State of the Art:
Software Architecture

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Apologia

- This SOTA talk is a mixture of
  – State of the practice
  – State of the research
  – State of the problem

Overview

4 *Rationale for a separate discipline*
- Models of software architecture and style
- Architectural specifications and their uses
- Codification of architectures, styles and elements
- Architectural processes
- Where next?

Rationale

- The architecture is there whether we make it explicit or not
- If it is implicit, then we have no way of
  – controlling it,
  – analyzing it,
  – reasoning about it, or
  – evolving it.

Rationale

- If it is implicit, we may not be able to
  – identify it,
  – understand it,
  – conform to it, or
  – maintain it.
- Basic Architectural problems
  – architectural mismatch
  – architectural drift
  – architectural erosion

Rationale

- Benefits of an explicit architecture
- Establishes the structure for satisfying system drivers
  – User/Market Requirements
  – Domain requirements
  – Business constraints
  – Product-line constraints
  – Project constraints

Rationale

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

Rationale

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

Rationale

- 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

Rationale

- 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

Overview

- Rationale for a separate discipline

4 *Models of software architecture and style*

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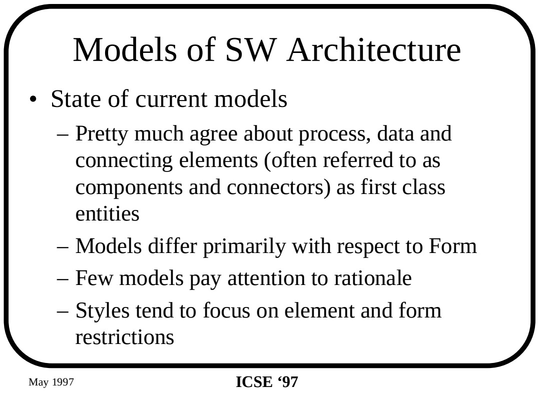
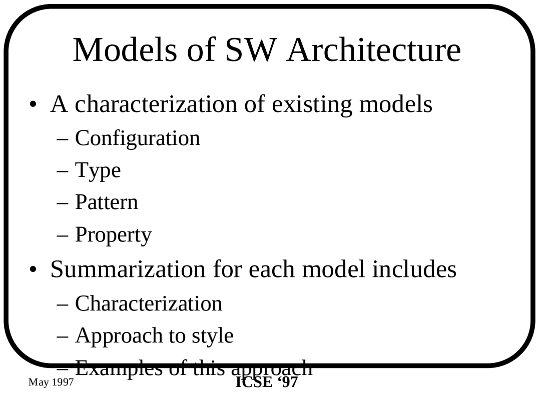
Models of SW Architecture

- Perry & Wolf 89/92 model of SW Architecture
- SW Architecture = (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



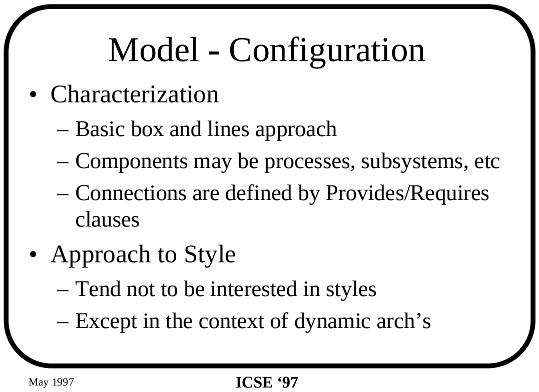
Models of SW Architecture

- State of current models
  - Pretty much agree about process, data and connecting elements (often referred to as components and connectors) 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



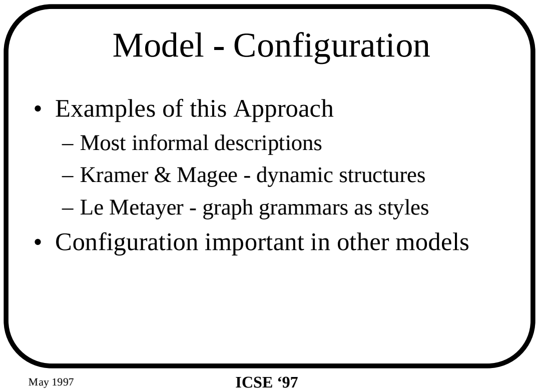
Models of SW Architecture

- A characterization of existing models
  - Configuration
  - Type
  - Pattern
  - Property
- Summarization for each model includes
  - Characterization
  - Approach to style
  - Examples of this approach



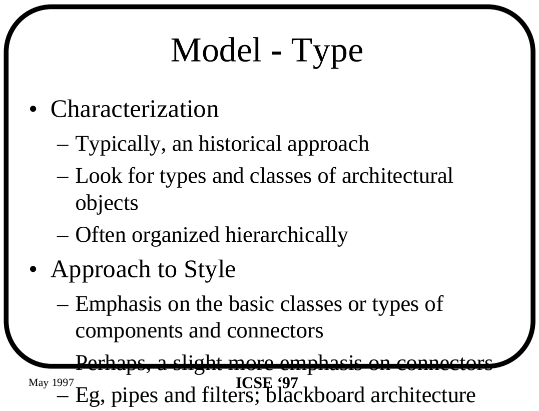
Model - Configuration

- 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



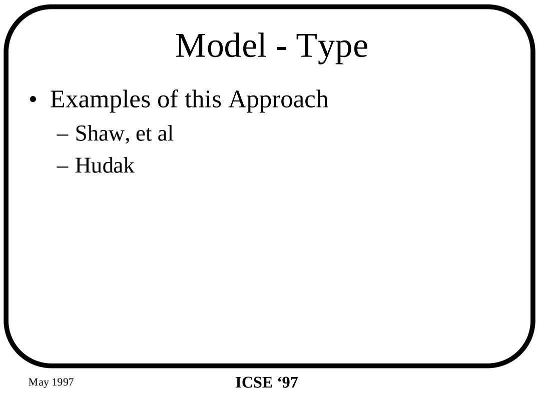
Model - Configuration

- 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
- 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



Model - Type

- 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

Overview

- Rationale for a separate discipline
- Models of software architecture and style

4 *Architectural specifications and their uses*

- Codification of architectures, styles and elements
- Architectural processes
- Where next?

Architectural Specifications and their Uses

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

Architectural Specifications

- Prescription
  - – Emphasis on intent, critical aspects
  - – Tendency towards minimality/incompleteness
  - – Problem domain emphasis
  - – Tendency towards high level constraints
- Description
  - – Emphasis on what exists
  - – Tendency towards completeness
  - – Implementation domain emphasis
  - – Tendency towards detailed descriptions

Architectural Specifications - Traceability

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

Architectural Specifications - Analysis

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

Architectural Specifications - Analysis

- Typical kinds of Analyses
  - – Consistency and Completeness
    - configuration completeness
    - configuration consistency
    - component - connector consistency

Architectural Specifications - 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
- – Style conformance

Architectural Specifications - Visualization & Simulation

- Graphical versions of text
- Graphical representation of analyses (Kramer & Magee)
  - – Full patterns of interactions
  - – Minimization of interactions
- Simulation of event patters (Luckham et al)
- Visualization and simulation of architectural intent
  - – Instrumented connectors (Balzer et al)

Architectural Specifications - 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/impl

Architectural Specifications - 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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4 *Codification of architectures, styles and elements*

- Architectural processes
- Where next?

Codification

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

Codification - Implementation 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 - Property Approach (Batory)

- 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)

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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4 *Architectural processes*

- Where next?

Architecture Processes

- Architecture Recovery
- Domain Specific
- Product Line
- Architecture Evolution

Architecture Recovery Process

- The models are suggestive of a recovery process
  - create a configuration model
  - determine the types of the components and connectors
  - determine the patterns of interactions among the components
  - abstract the properties of and relationships among the components and connectors
  - abstract useful styles

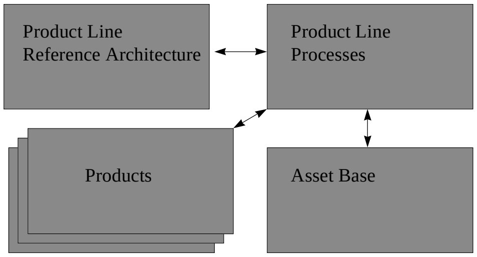
Domain Specific

- Problem vs implementation focus
- Create a business domain model
  - different from design level domain analysis (tends to be in the implementation domain)
  - Eg, messaging in terms of email, voicemail, fax, multi-media, etc - not GUI and DBs
- Populate architectural model with domain elements and appropriate interactions

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
  - – provision
  - – configure/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

Architectural Evolution

- From prototype to embedded system
  - – Transformations (Tracz, et al)
- Importance of connectors - significant for
  - – Evolving non-functional properties
  - – Improving problem solution (Balzer et al, instrumented connectors)

Architectural Evolution

- Dynamic evolution
  - – 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)

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4 *Where next?*

Where Next?

- Higher level ADLs
- Generic architectures and customization
- Increased product line architecture support
- Increased codification in both problem and solution domains
- Standardized domain-specific architectures
- Increased generation using codified solution domain
- Architectural evolution

Post-ICSE Addenda

- Garlan et al’s work is also relevant for the configuration model
- Where Next should have included `Multiple Views’
- Apologies to Jeff Magee for mispelling his name