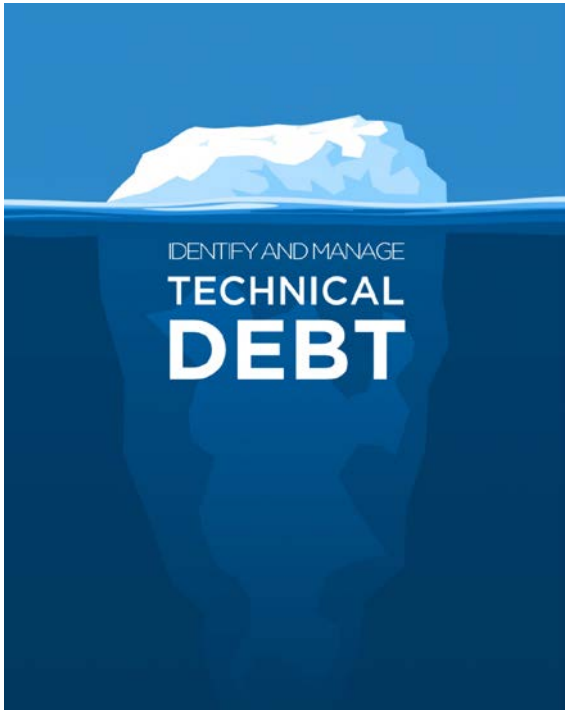
Context

Embedded software development is particularly challenging in the high-end technology sector, which is characterized by shortening product lifecycles, rising market fragmentation and rapid technological changes

The compromise between design-time qualities and business qualities, leads to the creation of a financial overhead in future maintenance activities, usually termed as technical debt



Embedded Software (ES), as a type of software targeting devices that are not typically thought of as computers, is usually specialized for a particular hardware and therefore has platform-specific run-time constraints (e.g., memory usage, processing power, etc.)



university of groningen

Case Study Design

Goal of this study:

Analyze the perception of technical debt in the embedded systems industry

- the expected lifetime of components that have TD,
- the types of technical debt that are frequently occurring,
- the significance of other quality attributes from the point of view of software engineers, in the context of embedded software development”

university of groningen

Case Study Design

Research Question 1

- What is the relationship between the expected lifetime of components and technical debt?

- Interest at some point can become larger than the principal
- TD in components with a high expected lifetime is more harmful

- Relationship between focus on maintainability and expected lifetime

university of groningen

Case Study Design

Research Question 2

- What types of technical debt (e.g., code, architectural, etc.) are more frequently occurring in embedded systems?

- 10 types of Technical Debt
- Require different approaches
- Support prioritization and monitoring of TD

university of groningen

Case Study Design

Research Question 3

- What is the significance of building maintainable software systems (with low TD) compared to satisfying other quality attributes?

- Trade-offs between run-time and design-time qualities
- Quality attributes taken into account in ES development
- Maintainability vs Other QAs
  - Which QAs are prioritized?
  - Which QAs are negotiable?

university of groningen

Case Selection

ID	Company Description			
	Application Domain	Country	Type	#Analyzed Components
C1	Telecommunications	Sweden	Large	1
C2	Automotive	Sweden	Large	1
C3	Mobile	Greece	SME	7
C4	Sensors	Greece	SME	3
C5	Printing	Netherlands	Large	1
C6	Smart Manufacturing	Austria	Large	6
C7	Media Devices	Finland	SME	1

university of groningen

Data Collection

[V1]	Textual description of project
[V2]	First release date of the project
[V3]	Number of releases until now
[V4]	Estimated lifespan of the TDI
[V5]	Types of debt identified *Requirements, Architecture, Design, Code, Test, Build, Documentation, Infrastructure, and Versioning*
[V6]	Importance of quality attributes along TDI evolution *Functional suitability, Reliability, Performance, Usability, Security, Compatibility, Maintainability, Portability*

university of groningen

Data Analysis

RQ	Analysis Plan	
	Used Variables	**Analysis**
1	**[V4]** Estimated Lifespan **[V6]** Importance of Maintainability	Descriptive statistics Cross-Tabulation chi-square test
2	**[V5]** Types of TD	Descriptive statistics
3	**[V6]** Importance of QAs	Descriptive statistics Wilcoxon Signed Rank

university of groningen

Results

RQ1

Relation Between Estimated Lifetime & Maintainability

- **Expected Lifetime:**
  <1 to 30 years
- **Mean Expected Lifetime:**
  12.40 years
- **Standard Deviation:**
  8.94
- **Median:**
  10 years

- **Short-term:** 45%
- **Long-term:** 55%

The technical debt management activities (TD repayment, prevention, etc.) are expected to be more relevant for projects for which long-term maintenance periods are anticipated.

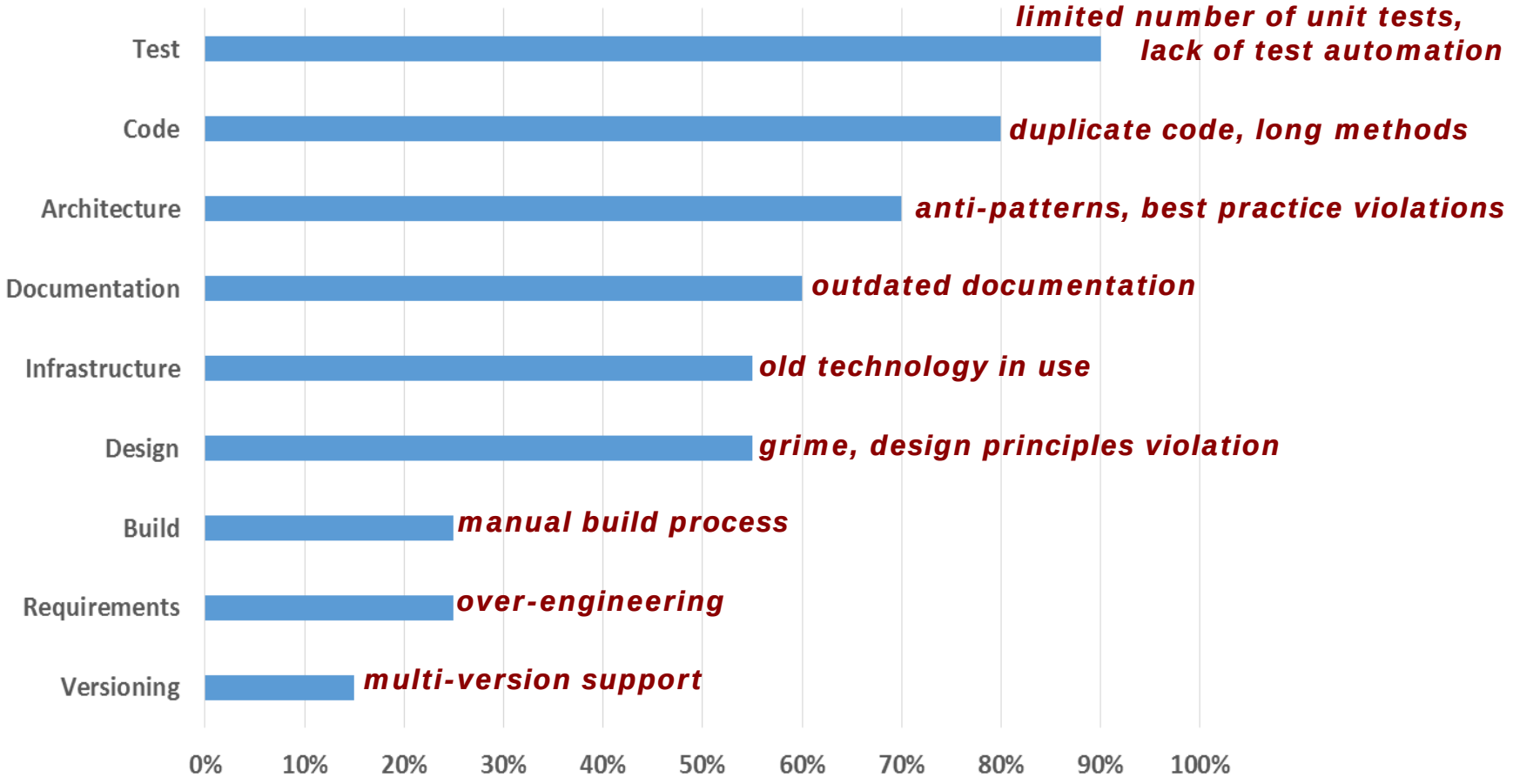
Estimated Lifespan		Maintainability				
		very low	Low	neutral	high	very high
Long	Observed Count	0,0	0,0	3,0	5,0	1,0
	Expected Count	1,4	1,4	1,4	4,5	0,5
Short	Observed Count	3,0	3,0	0,0	5,0	0,0
	Expected Count	1,7	1,7	1,7	5,5	0,6

university of groningen

Results

RQ2

TYPES OF DEBT FREQUENCIES



Results

RQ2

FREQUENT TYPES OF TECHNICAL DEBT

Type of Technical Debt Item	Frequency
Duplicate code	6
Limited number of unit tests	6
Complex code	3
Old technology in use	3
Lack of automated deployment	3
Violations of good architectural practices	2
Lack of test automation	2

Frequently Studied Types of Debt

- Design
- Architectural
- Documentation

Alves et al.

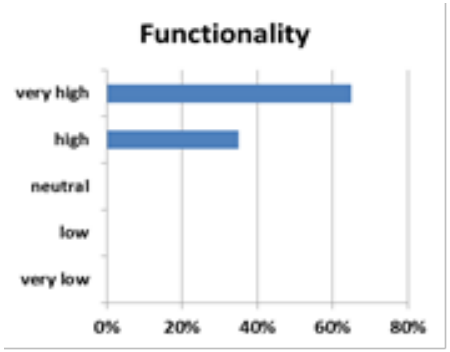
The most recurring types of technical debt in industry are test, architectural design, and source code debt. Architectural and design debt are among the most frequently studied by researchers, as well. On the other hand, some types of TD (e.g., test, code, and infrastructure), which are interesting for practitioners, are understudied by the research community.

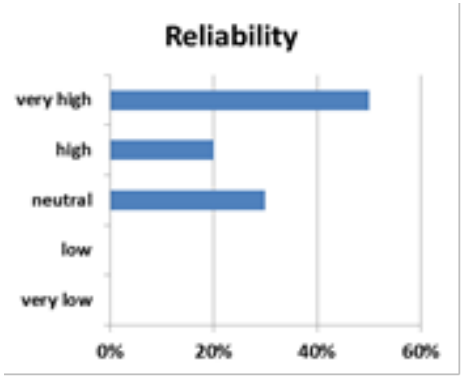
university of groningen

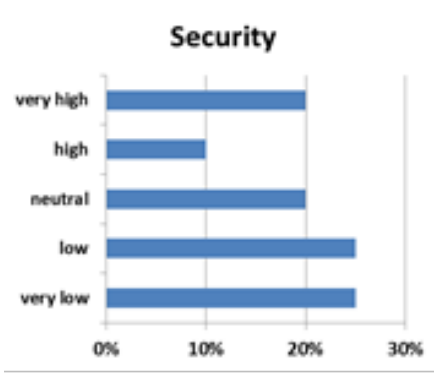
Results

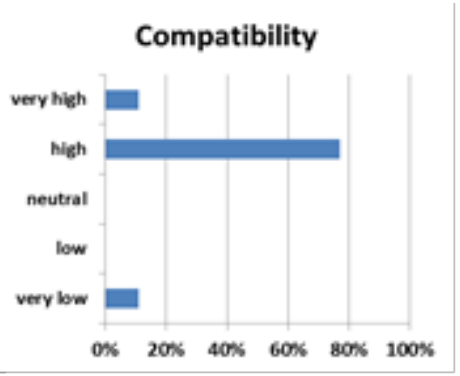
RQ3

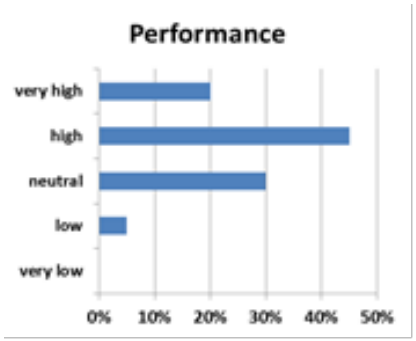
IMPORTANCE OF QUALITY ATTRIBUTES

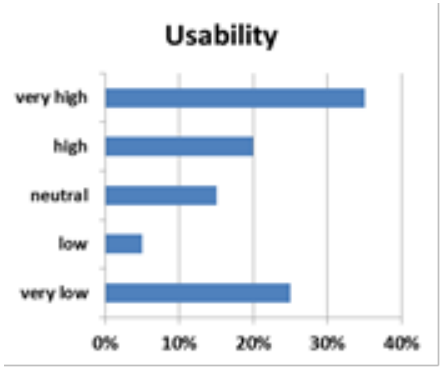


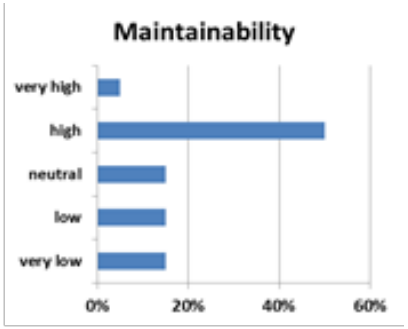


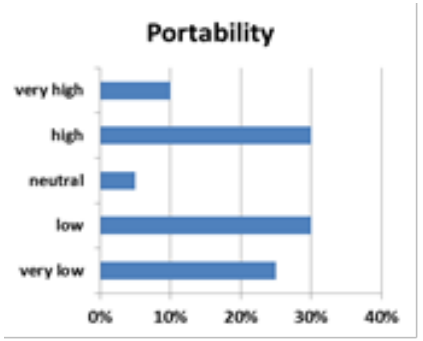












university of groningen

Results

RQ3

PRIORITY OF QAS VS. TECHNICAL DEBT

While managing technical debt in embedded software, some run-time quality attributes are given higher priority than maintainability. Specifically, the ES domain prioritizes reliability, functionality, and performance against maintainability.

Quality Attribute	Most Prioritized	N	Sig.
Functionality	Functionality	19	0,000
	Maintainability	0	
	Ties	1	
Reliability	Reliability	16	0,001
	Maintainability	2	
	Ties	2	
Performance	Performance	9	0,014
	Maintainability	2	
	Ties	9	
Usability	Usability	11	0,738
	Maintainability	6	
	Ties	3	
Security	Security	4	0,125
	Maintainability	8	
	Ties	8	
Compatibility	Compatibility	2	0,705
	Maintainability	2	
	Ties	5	
Portability	Portability	3	0,104
	Maintainability	9	
	Ties	8	

university of groningen

Implications to Researchers & Practitioners

Researchers

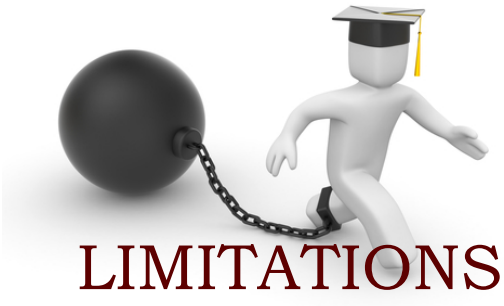
- More methods on the ***test, code*** and ***infrastructure*** level
- *TD prioritization* should consider **feature prioritization**
- Tools and methods for ***TD prevention***
- **D*omain-specific tools and methods*** that take into account the specific requirements

Practitioners

- Acknowledge the significance of **TD management**, especially for **long-term** projects
- *Effective monitoring of the most common **TD types** in the **embedded systems** domain*
- Select ***TD repayment*** *methods that do not harm important* ***run-time qualities***

university of groningen

Threats to Validity



- The case study has been performed on a small number of companies / cases
- The acknowledgment of maintainability as an important factor for long-lived products does not necessarily imply attention to TDM
- The trade-off between maintainability and run-time quality attributes is not directly transferrable to the notion of technical debt
- The possible misinterpretation of the quality attributes by practitioners while filling in the questionnaires

university of groningen

Thank you for your attention!

Questions???