Software Architecture and its relevance for Software Engineering

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Outline

- Software Architecture - Introduction
- Relevant Issues for SW Engineering
- Issues of Emerging Significance

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- Software Architecture - Introduction
  - ***Model of SWA and state of current research***
  - Architecture versus design
  - General relevance of architecture
- Relevant Issues for SW Engineering
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Models of SW Architecture

- Perry & Wolf 89/92 model of SWA
- SWA = (Elements, Form, Rationale)
- Elements : process, data and connecting
- Form is the set of properties of, and relationships among, the elements
- Rationale is the justification for the elements and form

State of Current Work

- Pretty much agree about process, data and connecting elements as first class entities
- Models differ primarily with respect to Form
- Few models pay attention to rationale
- Styles tend to focus on element and form restrictions

Current Approaches to Form

- Configuration
- Type
- Pattern
- Property

Model - Configuration

- Characterization
  - Basic box and lines approach
  - Components may be processes, subsystems, etc
  - Connections are defined by Provides/Requires clauses
- Approach to Style
  - Tend not to be interested in styles
  - Except in the context of dynamic arch's

Model - Configuration

- Examples of this Approach
  - Most informal descriptions
  - Kramer & Magee - dynamic structures
  - Le Metayer - graph grammars as styles
- Configuration important in other models

Model - Type

- Characterization
  - Typically, an historical approach
  - Look for types and classes of architectural objects
  - Often organized hierarchically

Model - Type

- Approach to Style
  - Emphasis on the basic classes or types of components and connectors
  - Perhaps, a slight more emphasis on connectors
  - Eg, pipes and filters; blackboard architecture
- Examples of this Approach
  - Shaw, et al
  - Hudak

Model - Pattern

- Characterization
  - Emphasis on patterns of interactions
  - Tendency to focus on connections with components as endpoints
- Approach to Style
  - Architectural instances are specializations of styles

Model - Pattern

- Examples of this Approach
  - Garlan et al (Wright, etc)
  - Invarardi and Wolf et al (use of CHAM - transformation patterns)
  - Luckham et al (Event patterns)
  - Kramer and Magee (Patterns of interactions)
  - Taylor et al (C2 style)
  - Gamma et al, Siemens (OO patterns)

Model - Property

- Characterization
  - Properties of (or constraints on) data, process and connecting elements
  - Relationships among data, process and connecting elements
- Approach to Style
  - Selection of some critical elements
  - Selection of some properties and relationships
  - Constraints on properties and relationships

Model - Property

- Examples of this Approach
  - Perry and Wolf
  - Moriconi and Qian
  - Batory

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Architecture vs Design

- Why separate architecture from design?
- Useful separation of concerns
- Akin to high level design
- Focuses on initial structural issues

Architecture vs Design

- Differences between Architecture and Design
  - Architecture is concerned about higher level issues
  - components vs procedures
  - interactions among components vs interfaces
  - constraints on components and interactions vs algorithms, procedures and types

Architecture vs Design

- Architecture is concerned with a different set of structural issues
  - Large-grained composition vs procedural composition
  - Component interactions (protocols) vs procedural/task interactions (pc, rpc, msgs, etc)
  - Information content vs data types and representations

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General Relevance

- Establishes the structure for satisfying system drivers
  - User/Market Requirements
  - Domain requirements
  - Business constraints
  - Product-line constraints
  - Project constraints

General Relevance

- Defines the important structural aspects
  - The load-bearing walls ,
  - The components, their properties and relationships,
  - The styles of initialization, fault recovery, reliability, etc

General Relevance

- Provides a structural framework for
  - System development,
  - System evolution,
  - Component design and implementation,
  - Asset generation and use/reuse, and
  - System composition

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- Software Architecture - Introduction
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  - ***Specification***
  - Codification
  - Reuse - Product Lines
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Uses of Architectural Specifications

- Prescription vs Description
- Traceability
- Analysis
- Visualization and simulation
- Configuration/Generation

Architectural Prescriptions

- Emphasis on intent, critical aspects
- Tendency towards minimality or incompleteness
- Problem domain emphasis
- Tendency towards high level constraints

Architectural Descriptions

- Emphasis on what exists
- Tendency towards completeness
- Implementation domain emphasis
- Tendency towards detailed descriptions

Traceability

- Rationale is link between architecture and its drivers
  - Non-functionally induced structure
  - Functionally induced structure
- Mapping to design/impl components

Analysis

- Level of analysis depends on
  - the underlying model
  - the expressiveness of the specification language
  - Configuration: standard build
  - Type: compiler technology
  - Pattern: model checking and simulation
  - Property: depends on
    - expressibility
    - decidability

Analysis

- Typical kinds of Analyses
  - Style conformance
  - Consistency and Completeness
    - configuration completeness
    - configuration consistency
    - component - connector consistency (Garlan et al)

Analysis

- Other functional properties
  - safety properties
  - mismatch detection (Invaradi & Wolf, et al)
  - satisfaction of component by subarchitecture (Moriconi et al)
- Non-functional properties, for example
  - performance
  - reliability

Visualization & Simulation

- Graphical versions of text
- Representation of analyses (Kramer/Magee)
  - Full patterns of interactions
  - Minimization of interactions
- Simulation of event patterns (Luckham et al)
- Visualization/simulation of architectural intent
  - Instrumented connectors (Balzer et al)

Configurations

- Build
  - Descriptive specifications
    - configuration model: straightforward
    - other models: need mapping to design/impl
  - Prescriptive specifications
    - determine completeness of arch spec
    - define/generate missing architectural components
    - need mapping to design/implementation

Configurations

- Generate
  - Descriptive specifications
    - Configuration/Type models: not enough information
    - Pattern/Property models: possible to leverage
  - Prescriptive specifications
    - Pattern/Property models useful
    - Need deep understanding of domains for completion
    - Once completed, possible to leverage

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  - Specification
  - ***Codification***
  - Reuse - Product Lines
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Codification

- Implementation components
- Type approach
- Patterns approach
- Property approach
- In general, still a long way to go

Codification - Components

- Basic Platforms
  - Common components: GUIs, object mgmt, etc
  - Domain-specific: application-specific platforms
    - first step towards a product line architecture
- Shared Assets
  - Motivation: cost, interval leverage
  - first step towards domain specialization
- Serves as basis for architectural generation

Codification - Type Approach

- Classified existing common components and connectors
- Tendency:
  - Functional classification
  - Solution domain
- Codified styles: restriction of component and connector types
  - For example, pipes and filters

Codification - Pattern Approach

- Design patterns - micro-architectural
- Tends to be informal
- Architectural idioms - closer to type approach
- Styles - defined in terms of patterns
  - event patterns
  - interaction patterns

Codification - Properties

- Domain-specific architectural assets
  - Components appropriate to the domain
  - Components defined by properties
- Consistent architectural instance created by
  - Component composition on the basis of desired properties
  - Propagating and satisfying the desired properties (ala Perry's Inscape, Batory's Genvoca)

Codification - Long Way To Go

- Need non-functional properties
- Understanding of interaction between functional and non-functional properties
- Codification in problem domain
  - Domain-specific templates
  - Applicability of codified solution domain components to problem domain components

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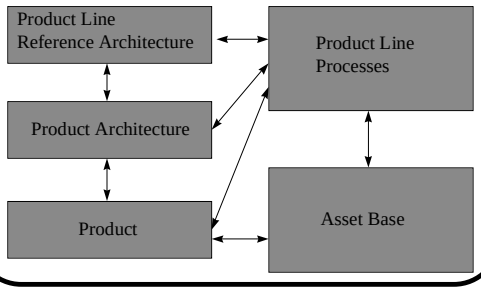
Product Line - Basic Aspects

- Begin with product instances
  - legacy based
  - use architecture recovery processes
- Focus on appropriate business domain
  - use domain specific architectural processes
  - map from recovered to domain architecture
- Abstract/Generalize to Product Line Architecture

Product Line - Overview



Product Line - Issues

- Product Line Reference Architecture
- Product Line Processes
- Asset Base
- Supporting Technology
- Organizational Issues

Product Line - Ref Architecture

- Domain-specific prescription or description
- Parameterized architectural components
- Refinement into sub-architectures
- Style descriptions for
  - critical architectural aspects
  - orthogonal aspects - eg, initialization, fault recovery, etc

Product Line Processes

- Create/evolve the reference architecture
- Create/evolve architectural instances
  - instantiate and provision
  - configure and generate
- Create/evolve asset base
  - shared components
  - specialized components
- Use asset base for architectural instance/impl

Asset Base

- Design component descriptions
  - common interfaces
  - common implementations
  - product-specific implementations
- Various supporting platforms
- Product specific components

Supporting Technology

- Architecture
  - Analysis - sufficiency, satisfaction
  - Instantiating, provisioning, customization
  - Generation/configuration
- Design/Implementation
  - Architecture satisfaction analysis
  - Component composition/analysis
  - Connector optimization
  - Run-time generation

Organizational Considerations

- Architecture/Asset base
  - across product lines
  - product line specific
  - product specific
- Supporting technology
  - global to the company
- Processes - support multiple product lines

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  - ***Styles***
  - Connectors
  - Dynamics

Styles

- An incomplete architectural prescription
- Focuses on certain aspects of the architecture
  - architectural elements
  - formal characteristics
  - constraints on architectural elements
  - constraints on formal characteristics

Styles

- Problem: Restrict the architectural structure
  - for example, strict layering of the architecture
- Solution: layered architecture style
  - constrain the interactions
    - any interaction at elements on the same level
    - no interactions at more than one level away
    - level below: initiate interactions only
    - level above: react interactions only

Styles

- Problem: multi-dimensional organization
  - Select one as primary, others as secondary
- Solution: Styles for the secondary dimensions
  - primary dimension: architectural elements
  - secondary dimensions then distributed over primary
  - styles define the characteristics of the distributed dimensions

Styles

- Useful rule of thumb: a style for a domain
- Problem: multiple domains in any significant architecture
- Challenge: integrating the styles consistently

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  - ***Connectors***
  - Dynamics

Connectors

- Primarily thought of means of communication
  - procedure call, remote procedure call
  - message passing with various levels of service
  - constraints on structure and directions - pipes
  - constraints on quality of service - persistence

Connectors

- Extremely useful in this context
  - separates computation from interaction
  - can change some non-functional characteristics by changing connectors
    - from prototype to embedded system via connectors (Tracz)
    - improve performance via connector optimization

Connectors

- Can be used as means of mediation
  - govern access to share data structures
  - provide synchronization, exclusion
    - critical sections
    - monitors
  - determine what is allowed and when
    - readers/writers policies
    - path expressions

Connectors

- Extremely useful in this context
  - separates mediation control from computation
    - localizes synchronization and exclusion control
    - localizes operational policies
  - separate mediation from communication
  - compose communication and mediation connectors

Connectors

- Can be used a means of coordination
  - determine control of computation
    - elements of control in communication
    - elements of control in mediation
  - control loci of execution
  - control delivery of data

Connectors

- Extremely useful in this context
  - separate aspects of control from computation
  - instrumented connectors (Balzer)
    - mutual invocation - like coroutines
    - coordination of computation results and data delivery
  - fault tolerance
    - separate exception handling as a plane of control
    - becomes compositional not integral

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  - Connectors
  - ***Dynamics***

Dynamics

- Allowed dynamic changes
  - creation/destruction of components and connectors (Kramer & Magee)
  - to respond to dynamic system requirements
- Appropriate support for
  - distribution independence
  - dynamic linking, registration (Taylor et al)

Conclusions

- Separates out useful level of concern
  - problem domain meets implementation domain
- Defines important constraints on the system
- Basic structure of the system
- Means of capitalizing on assets
- Moves us from integral to compositional
  - eg, Browne's performance models
- Integrates composition with generation