Variability and Architecture

SPLE Course, DAT165, L2 & L3

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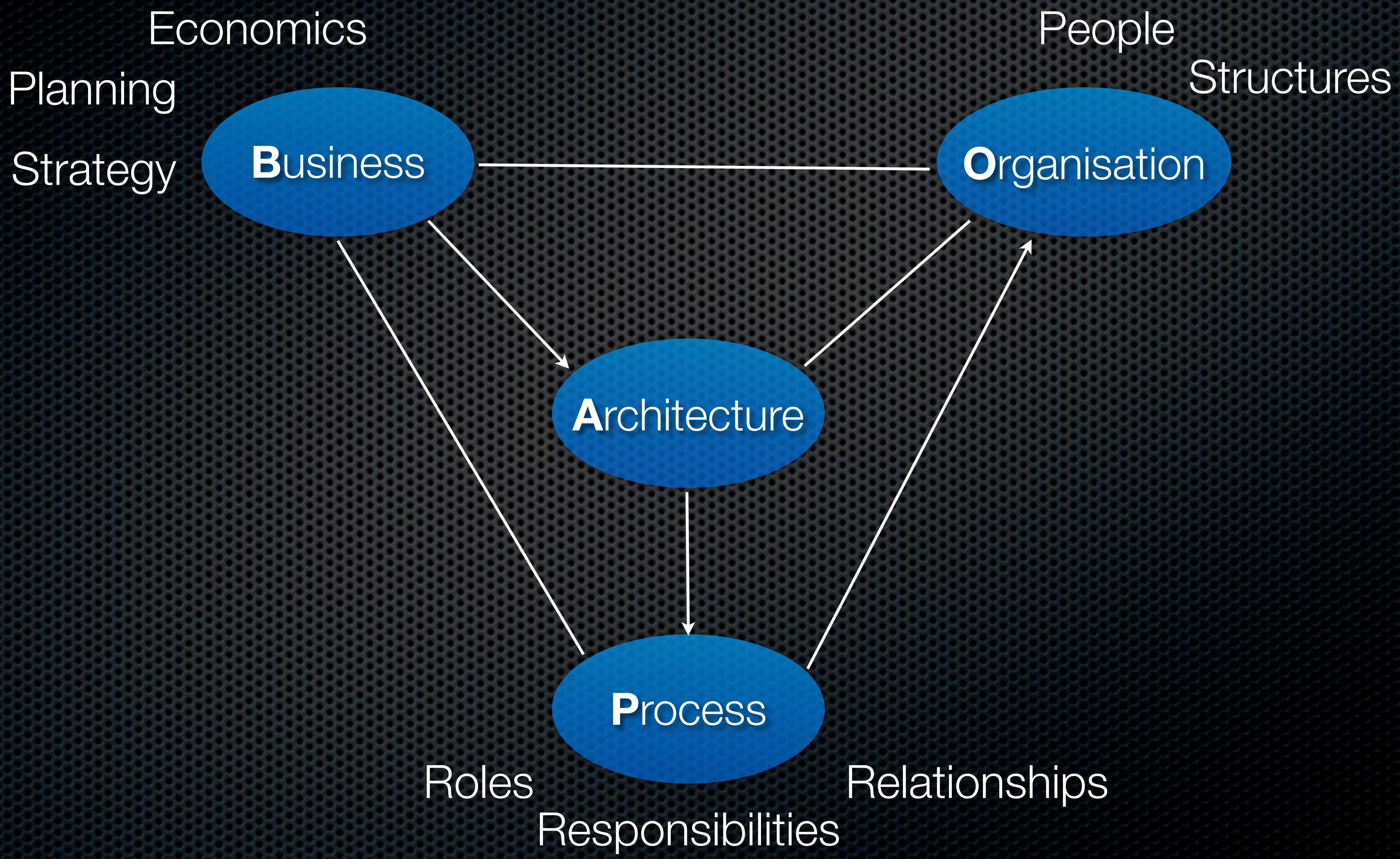
Acronyms used

- DE = Domain Engineering
- AE = Application Engineering
- RefArch = Reference Architecture
- TTM = Time To Market
- SW = Software
- SPL = Software Product Line
- SPLE = SPL Engineering (and course book!)
- Dev = Development

Definitions

- Variability subject - a var item of the real world
- Var object - particular instance of a subject
- Var point - represents a var subject + contextual info
- Variant - represents a var object
- Internal/External var
- For SPL, having 10 variation points with 3 possible variants, gives 3^{10} (59,049) configs

Lectures - Overview (BAPO Model)



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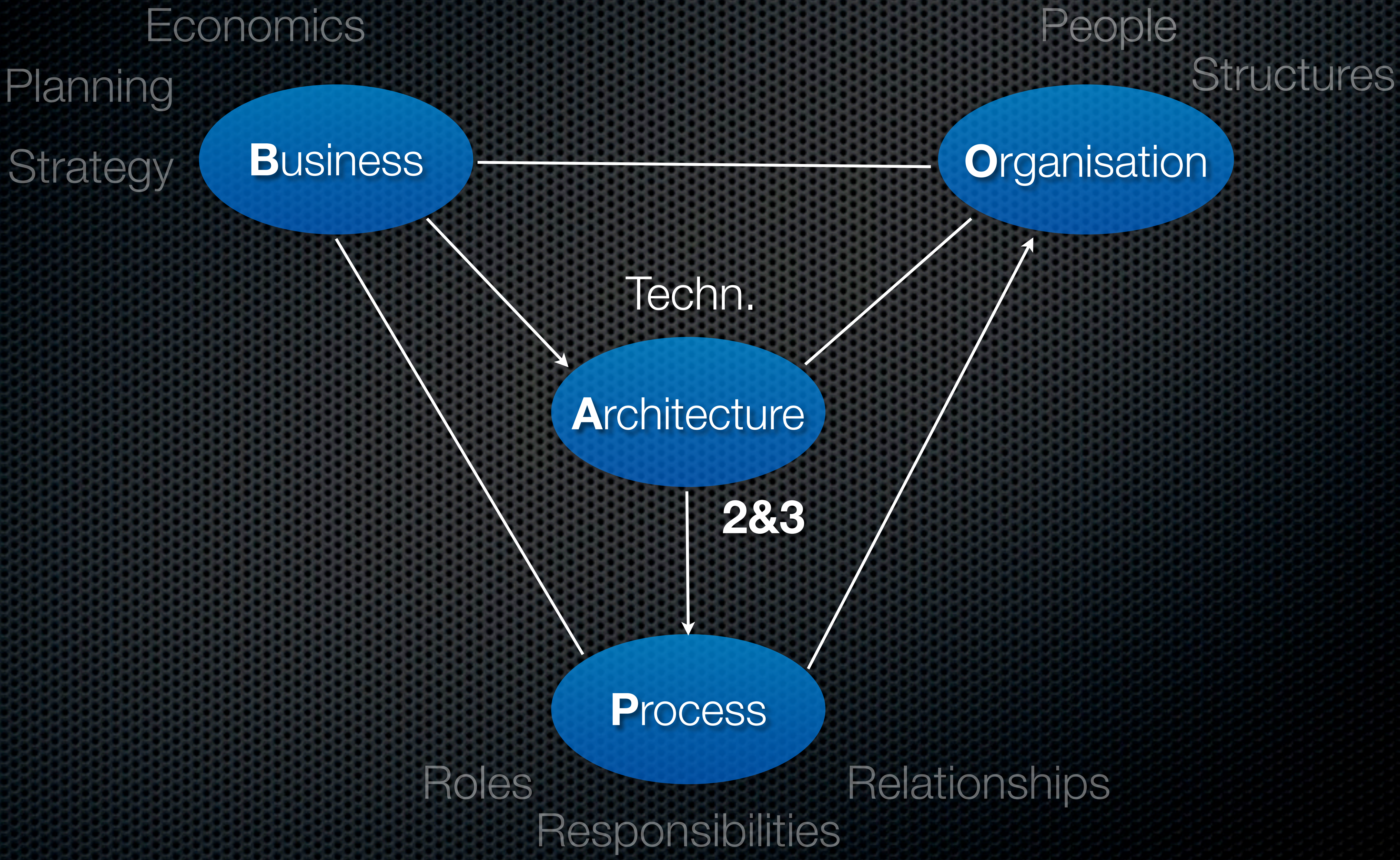
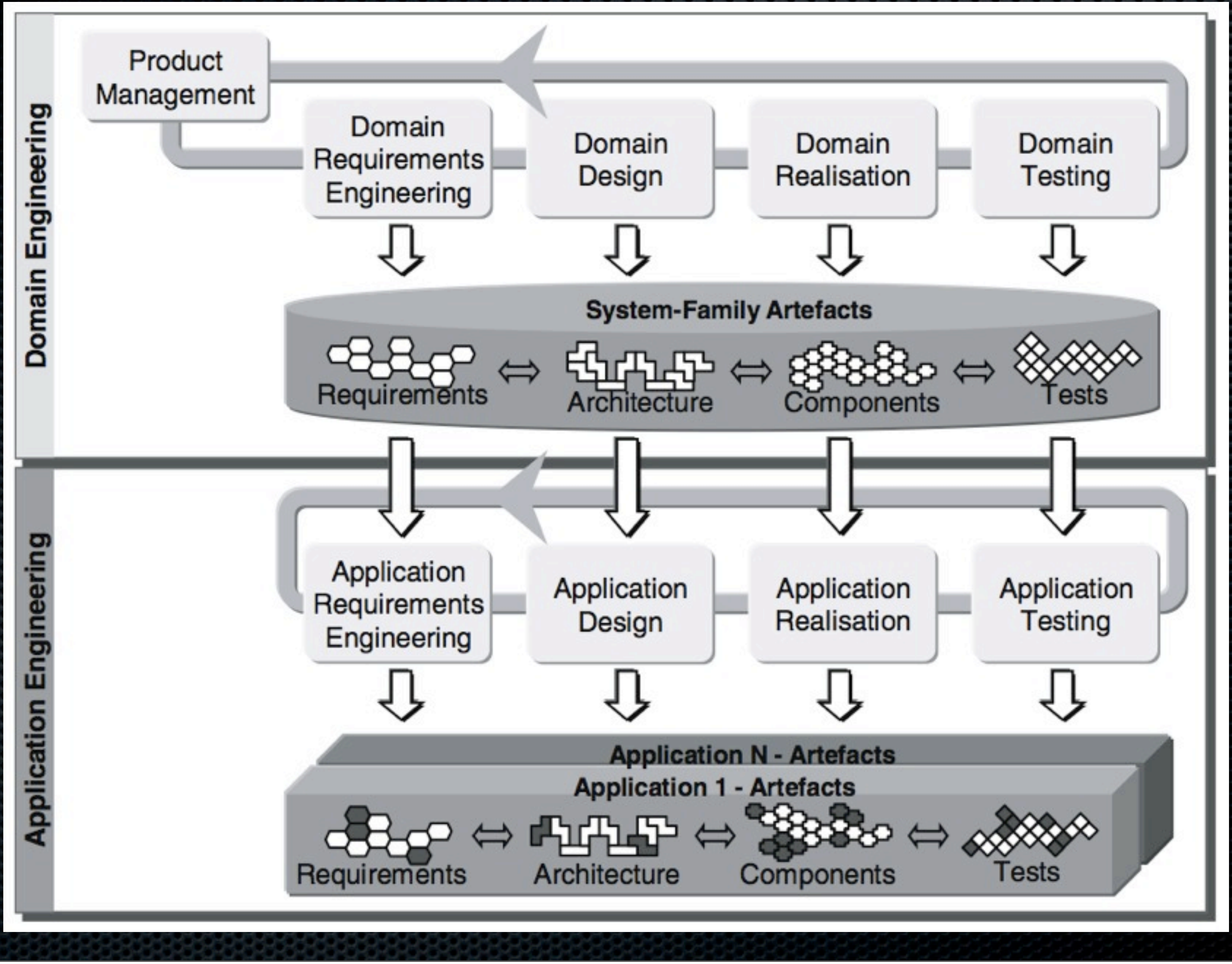
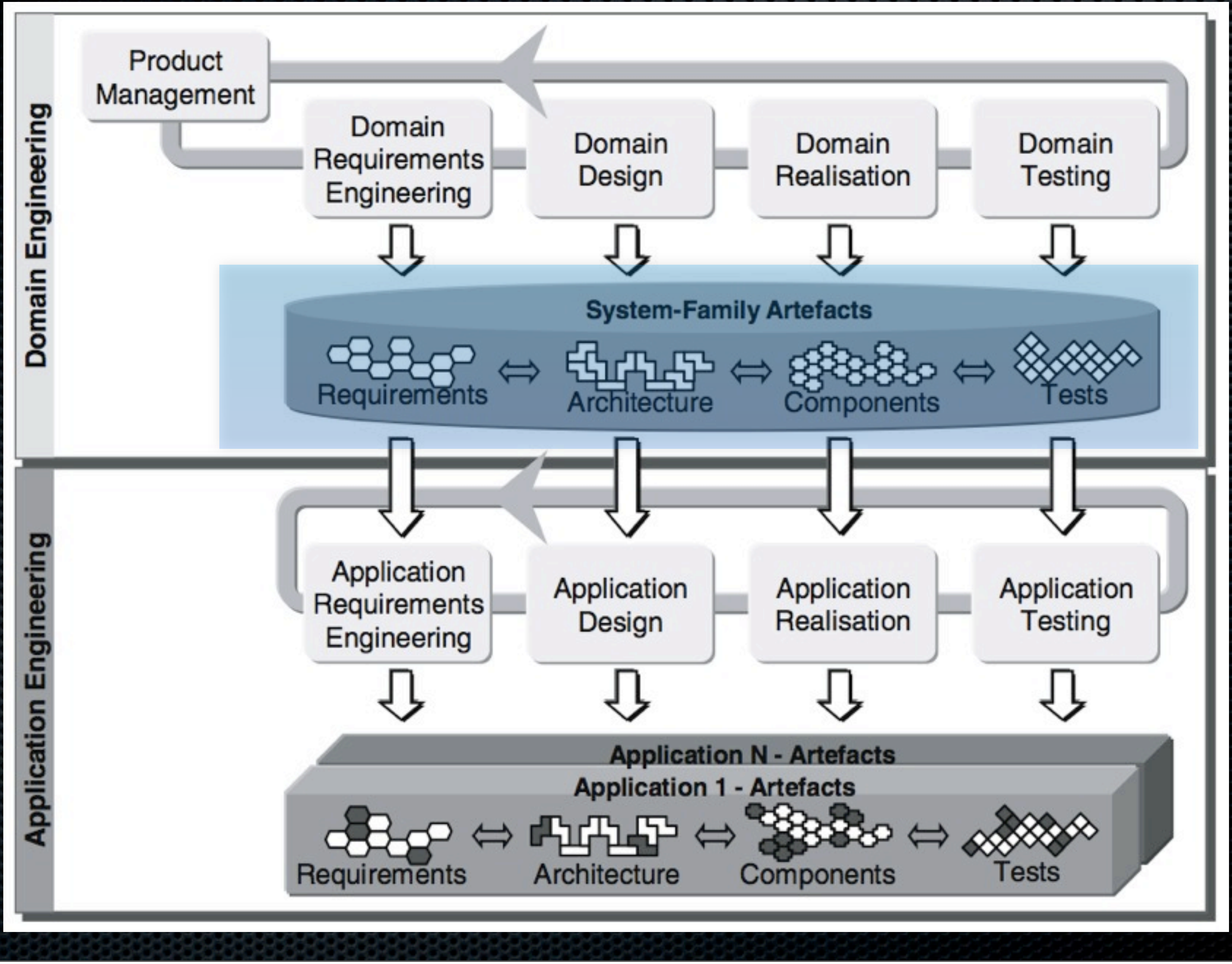


Domain and Application Engineering



Domain and Application Engineering



Variability Management

- SPL = Commonality + Explicit Variability
- Variability is explicitly managed, i.e.
  - Defined, represented, discussed, exploited, implemented, evolved etc.

Feature	Prod. 1	Prod. 2	Prod. 3
Game engine	3D, C++	3D, C++	3D, C++
Score upload	No	Yes	Yes
Lead character	Mario	Ferrari	None, puzzle

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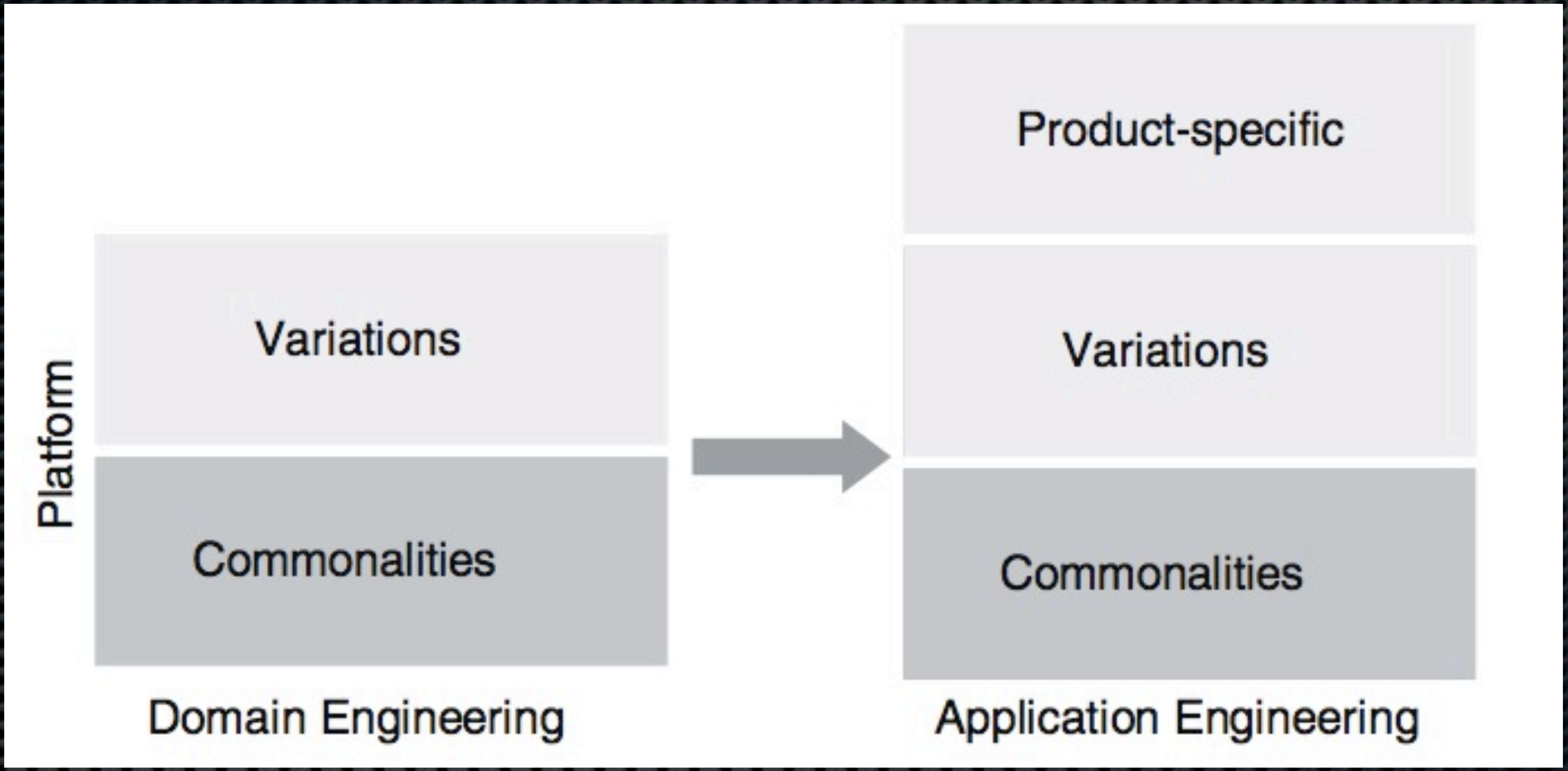
Variation,
supported in SPL

Product-specific,
not supported (now)

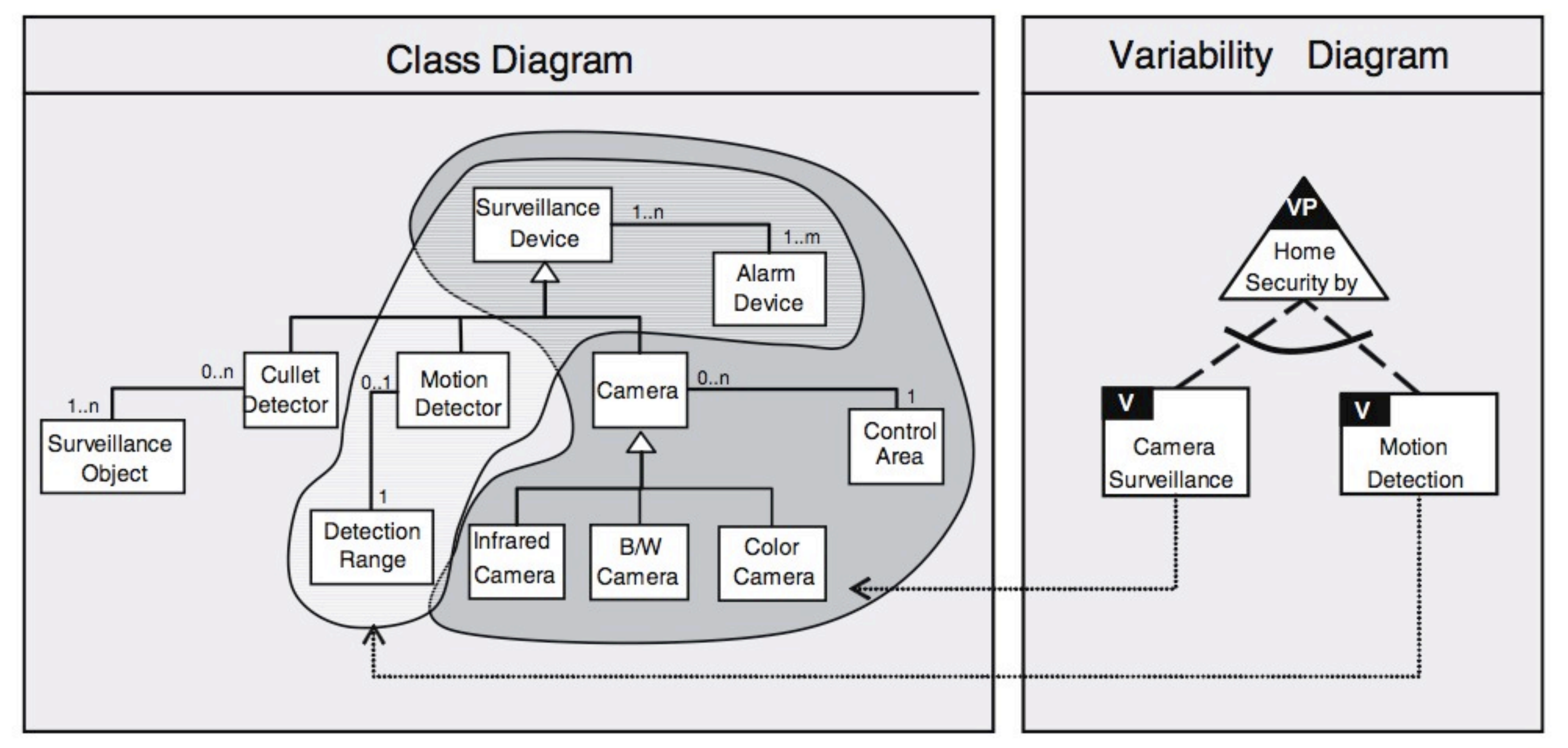
Types of Variability



Variability Documentation

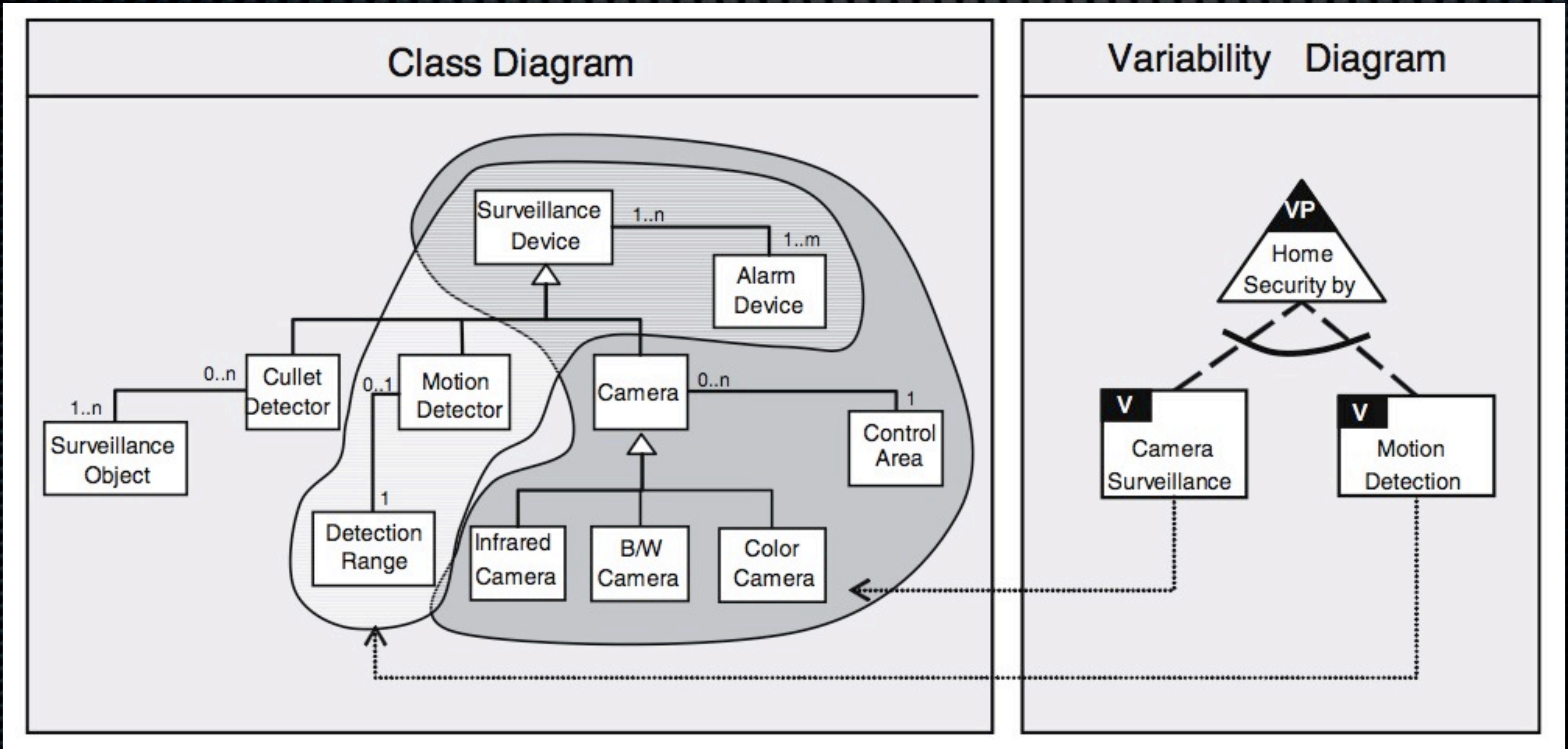
- What varies?
  - Variation points
- Why does it vary?
  - Context, Reasons
- How does it vary?
  - Variants, Dependencies, Constraints
- For whom is it documented?
  - Internal & External Stakeholders
- Improves: Decision Making, Communication & Traceability

Graphical Variability Modeling

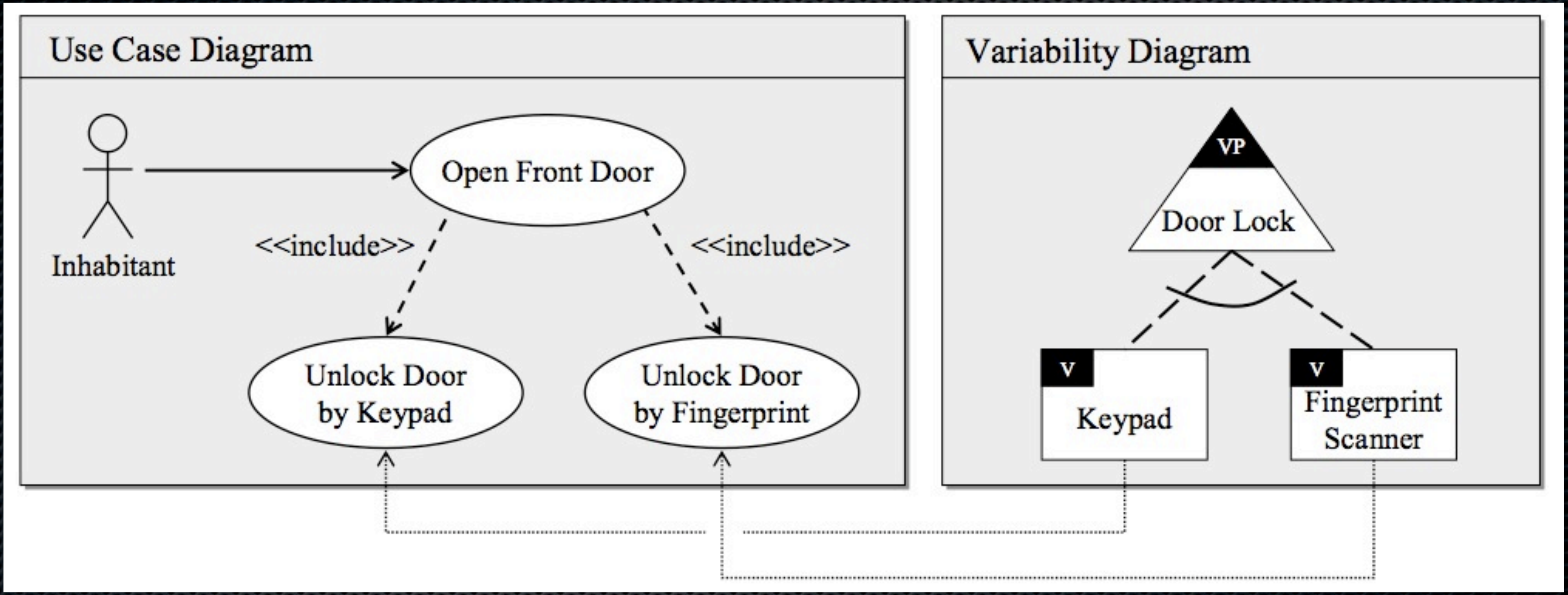


Graphical Variability Modeling

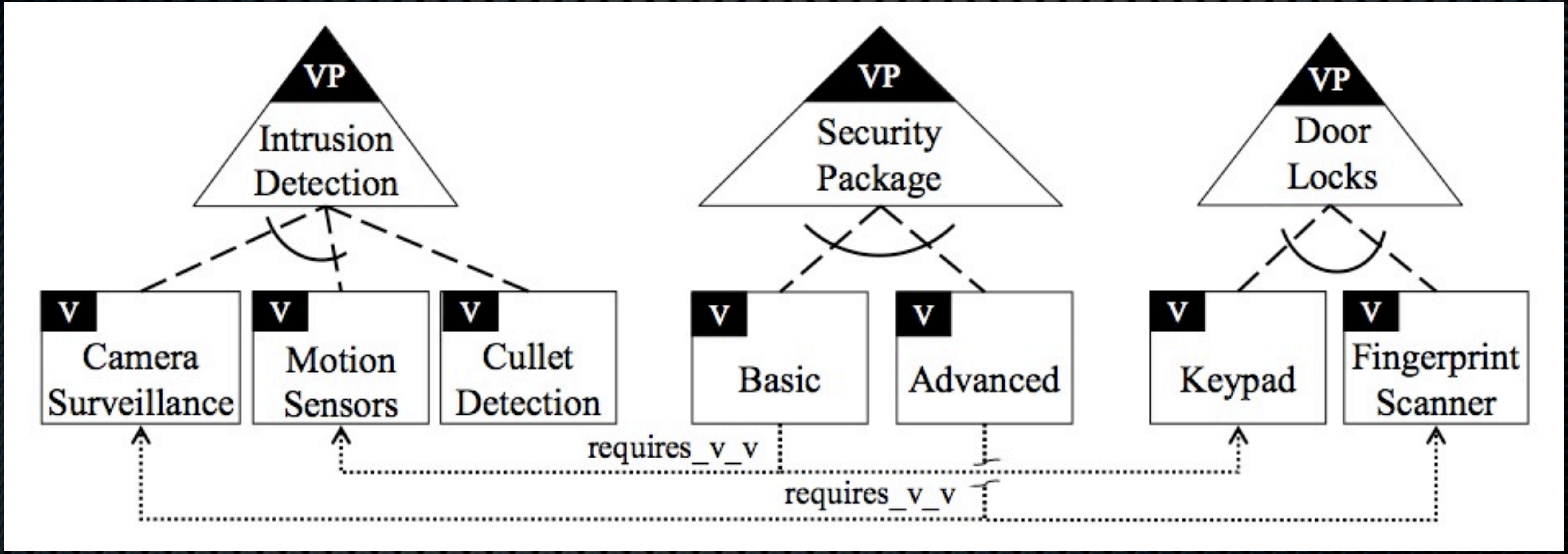
Separate Model!



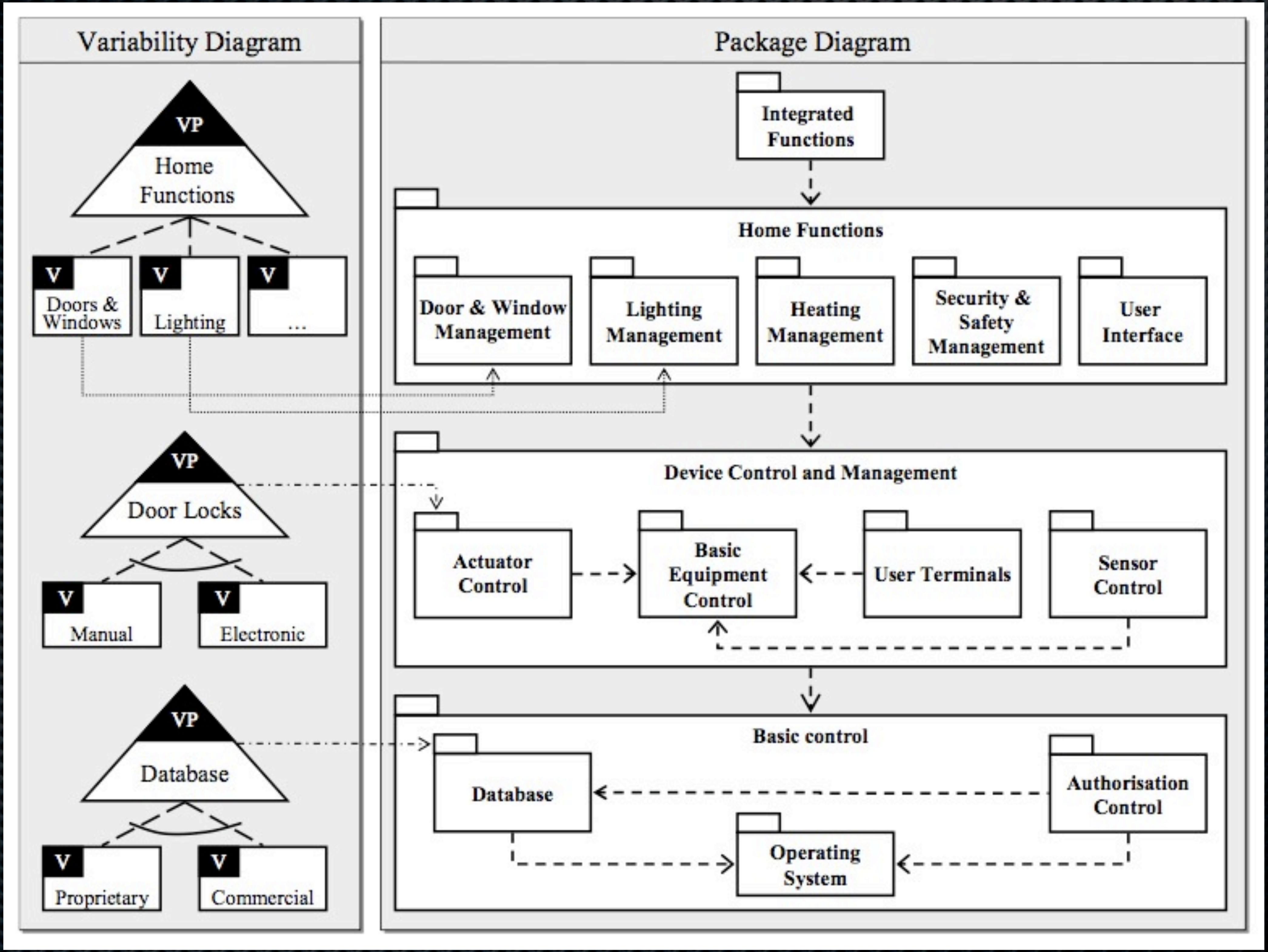
Same variability notation throughout



Packages of variants



Variability in packages/sub-systems



Architecture

Reference Architecture

- Single, shared architecture, common to all products
  - Normal architecture for commonalities
  - Variation points, variants etc for rest
- Not always there in practice, too plan-driven
  - Extract the reference architecture gradually

Time for a paper...

Industry example: Meantime Game Company

- Brazilian company developing mobile games
  - 60 games, 400 devices, 6 languages, 40 developers
- Critical requirement: Portability (Many mobiles)
  - User interface differences
  - CPU, memory and size constraints
  - Support API differences (J2ME, BREW & proprietary)
  - Carrier-specific requirements
  - Internationalization

Industry example: Meantime Game Company

- Developed MG2P = Meantime Game Porting Platform
  - Mobile Domain Database (MDD)
  - Meantime Base Architecture (MBA)
  - Meantime Build System (MBS)
- MDD captures basic Commonality + Variability
  - Variations: Device-specifics, Game types/APIs, Known issues, Language, Game features
  - Families of similar MobApps and Games (in porting context)
  - Typical device for each family chosen (least powerful, most issues)

Configuration knowledge in MDD

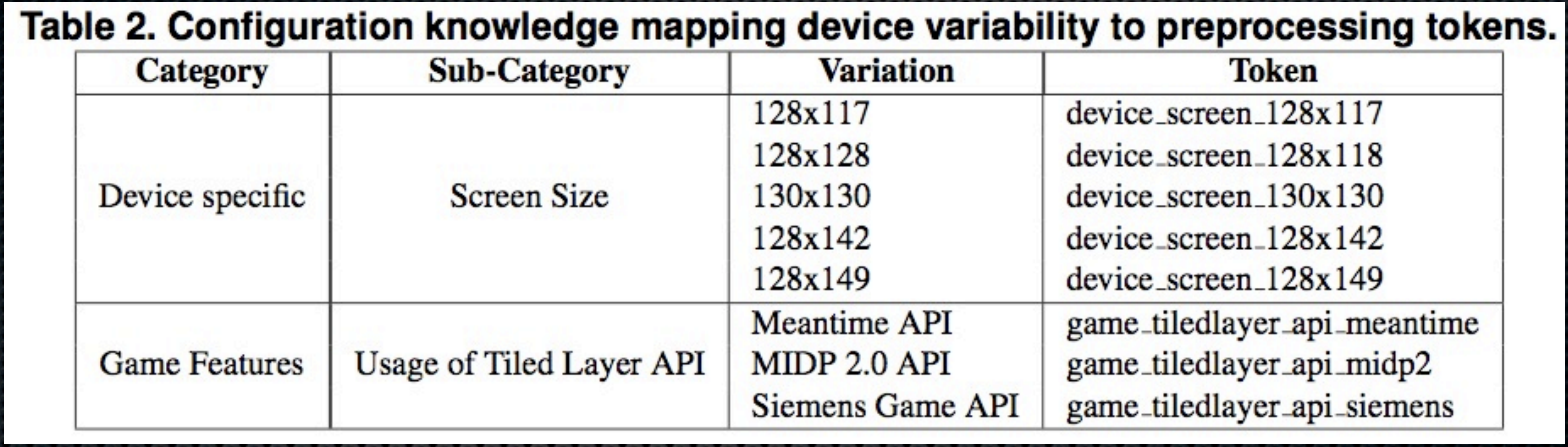


Table 2. Configuration knowledge mapping device variability to preprocessing tokens.

Category	Sub-Category	Variation	Token
Device specific	Screen Size	128x117	device_screen_128x117
		128x128	device_screen_128x118
		130x130	device_screen_130x130
		128x142	device_screen_128x142
		128x149	device_screen_128x149
Game Features	Usage of Tiled Layer API	Meantime API	game_tiledlayer_api_meantime
		MIDP 2.0 API	game_tiledlayer_api_midp2
		Siemens Game API	game_tiledlayer_api_siemens

Industry example: Meantime Game Company

- Meantime base Architecture
  - Same code base and file structure for all games
  - J2ME does not allow libraries => MBA copied for each new game
  - Pre-processing tokens from MDD handles variability
- Meantime build system
  - Built on Antenna pre-processor and Ant, more flexible

Architectural Concerns

- Architecturally significant requirements
  - Key requirements affecting the whole architecture
- Conceptual architecture
  - Key concepts of architecture
- Architectural structure
  - Decomposition into components and relations
- Architectural texture
  - Rules for using, instantiating and evolving architecture

Architecturally Significant Requirements

- Central to the purpose of the products, or,
- Technically challenging / Technical constraints
- Examples:
  - The system must encrypt all network traffic
  - The game must deploy on all mobile phones by the top 5 manufacturers that are released after 2007
  - The system must always give responses to user queries within 3 seconds
  - The system must provide a visual overview of the current flow of resources in the factory being managed
- Quality/Non-func. requirements often decisive

Conceptual Architecture

- Most important concepts + their relations
- Mental model of of domain to understand and simplify the problem
    - (Related to “System Metaphor” in Extreme Programming)

Architectural Structure

- Division into components
    - Sub-systems/units with clear interfaces
- Connections between components

Architectural Texture

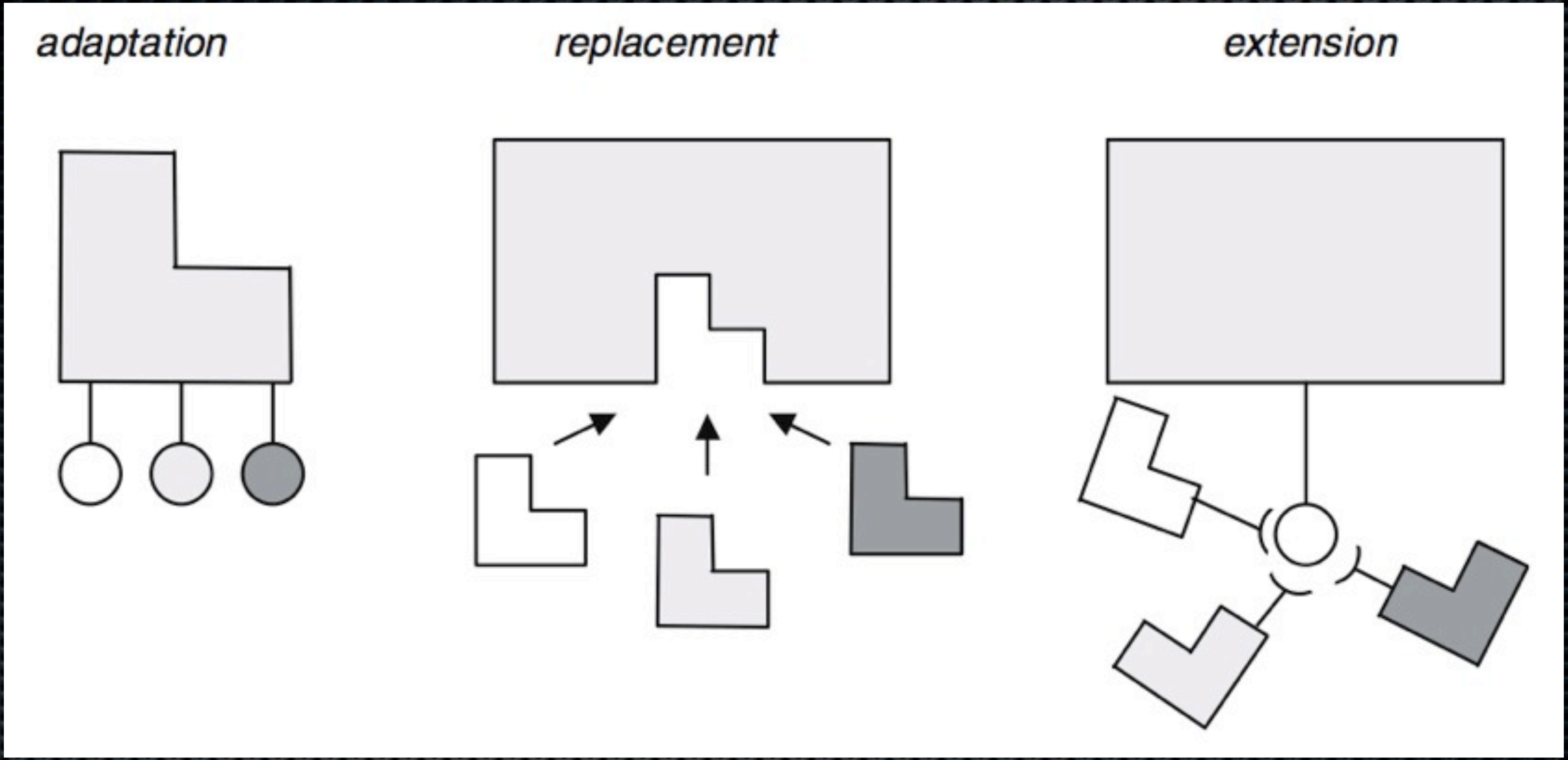
- “Manual” for the Reference Architecture
  - Guidelines, rules, “Philosophy” for
    - Using and
    - Evolving the RefArch
- Examples:
  - Coding standard
  - Design patterns
  - Architectural styles

Creating a Reference Architecture

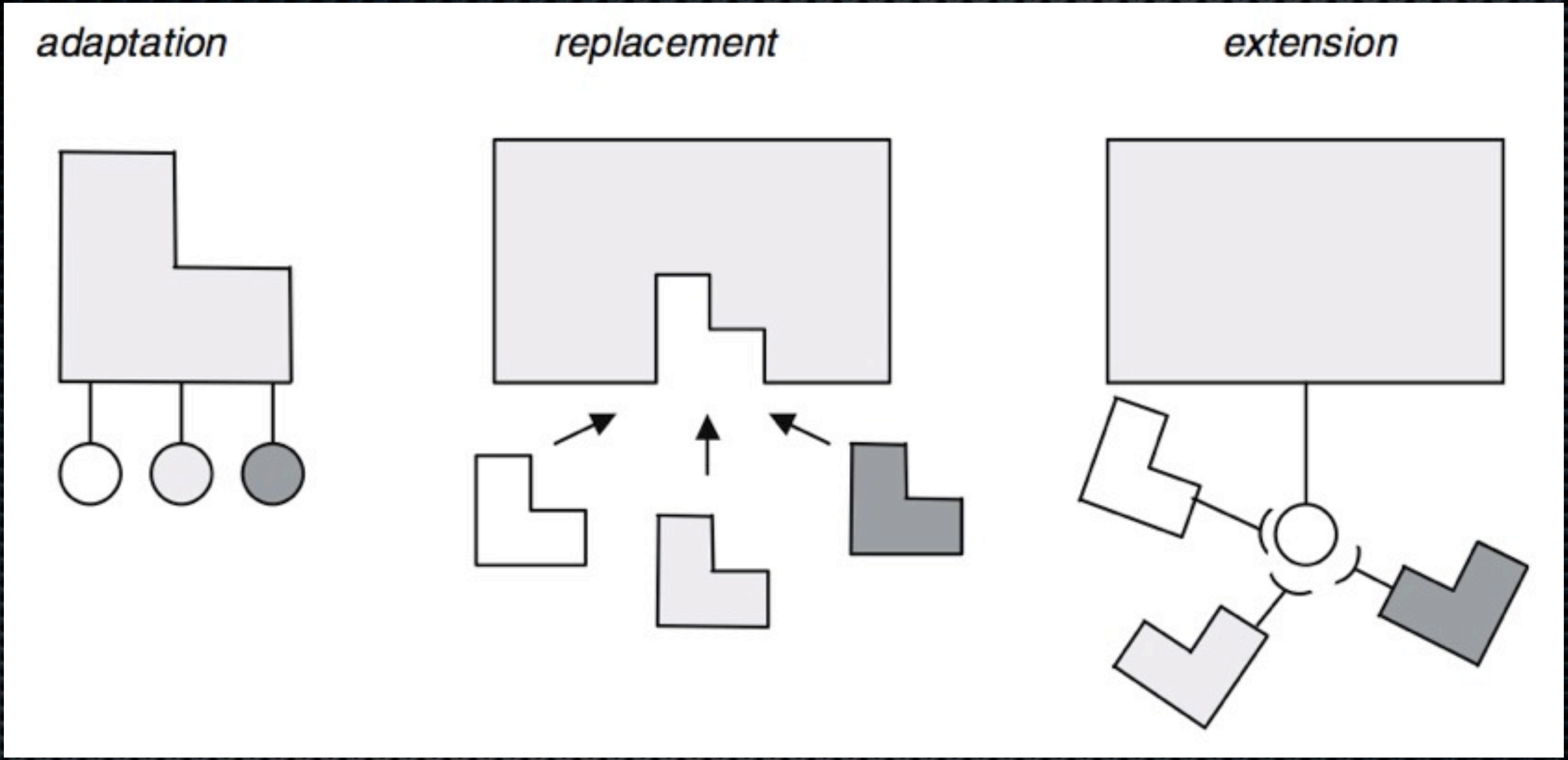
- “Normal” architecting methods can be used
  - Attribute-Driven Design, ..., OO, ..., Design Patterns, ...
- Differences:
  - More products, often more Stakeholders => Communicate
  - Also more Requirements conflicts => Resolve (elicited)
- Three basic ways to support variability:
  - Adaptation
  - Replacement
  - Extension

Variability mechanisms

Variability Mechanisms

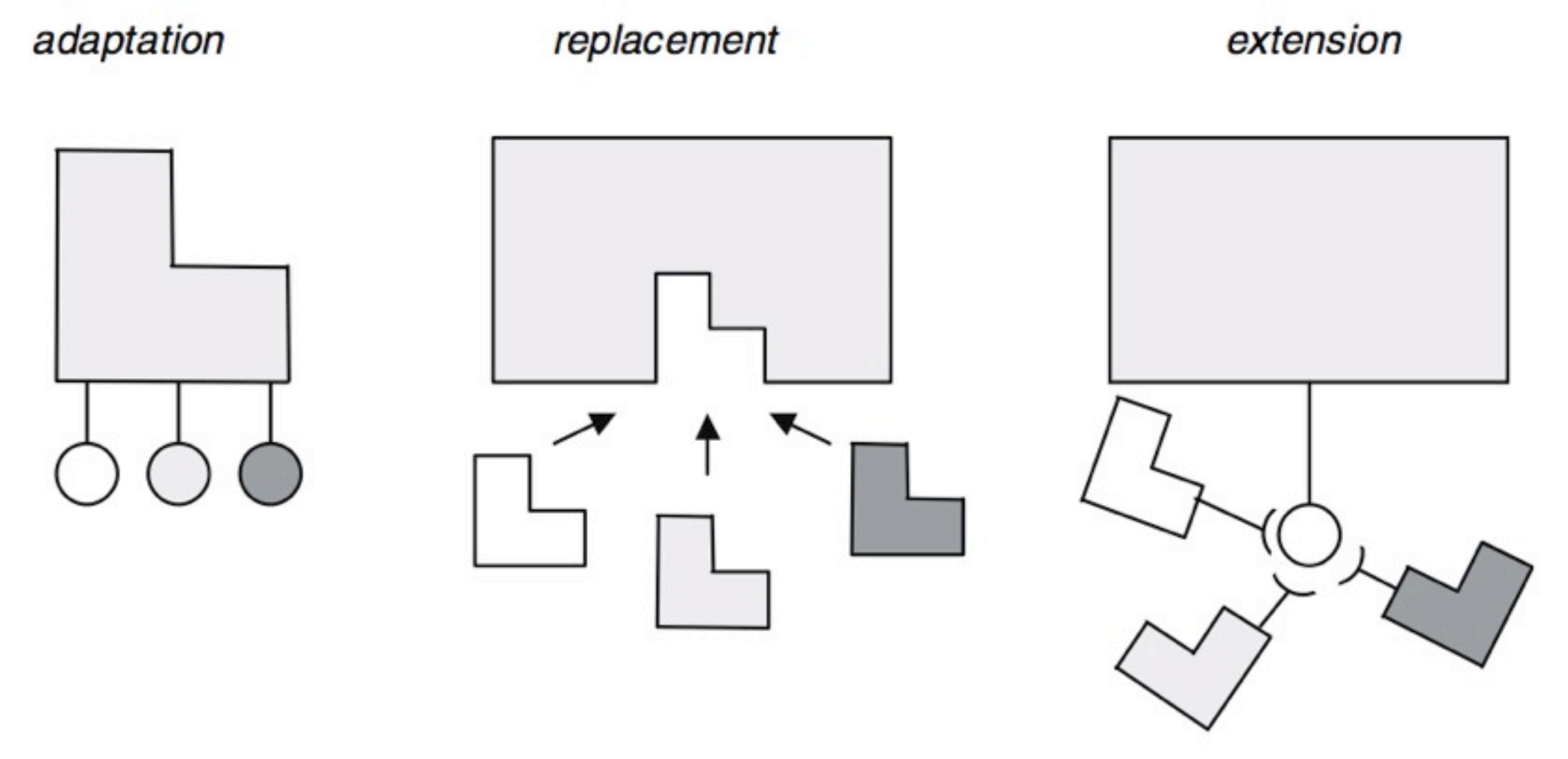


Variability Mechanisms



Only 1 component
implementations
Adaptable behavior

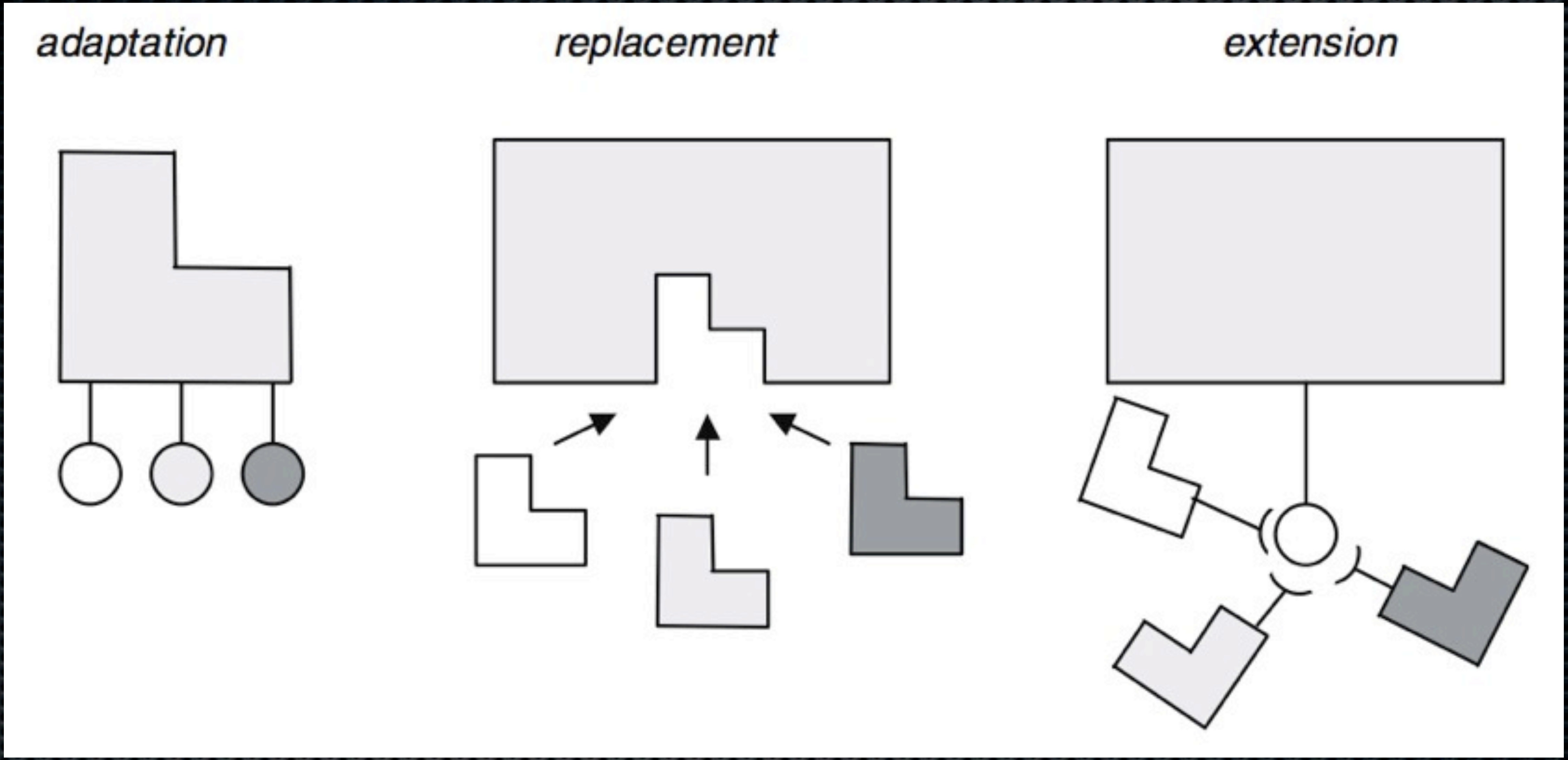
Variability Mechanisms



Only 1 component implementations
Adaptable behavior

Multiple component implementations
Choose one, or develop product-specific

Variability Mechanisms



Only 1 component implementations
Adaptable behavior

Multiple component implementations
Choose one, or develop product-specific

Generic interface for adding components

Adaptation mechanisms

- Inheritance
  - subclass changes/overrides behavior
- Patching
  - partial behavior change with little maintenance
  - DE: component, AE: patch
- Compile-time config
  - Pre-processors or macros, Makefiles
- Configuration
  - Interface to choose between multiple implementations
  - Parameters or configuration file to make choice

Replacement mechanisms

- Code generation
  - Generates code from high-level description (model, script)
  - Glue code or whole components/sub-systems
- Component replacement
  - Default component is replaced with another one
  - Often 3rd party components
  - Wrappers may be needed

Extension mechanisms

- Plug-ins
  - Architecture has interface to “plug in” components
  - Example: CORBA, COM, etc
  - Example: Strategy Design Pattern (functionality can be selected at runtime)

Variability & Commonality SPL Motivations

- Increase in the number of products that can be released
- Manage multiple, diverse products in one portfolio
- Improve product commonality
  - Not only for complexity management,
  - also for marketing (same look-and-feel)

Time for a paper...

Industry Case: Philips Consumer Electronics

- 16,000 employees, €10 Billion turnover (1/3 is TVs)
- 250 developers
- Single SPL for mid- and high-range TVs
- SPL developed 1996-2000, in use since then
- Trends, more complex SW:
  - More features (MPEG4, Sound processing, HW->SW)
  - Globalized market
  - Shorter product cycles and TTM
  - Product convergence

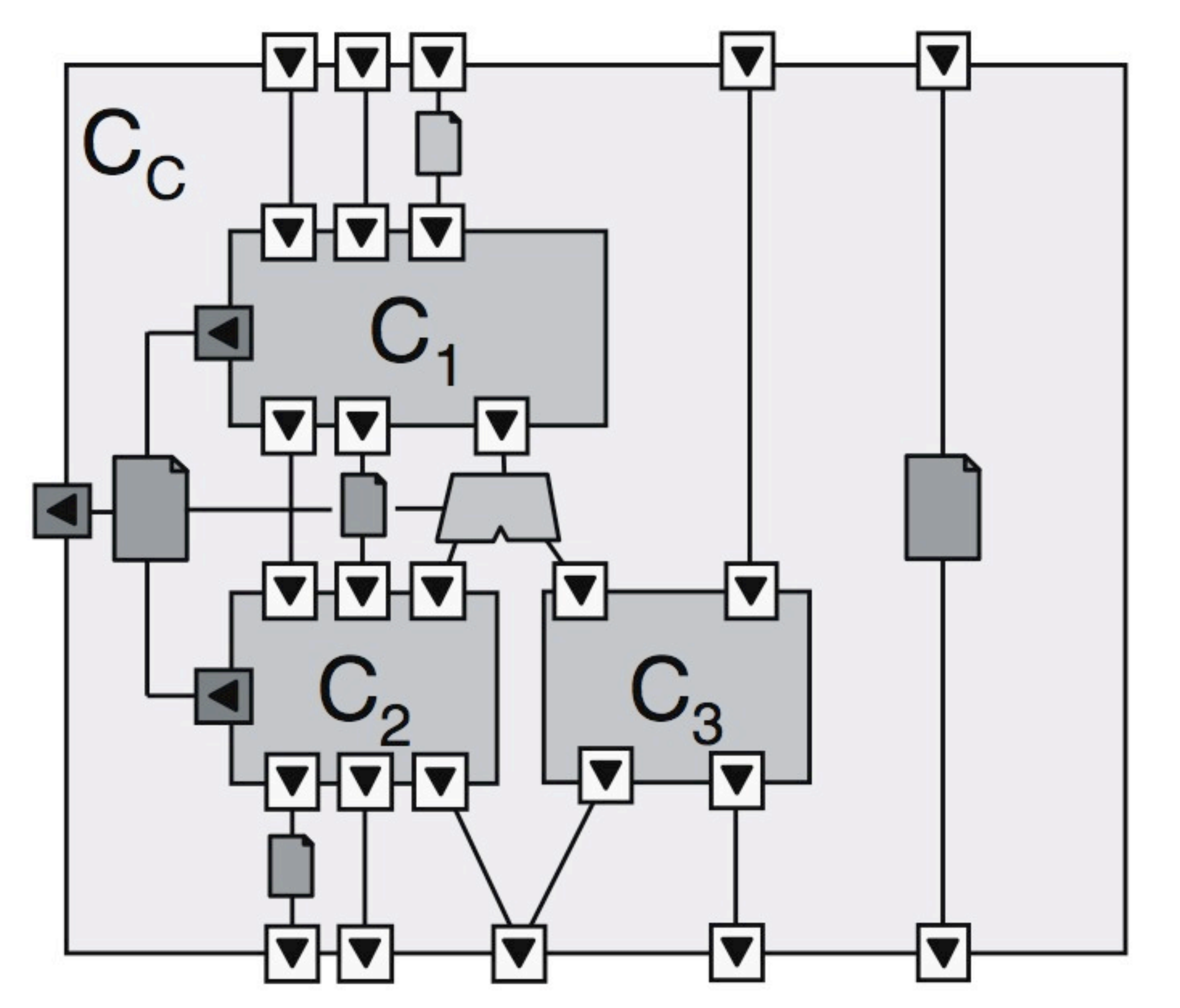
Industry Case: Philips Consumer Electronics

- Hundreds of Variability parameters -> Hierarchy
- Evolution rules: What can be changed without affecting other parts? (HW dependencies)
- Compositional approach technically
  - Describe which components to combine into new product
  - Simplified convergence (DVD+TV, TV+VCR, ...)

Industry Case: Philips Consumer Electronics

- Koala Component Model
  - Component = Specification + Implementation
  - Hierarchical - group of components can be one component at higher level
  - Implemented in C, interfaces in separate files
  - Component descriptions to generate build/make files
    - Interface Description Language + Tools to work with it
  - No extra run-time costs (resource-constrained HW)

Industry Case: Philips Consumer Electronics



Industry Case: Philips Consumer Electronics

- Variability
  - Compound components can have “Diversity parameters”
  - Switches to choose sub-components
- Packages group components and interfaces to larger units
  - Also the packages are hierarchical
- Product is a selection of packages

Industry Case: Philips Consumer Electronics

- Reference architecture?
- What are the Variability mechanisms? (Adaptation, Replacement, Extension)
- Documentation of variability?

Industry Case: Philips Consumer Electronics

- Reference architecture?
  - No, since it would not help for creating combi-products
  - Maybe for small line of TVs, not for whole range over multiple years
- What are the Variability mechanisms? (Adaptation, Replacement, Extension)
- Documentation of variability?
  - Only: Component & Interface data sheets + sub-system design notes

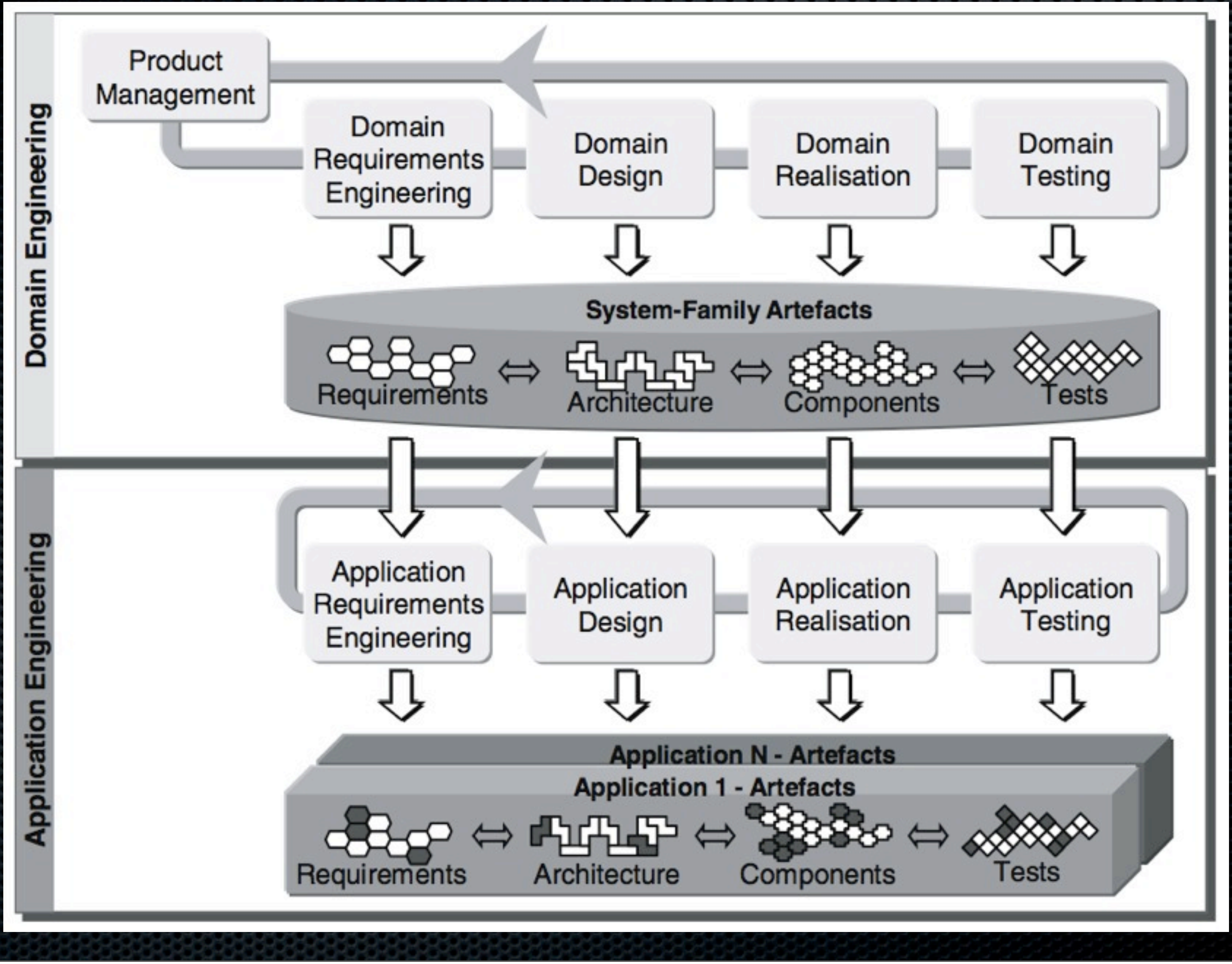
Industry Case: Philips Consumer Electronics

- Results / Lessons learned
  - Diversity of products produced on time, Variability not a problem
  - Late-joining architects don’t understand Koala’s motivation
  - Architecture has lasted longer than any previous
  - Took three years to be successful
  - Config Management system fails at sub-file level variability
    - Better to solve variability in arch & use traditional CM

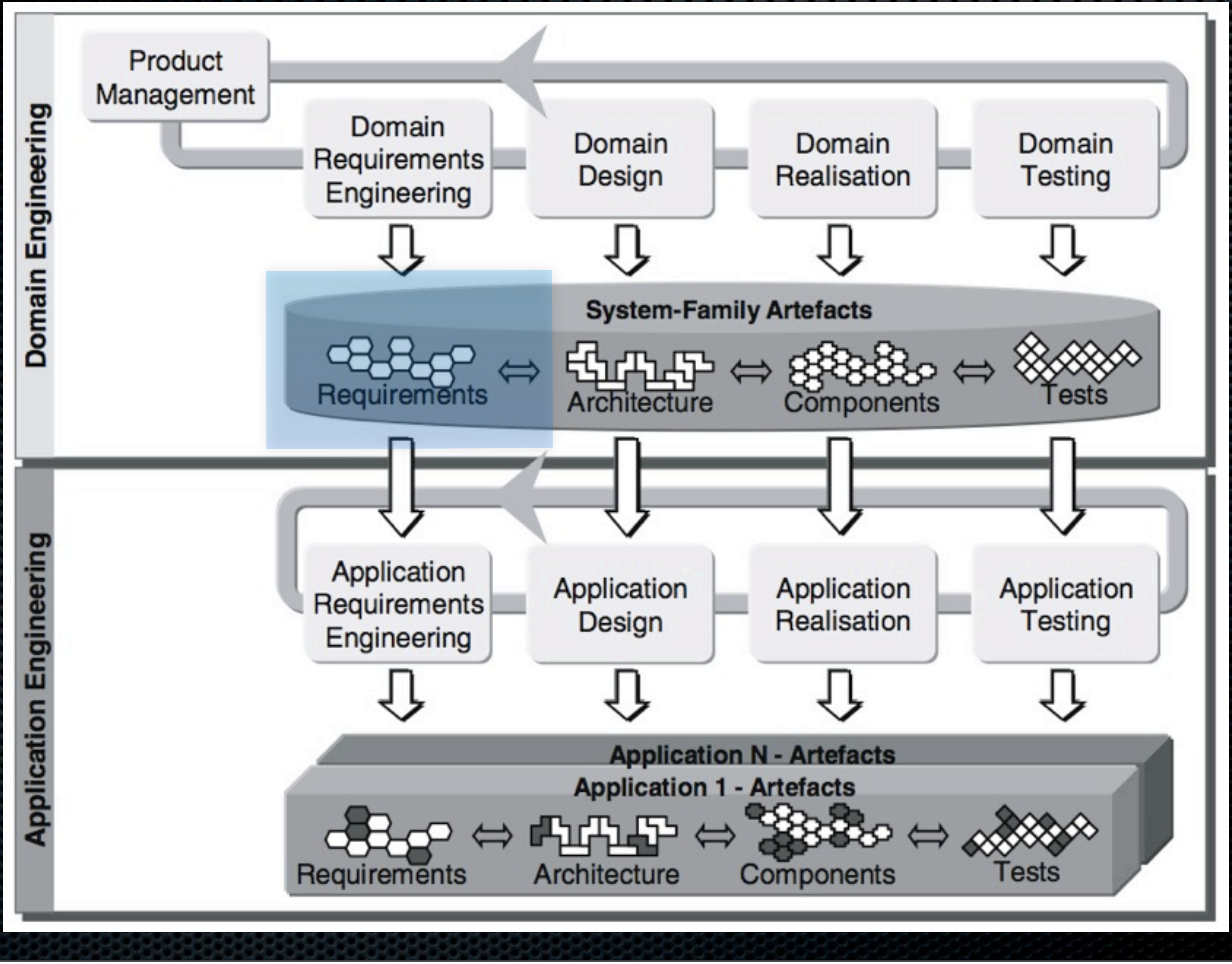
Evolving a Reference Architecture

- Evolution is a must:
  - Market changes
  - Features or products become redundant
  - Company mergers
  - 3rd party component updates
  - New technology
- Unintentional evolution:
  - Software/documentation rot, Maintenance, Erosion
  - Refactoring can counter

Domain and Application Engineering



Domain and Application Engineering



Requirements Variability - Textual

- The game should support
  - ... either 32-bit color output...
  - ... or 16-bit color output...
  - ... from the graphics engine.

Requirements Variability - Textual

Variation point

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Variation point

Variation 1

Requirements Variability - Textual

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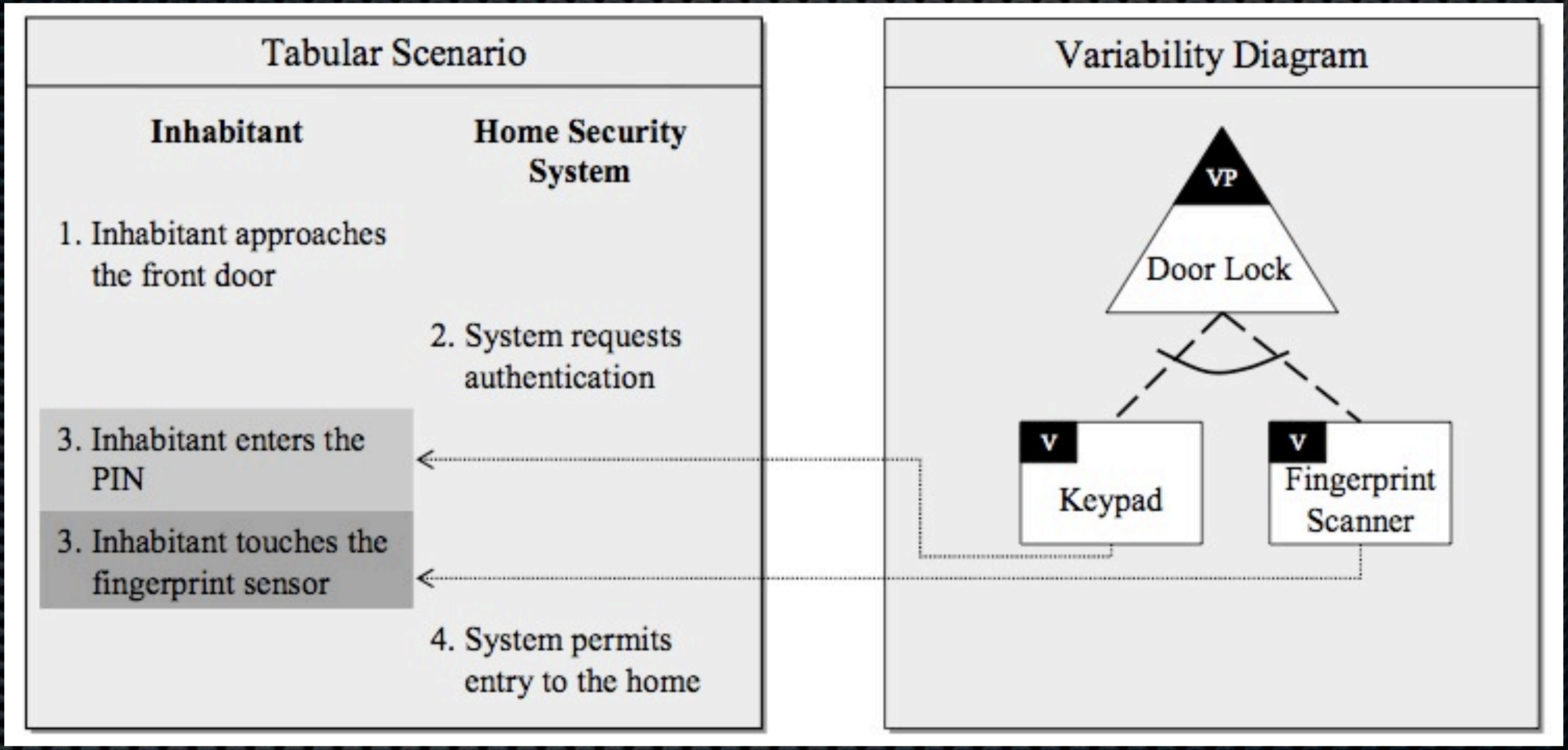
Variation point

Variation 1

Variation 2

Requirements Variability - Use Cases



Tabular Scenario

Inhabitant	Home Security System
1. Inhabitant approaches the front door	
	2. System requests authentication
3. Inhabitant enters the PIN	
3. Inhabitant touches the fingerprint sensor	
	4. System permits entry to the home

Scoping

- Defining the scope of the product line
  - Which products are within the boundaries of the SPL?
  - Which products are not supported by the SPL?
  - Product Portfolio Scoping
  - Technical, Marketing and Strategic Decision
- Other levels (built on PPS):
  - Domain scoping = Identify major domains relevant for SPL
  - Asset scoping = Define functionality for reusable components
- Active research area

Example scoping: Philips Consumer Elec.

- Main SPL Scope = “Mid- and High-range TVs”
  - Support convergent/combi-products
  - Not low-end TVs
    - Less features => less variability
    - Less product-to-product changes => less variability
    - HW+SW mainly bought from 3rd party
- Flexible and Ongoing Domain Scoping
  - Convergence & short cycles requires new domains
- Asset scoping built into component framework

Product Portfolio Scoping

- 1. Define Product Line Market
- 2. Determine relevant Product Types
  - Product Map = List of example products/types with their main features = Defines the Portfolio
- 3. Analyze Market Position & Define Products
  - KANO Model (next slide)
- 4. Analyze interrelations between products
  - Competition - PL Cannibalization
  - Support - Entry-level sells premium-level

Product Portfolio Scoping

Identifying Commonality and Variability is natural in scoping => SPL good fit

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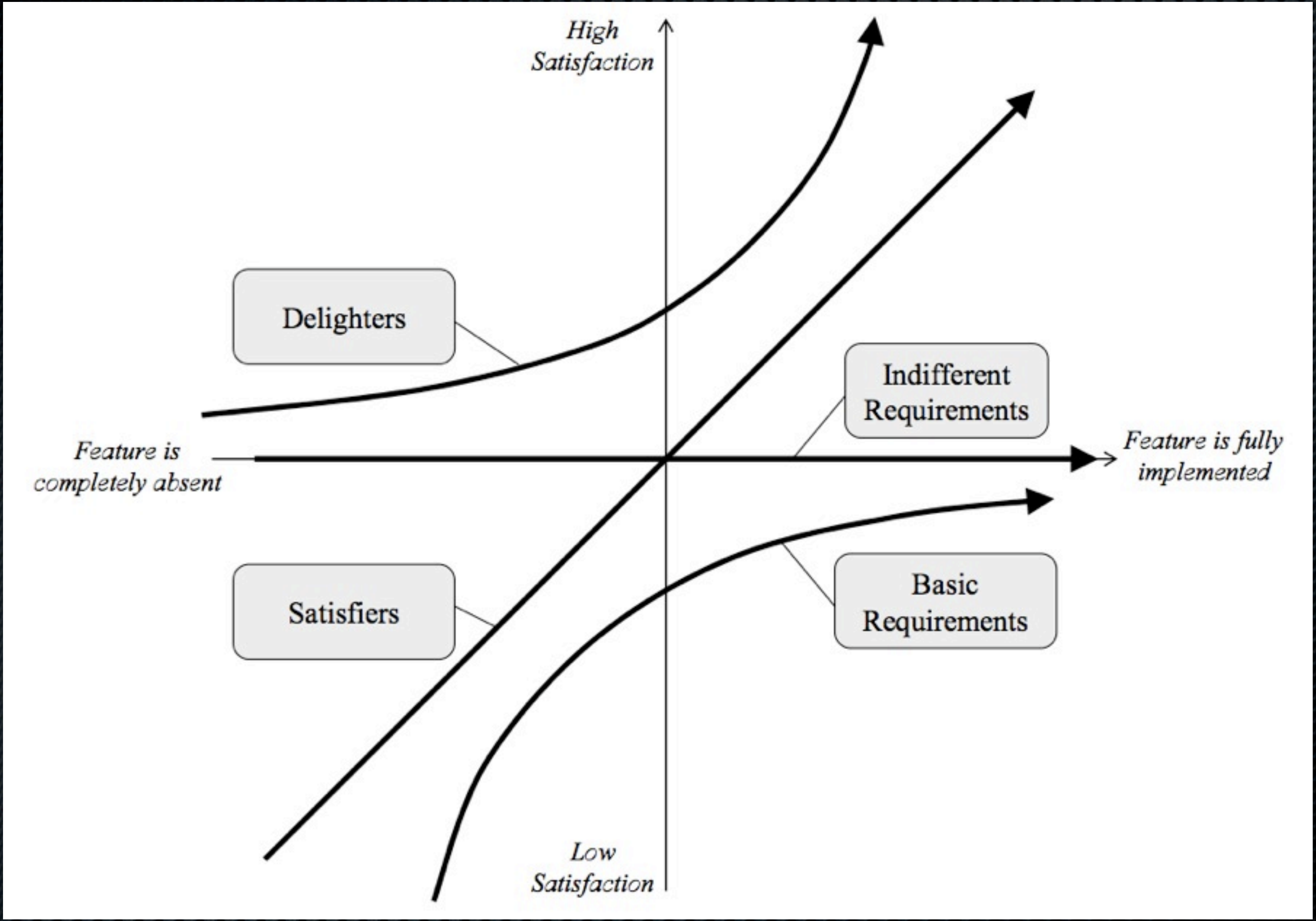
KANO Model


High Satisfaction
Delighters
Indifferent Requirements
Feature is completely absent
Feature is fully implemented
Satisfiers
Basic Requirements
Low Satisfaction

Domain Requirements Engineering & Analysis

- Normal RE and Analysis but Precise Variability Defs
  - Commonality Analysis
  - Variability Analysis
  - Variability Modeling
- Methods
  - App-Req Matrix
  - Priority-based Analysis (KANO)
  - Checklists

L2: Variability & Architecture

- Introduction to Variability and Variability Management
  - Motivation
  - Realizing variability - adaptation, replacement & extension
- Reference architecture
  - Creation & Variation points
- Architecture concerns
- Experiences from industry

L3: Variability, scoping & domain analysis

- Concrete variation mechanisms
  - Inheritance, Patching, Compile-time config, Configuration, Code generation, Component replacement, Plug-ins
- Domain design & realization
- Ref Architecture Evolution
- Experiences from industry

References

- V. Alves, T. Camara, C. Alves, “Experiences with Mobile Games Product Line Development at Meantime”, SPLC’08, Limerick, Ireland, 8-12 Sept, 2008.