Software Architecture Process And Management

Computer Science 4th Year, Created By Monkeys

Contents

1 Introduction

1.1 Learning Outcomes of the course

- Integrate knowledge of software architecture to capture **quality attribute** requirements for a system, **evaluate proposed architectures** and create options for **improvement**.
- Analyse and justify complex **trade-off decisions** between **competing software architectures**.
- Evaluate the **strengths** and **weaknesses** of software architecture in support of particular approaches to **design**, **process** and **management** for a particular system and make **recommendations** on the **choice of process** for that system.
- Working in a group to **critically reflect** on aspects of the **software architecture literature** and practice to create a resource that support their learning in software architecture.

1.2 What is Success for a Large Project?

A large project will be considered successful if:

- The software is delivered on schedule
- Development costs are within budget
- The software meets the needs of users

1.3 Software Architecture

Software Architecture Definitions

1. The software architecture of a system is the **set of structures** needed to reason about the system, which comprise software elements, relations among them and properties of both. (Bass, Clements, Kazman 2013)
2. A software system's architecture is the set of **principal design decisions** about the system (R.N Talyor et al)

Architecture is a collection of structures
We observe three frequently types of structure:

1. **Modular Structure**: static structure that focuses on how the functionality is divided up, structured, and assigned to development and implementation teams.
2. **Component and Connector structure**: runtime structures that focus on how components interact.
3. **Allocation structures**: mapping to organizational, development, installation, execution environments.

Architecture is an Abstraction

Architecture is used to **suppress** detail that is unimportant for the reasoning we are doing. In particular it **abstracts away** from the private details of **implementation details** of specific methods.

** All systems have architectures (even if people have forgotten them) **

Complicated systems are embedded in organisation and we can often see architecture through practice:

- *How is the system developed?* -> This will often provide **clues to structures**.
- *How is the maintenance, evolution, issue reporting dealt with?* -> This will often help with **modularity**.
- *What are the failure characteristics of the system in operation?* -> This will often suggest **component and connector structure**.

1.4 Case Study: General Practice Extraction System

"The General Practice Extraction Service (GPES)" is an IT system designed to allow NHS organizations to extract data from **all** GP practice computers. *This is because different GP's have different contracts and therefore use different software to save patient data.*

Basic idea is to create an API to query every system from all different software's created for different GP's. This will allow generic extraction of **patient data** regardless of their GP.

Customers

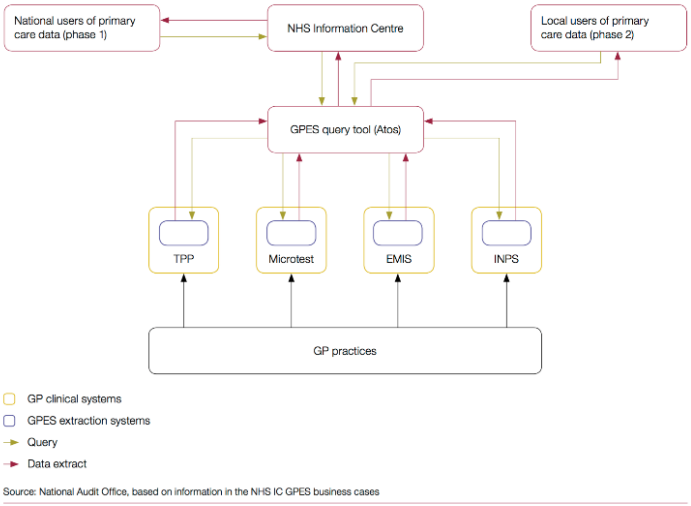
Figure 1
Proposed GPES customers and potential benefits

Organisation	Main use	Benefits of GPES
NHS England	Commission and pay for GP services	Wider and more flexible data indicators, to monitor and reward high-quality care.
National Institute for Health and Care Excellence	Research to help produce clinical guidelines	More records to give greater confidence in data, especially for less common conditions.
UK Biobank	Medical research, on health of 500,000 project participants	Extract detailed data for participants, despite geographical spread and different GP practices.
Healthcare Quality Improvement Partnership	Clinical audits – assessing care quality	Wider range of clinical audits, especially where little data previously available, such as care for those with learning disabilities.
Medicines and Healthcare Products Regulatory Agency	Monitor side effects of medicines	Tapping into data on side effects in GP computer systems to pass on information more efficiently.
Clinical Practice Research Datalink	Support observational and public health research	More records to give greater confidence in data, especially for less common conditions.

Source: National Audit Office interviews with HSCIC staff and proposed GPES customers

Structure

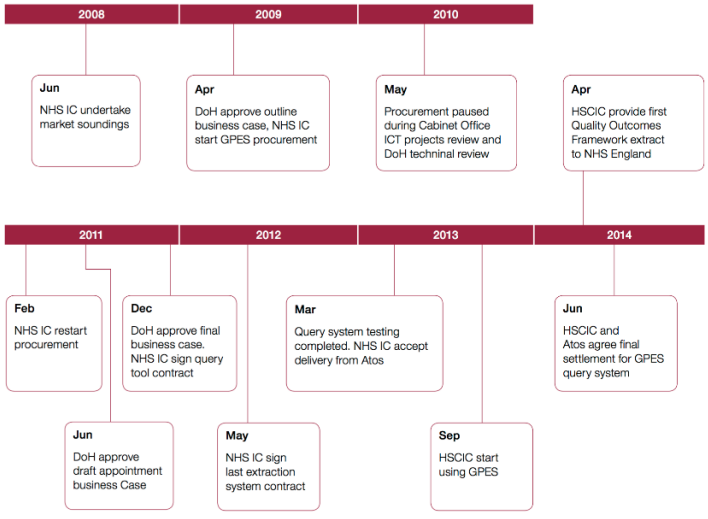
Figure 2
Design of the General Practice Extraction Service



Source: National Audit Office, based on information in the NHS IC GPES business cases

Timeline

Figure 3
Timeline for the GPES procurement



Source: National Audit Office analysis of NHS IC business cases and interviews with HSCIC staff

National Audit office Conclusion of the GPES Project

- The project has been significantly delayed and many customers have yet to receive data.

- Mistakes in the original procurement and contract management contributed to the losses of public funds. This occurred through asset write-off's and settlements with suppliers
- Only **one** customer, *NHS England* has so far received data from GPES.

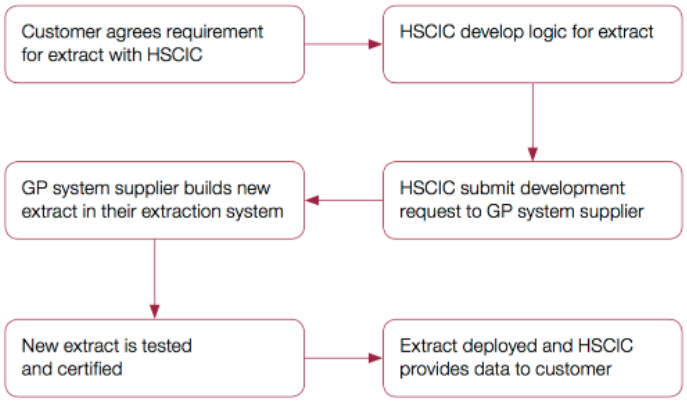
Originally the business plan for GPES said the service would start in **2009-2010**. It actually took until **2014** for the first extraction to take place. The total expected loss for the GPES project rose from **£14 million** to **£40 million** during the *planning* and *procurement stage*.

Data Extract Issues

- First GP system suppliers were asked to fulfil a common query language for the extraction process (this was not in their interest as it would cost them alot to makes these changes to their current systems and thus pretty much refused to do so).
- This requirement then changed to each GP system supplier creating their own logical 'business rules' which would be used to extract the data. (Different for each supplier, one API to query each supplier to extract data)
- NHS IC's using a non-competitive procurement approach, in-addition to the changes in design both contributed to the restrictive process for *extracts*.
- HSCIC (the successor of the NHS IC) has continued to use the GPSOC framework to require data sharing between NHS systems. *The new framework (2014) states that the principal clinical system suppliers must provide an interface method for third-party system uses.*
- **HSCIC cannot do wide range nor scale of data extracts. Due to the design of the GPES system and the restrictions in the supplier contracts. (Over 100 different extracts have been requested) HSCIC estimate that they will only be able to design 24 new extracts in 2015-16**

Data Extract Issue ctd

Figure 6
Process to develop a new GPES data extract



Source: National Audit Office

Data Extract Issue concluded

- What's the difference in the two approaches to the HSCIC and the Software vendors?
- Are there still issues with the final process?
- **4.10** GPES will continue to operate in the short term, as its data is critical for determining payments to GPs. Its coverage of all practices in England cannot currently be replicated by other primary care data extraction systems.
- **4.11** However, limited capacity and the dif culty of developing new extracts deters wider use. The HSCIC has acknowledged there is unlikely to be a long-term future for all or part of the GPES. However, they intend to reuse parts for a replacement system if possible. The HSCIC estimate that they will achieve less than two more years of use from the GPES in its current form, in contrast to the five-year minimum lifetime assumed for new IT systems.

2 Basic Concepts of Architectures

2.1 What is good architecture?

The architecture is appropriate for the **context of use**. E.g. 3-tier e-commerce architecture is not appropriate for a avionics project.

Guidance on 'good architecture' focuses on:

- **Process**
- **Structure**

Software architecture should capture the **principal design** decisions about the system. The **Blueprint** for software architecture focuses on:

- Structure
- Component behaviour
- Component interaction and how that influences **Quality Attributes** of the *systems*.

2.2 Process

Architect teams are often small and **maintains the integrity** of the architecture. The architecture is *justified* in relation to a **prioritized list of quality attributes** that need to be managed. **Stakeholders interests** are documented and are used to build the type of architecture that will reflect them.

Architecture is often evaluated in terms of *how well it delivers the quality attributes*. Software architectures are often chosen to allow **incremental implementation**. (I.e Low coupling, high cohesion)
- Definitions for coupling and cohesion!

2.3 Structure

The structure of architecture will differ depending on the requirements of the software, often the following are utilised:

- **Modularity** → Hides information, separates concerns, allows good robust interfaces that are unlikely to change
- Well known **patterns and tactics** are often implemented
- Architecture built to NOT depend on **particular versions of tools**, or **special features** *unless its essential!*
- Modules *producing* data should be **separate** from those *consuming* data
- Usually a complex mapping between **modules** *(static structure)* and **components** *(dynamic structure)*

- MINIMISE the number of ways of **interaction between components**
- The architecture should clearly **identify resource contention issues** and deal with them. (E.g. network capacity, minimise network throughput using different techniques [EXC])

Prescriptive vs Descriptive Structures
Prescriptive structure is what we use to model the system before it is built. It is the aim the architect has while generating the blueprint *(UMLAsBlueprint, forward engineering)*, however it is often to *tidy* and unrealistic to be able to model the architecture of a system.

Descriptive structure is usually made after the system has been created. It is used to describe the entire system, how the **components** interact, the responsibilities of each **module** *(usually extremely messy)* etc ...

2.4 The Importance of Architecture

Software Architecture has several uses:

1. Enables us to manage the **key attributes** of a system
2. Allows reasoning about and managing **change**
3. Allows predictions of **key quality attributes**
4. Allows **improved communication** between stakeholders
5. Defines **constraints** on the software's implementation
6. Provides the basis for **evolutionary prototyping**
7. Is the key artefact for reasoning about **cost** and **scheduling**
8. Focuses on the assembly of **components** rather than the **creation/implementation** of components

Other uses are:

- *Reflects the structure of an organisation*
- *Can be used as the transferable, reusable model at the heard of a product line*
- *Restricts design alternative and channels developer effort in a coordinated way*
- *Provides the basis for training new team members*

2.5 Managing Attributes and Change

It is a fact that the majority of software projects will undergo requirements change. This may also change **key quality attributes** of the system. The idea is to use architecture that will minimise the change to the *architecture* and allow the system to be **modifiable** utilising the same abstract **architectural** ideas.

Managing change can be reasoned about on three levels:

1. Inside an element *[cheapest]*
2. Between elements maintaining the architecture *[can be costly]*
3. Requiring architecture change (we wish to avoid this as much as possible) *[most expensive change]*

2.6 Prediction of Attributes

We can attempt to predict the **key quality attributes** of the system based on *requirements* and possible (logical) *system extensions* in the future. Planning for these changes will minimise need for architectural change, which in turn will **reduce the cost** in future work.

**** Models should be able to be built based on the predictions of the attributes and requirements ****

2.7 Communication Between Stakeholders

A well documented architecture allows **improved communication** between stakeholders. Some examples of how the documented architecture can help with communication are the following:

- User has particular requirements in terms of user experience
- Customer needs to know about schedule, budget and meeting regulations in their market
- Project manager needs to know the dependences in terms of the modules and components

These might be accommodated by different views of the system that are consistent

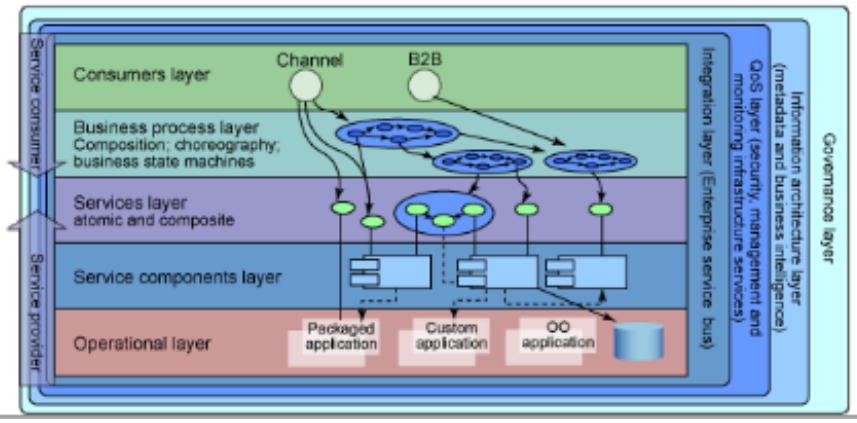
2.8 Early Design and Constraints

Early design carries the *most fundamental* design decisions, e.g:

- What the **key quality attributes** are
- The **architecture form/type** that will give the best control over these attributes
- The characterisation of the behaviour of the architecture elements

Constraints

- Defines constraints on implementation:
  - Architecture specifies the elements and their interaction
  - For example, layered architecture usually constrain access to be between adjacent layers



2.9 Evolutionary Prototyping

Evolutionary Prototyping allows a system to be constantly tested under real conditions as it is being developed. As *bugs* are detected they are fixed and tested in the next prototype. Examples of systems that used **evolutionary prototyping** are:

- Plug and Play - early experience of the BASE functionality + extensibility.
- Real time architectures - early experience with scheduling. *(Worse case execution times guide design and deployment)*

2.10 Cost and Scheduling

Reasoning about the **following topics** allows for effect cost and scheduling in a software project:

- Capturing dependencies
- Estimation of required efforts for different sections

- Allocating effort to elements
- Understanding of how elements influence each other
- Use architecture to interpret bottom-up estimates from teams working on elements

2.11 Product Line (Model)

The **product line** model is a *transferable and reusable* model. **Elements** are assets that compose to give new *functionality.* The architecture provides the means to **compose the elements**. A planned approach allows the reuse of architectural elements *(think object inheritance).*

2.12 Component Level & Channelling Development

At the component level we focus on the **assembly** of components rather than the **creation** of them! With well designed elements and architecture we can combine elements from different **producers** *(provided they conform to a standardized interface).* This provides the following **benefits**:

- Decrease time to market
- More reliability
- Lower cost
- Flexibility *(e.g. using multiple or alternate suppliers for a component)*

Channelling Development restricts alternatives and channels developer effort in a coordinate way. This provides a defined **context** for the developer. Well defined **interfaces** and clear ideas of the **functionality & quality attributes** are required!

**** The overall goal is to provide clarity on what is an architectural decision and what is a development decision. ****

3 Context Design

Software architects and architecture have arisen as systems have grown in: *scale*, *economic importance* and *criticality*. Architecture plays different roles in different contexts. The **main contexts** are:

- Technical Context
- Project Life-cycle Context
- Business Context
- Professional Context

3.1 Technical Context

The **technical context** is whereby the architecture supports technical activity. For example this could be in **measuring** a statistic, the **verification & validation** process, **compliance** ...

The architecture provides a means for controlling **quality attributes** of the system. In the **context of design** activities we try and choose architectures that **enable the attributes** we care most about. We may find through analysing already *existing systems* that specific architectures inhibit (prevent) particular quality attributes.

** Architecture does not often have much to say about the functionality of a system, because they provide containers for functionality. **

3.1.1 Controlling Quality Attributes

Usually we care about multiple quality attributes at once. Selecting a type of architecture will allow specific quality attributes to be ensured for when it is deployed to the end user. Examples of **quality attributes** we might care about for a particular system are:

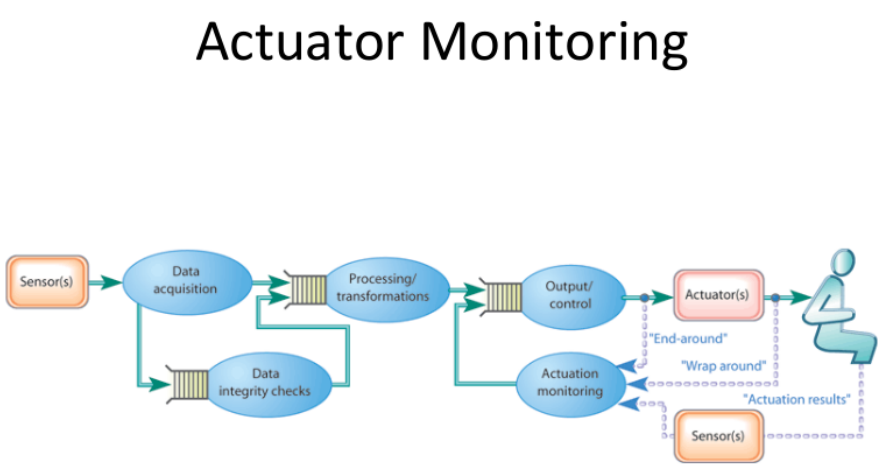
QA	Description
Safety	The safety of a system is whereby we worry about ensuring that the **system only behaves as is intended** and has no additional behaviour that is unspecified.
Testability	The testability of a system ensures that **elements are clearly isolated**. That we know the **expected behaviour of components**. We know the **relations of modules** to track down faulty code and finally we know how the **components are intended to integrate together** to give overall behaviour.
Availability	The availability of a system is whereby we worry about ensuring there is a **system to take over**, in the case the original system fails.

Other examples of quality attributes include **performance**, **usability**, **interoperability** ...

These examples of quality attributes related to the **actuator monitoring** system that was described in lectures. As actuators are physical devices they will suffer from *'wear and tear'* and eventually break. In safety critical system (for example cars, aeroplanes) these actuators require monitoring in order to prevent worst-case scenario's when they do break, and have them repaired beforehand.

The architecture for the actuator monitoring system will be required to hold at least those three quality attributes:

1. Availability - To ensure it is always monitoring the actuators
2. Safety - To ensure the monitoring system does not deviate from intended behaviour (no false positives or false negative)
3. Testability - To provide certainty that of the safety and availability is should provide.



3.2 Project Life-cycle Context

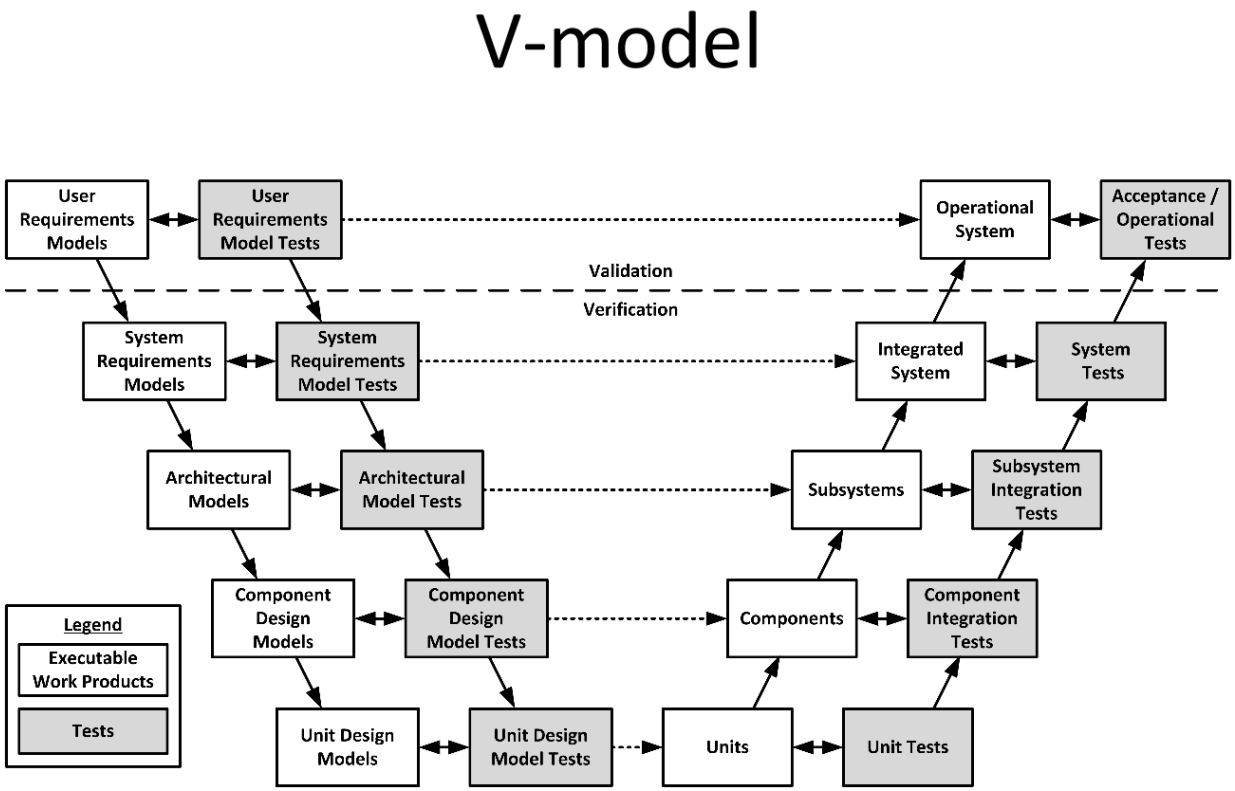
The **project life cycle context** describe how the project will develop over time. The architecture is then created to adopt the life-cycle that is best for a particular project. When creating a project life-cycle the following must be complete *(these are all done best by talking about the architecture)*:

- Making a business case for the system
- Understanding the requirements that concern quality attributes
- Deciding on architecture
- Documenting architecture

- Analysing and evaluating architecture
- Implementing and testing the system based on architecture
- Ensuring the implementation conforms to the architecture

3.2.1 V-Model

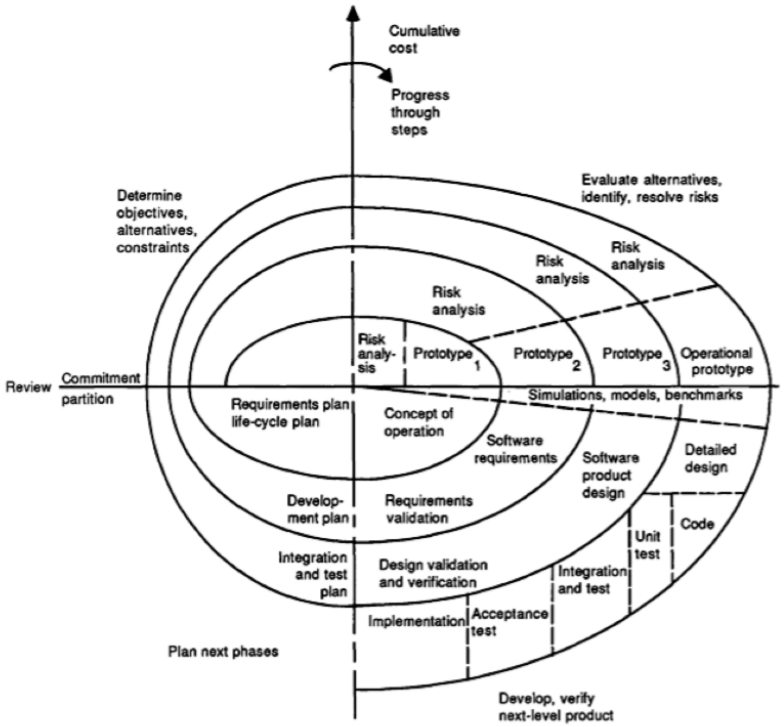
The **V-Model** is a development of *waterfall* and explicitly includes architectural design as a stage. It highly focuses on **requirements based testing** all the way down to the unit level!



3.2.2 Spiral Model

The **(Boehm's spiral model** is a type of *iterative model*. It focuses on project risk management by constantly creating prototypes to be tested all the way through the development life-cycle.

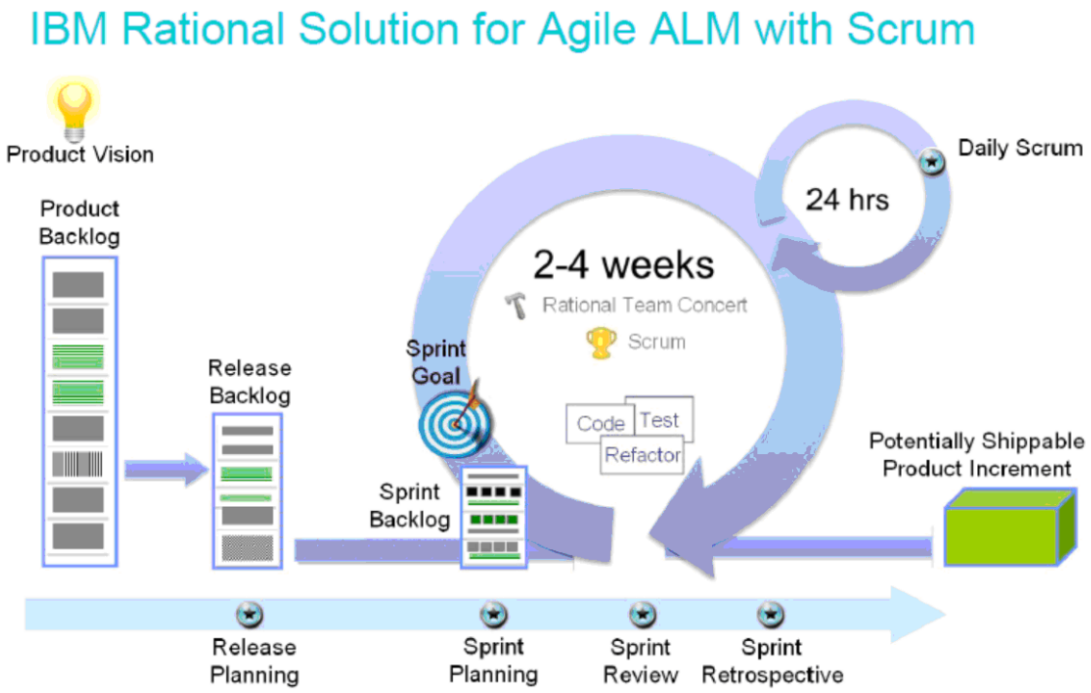
Spiral Model



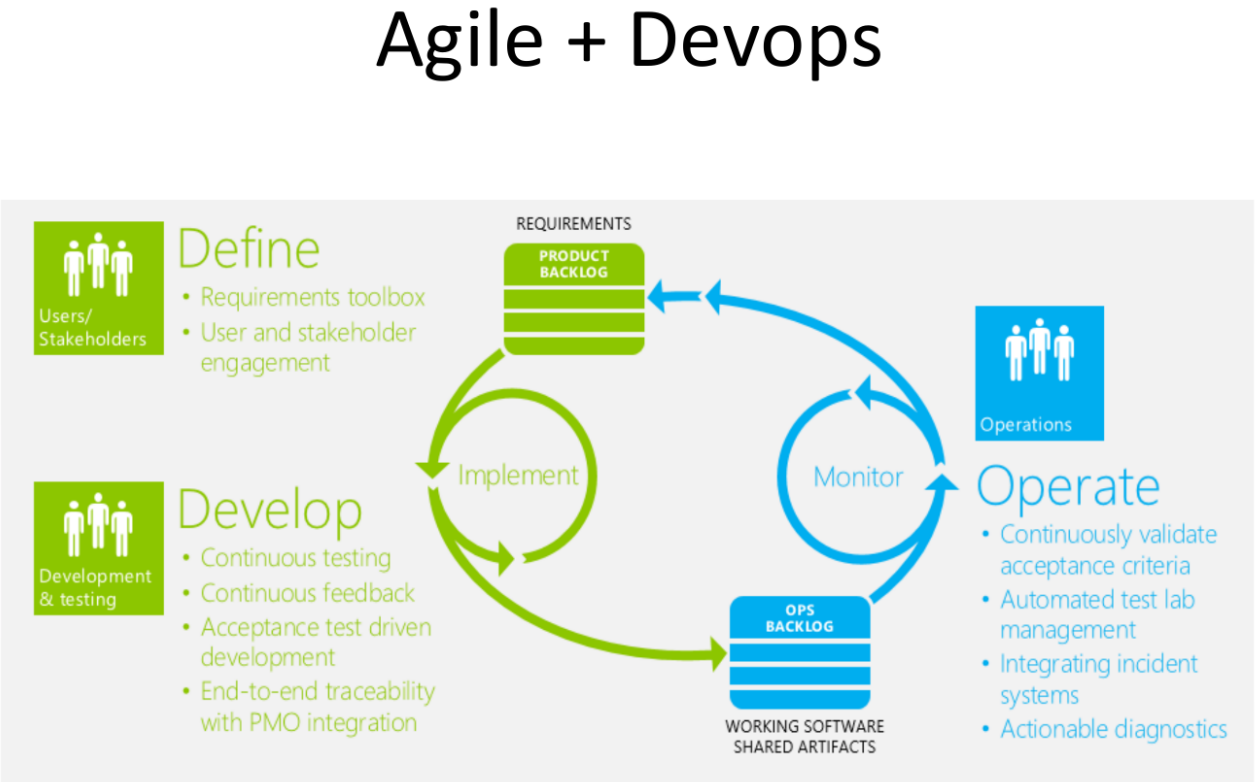
3.2.3 Agile Development

The **Agile** development life-cycle is an iterative and incremental method of managing the design and building of a software product. The image below show two different forms of **agile** development. One with and one without Devops.

Agile


IBM Rational Solution for Agile ALM with Scrum
Product Vision
Product Backlog
Release Backlog
Sprint Goal
Sprint Backlog
2-4 weeks
Rational Team Concert
Scrum
Code
Test
Refactor
24 hrs
Daily Scrum
Potentially Shippable Product Increment
Release Planning
Sprint Planning
Sprint Review
Sprint Retrospective

3.2.4 Agile + Devops



3.3 Business Context

The **business context** is discussed in later lectures. Two aspects we cover are:

1. How the organisation structure of stakeholders can drive architectural decisions and shapes decisions taking around architecture.
2. How architectural expertise drives the structure of development organisation in terms of their functional units and interrelationships.

3.4 Professional Context

The architectural perspective gives you as a professional:

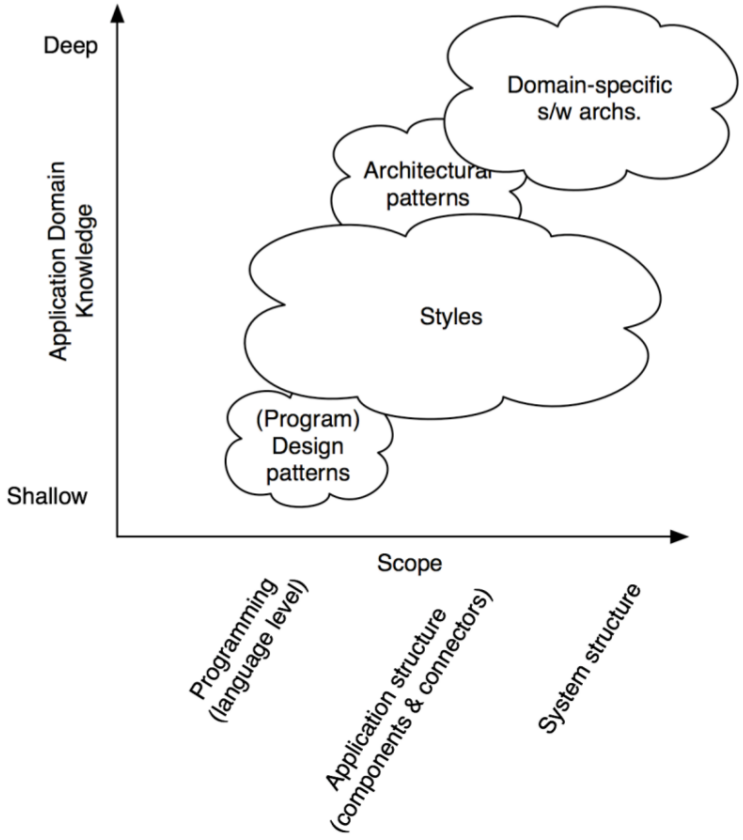
- A way of describing your expertise
- Your skills as an architect will be recognised within organisations you work within

- You can use architecture as a way of describing your past experience
- You can specialise in particular classes of architecture (e.g. financial architecture)

3.5 Domain-Specific Software Architecture

Design in the Technical Context

Design is a mixture of **creativity** and the use of **knowledge** that is institutionalised in the context. This takes the form of **reusable structures**. These reusable structures also influence other aspects of context, helping to shape **processes, organisations** and **professions**. We can plot different sorts of **architectural structures** depending on the degree to which it is **specific to a domain** and the extent to which it **influences the system**.



Domain Specific Software Architectures

DSSA is a collection of (pre-decided) **design decisions**. They capture important aspects of a particular task **(domain)** They are **common** across a range of systems in the domain and typically will have some predefined structures depending on the attributes we want to control.

These are **not** general purpose because they incorporate many specific characteristics of the **domain**. The main benefit is the extent to which **design knowledge is captured**. There are however problems, over time basic information can be forgotten.

** Bridge example given, where key information was forgotten regarding the architecture of suspension bridges (from the 19th century). This results in a bridge collapsing because of wind. **

3.6 Architectural Patterns

An architectural pattern is a set of **architectural design decisions** that are applicable to a **recurring design problem**, and **parametrized** to action for different **software development contexts** in which that problem appears.

They are similar to **DSSA** but capture less of the behaviour and attributes of the system. They are **more general** because they are intended to abstract a common **pattern over several domains**.
Three common architectural patterns that are used are listed below:

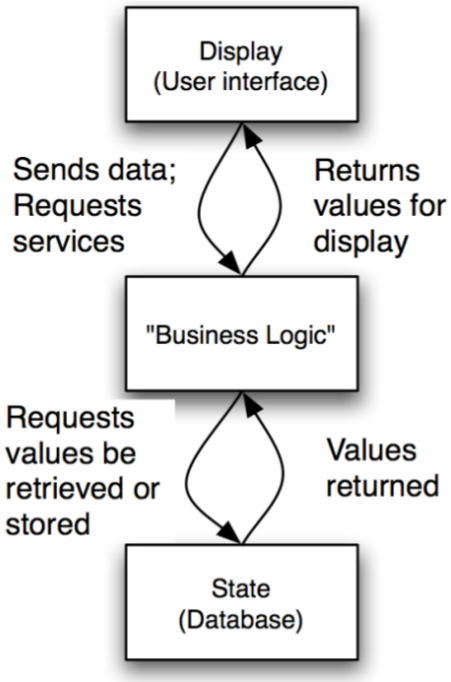
1. State Logic Display: Three-Tiered Pattern
2. Model View Controller Pattern
3. Sense Compute Control Pattern

Contexts shape design. The **technical context** identifies features we want to control and **packages** a range of other properties. Standard architectures (*patterns and domain specific architectures DSSA*) **package these**. The other context we consider also help to shape the choice of architecture.

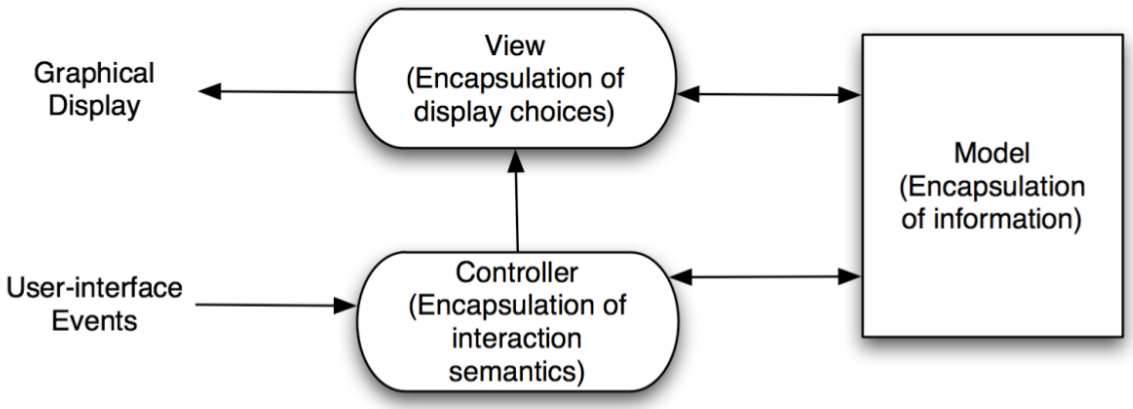
**** In design we use pre-decided strcutures and then alter/extend them as and when we need too. ****

State-Logic-Display: Three-Tiered Pattern

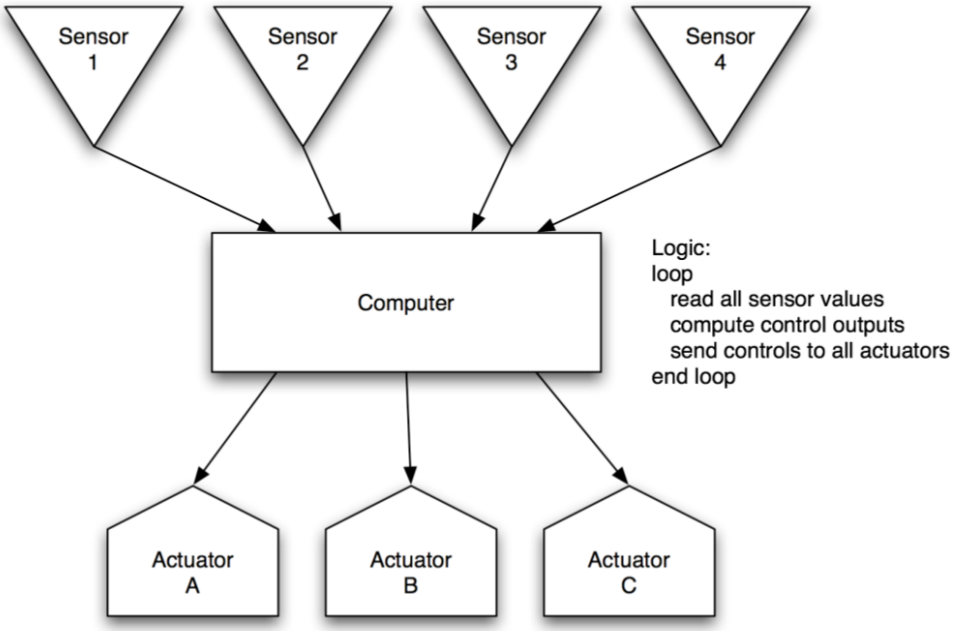
- Application Examples
  - Business applications
  - Multi-player games
  - Web-based applications



Model-View-Controller



Sense-Compute-Control



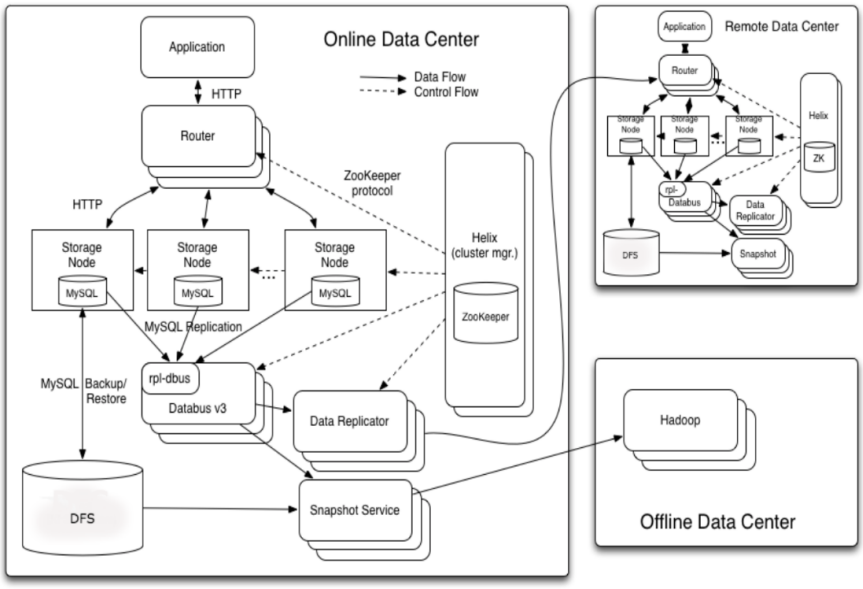
Objective: Structuring embedded control applications

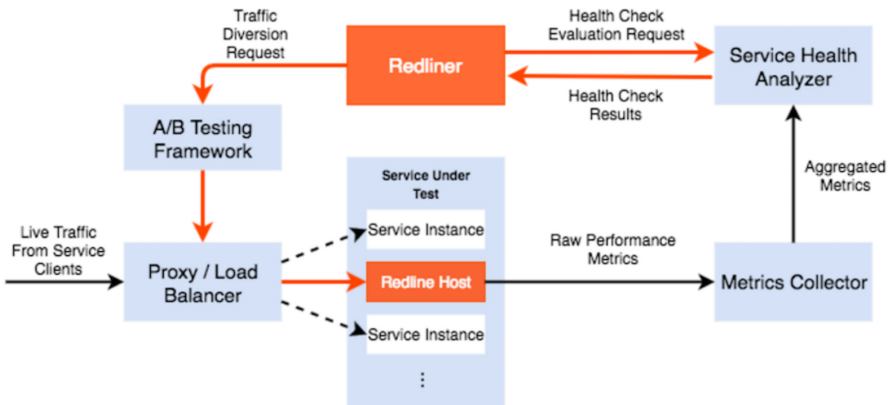
10 Connectors

Software connectors are key elements of the software's architecture. They define the rules of **interaction** between **components**. There are various levels of software connectors that range from *simple* to *complex* connections.

- Simple: shared variable access, method calls ...
- Complex: database access, client-server, scheduler, load balancer ...

In a projects **code base** the connections between components are often implicit and can be noticed easily. In the architecture design we **explicitly identify** them, to allow us to capture **system interactions** (at the level of the components). The specification for interactions are often *complex.* An example for **LinkedIn** is provided below:





10.1 What is Different About Connectors?

Depending on the software project, **components** will have **application-specific** functionality. **Connectors** provide *interaction mechanisms* that are *generic* across different application. **Interaction** may involve **multiple components**, and may have a protocol associated to it.

10.2 Benefits of Explicit Connectors

- **Interaction** is defined by the arrangement of the connectors (as far as possible)
- **Component interaction** is defined by the pattern of connectors in the architecture
- **Interaction** is *"independent"* of the components

10.3 Roles Played By Software Connectors

The specification of the connector protocols determine:

- The types of interfaces
- Properties of interaction
- Riles about ordering interaction
- Measurable features of interactions

Connectors often have multiple roles, the main roles are:

- Communication
- Coordination
- Conversion
- Facilitation

10.4 Communication

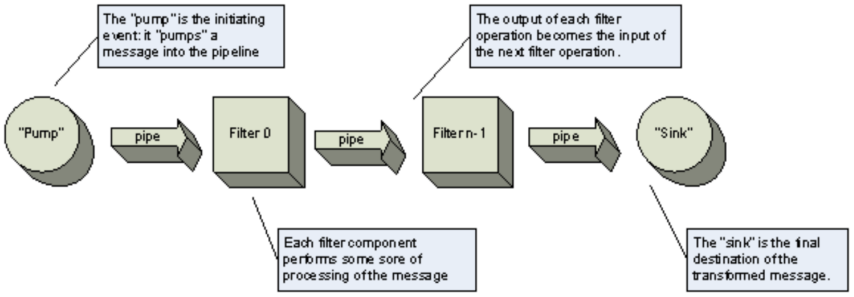
Information is transmitted between **components** (e.g. message passing; method calls). **Connectors** constrain:

- **Direction of flow** (The pipes in the image below)
- **Capacity / rate of flow**

** Additional Information **

- Connector providing communication services support **transmission** of data among components

- Data transfer services are a primary building block of component interaction
- Components routinely pass messages, exchange data to be processed and communication results of computations



Connectors influence measurable quality attributes of the system. It separates **communication** from functional aspects.

10.5 Coordination

Coordination controls the timing **relationship** of the functional aspects of the system.

** Additional Information **

- Connectors providing coordination services support transfer of **control** among components
- Components interact by passing the thread of execution to each other
- **Function calls and method invocations are examples of coordination connectors**
- Higher-order connectors, such as signals and load balancing connectors provide richer, more complex interaction built and coordination services

10.6 Conversion

Conversion is how to get components to interact that **do not** have the right means of interaction. **Incompatibilities** might be related to: datatypes, ordering, frequency, structure of parameters etc ...

Examples of types of converters:

- Wrappers: deal with structural issues
- Adaptors: deal with datatype incompatibilities

** Additional Information **

- Connectors providing conversion services **transform the interaction** required by one component to that provided by another
- Enabling heterogeneous components to interact with each other is **not** a trivial task
- Conversion services allow components that have not been specifically tailored for each other to establish and conduct interaction

10.7 Facilitation

Facilitation enables interaction among a group of components that are intended to interact with one and other.
** Additional Information **

- Improve interaction of components that were intended to interoperate (usually **optimise** or streamlines interactions)
- Ensure proper performance profiles (load balancing or scheduling)
- Synchronization mechanisms (monitors $\rightarrow$ enforce mutex access to resources)

10.8 Types of Connectors (Talyor, Medvidovic & Dashofy)

Connector	Description
Method/Procedure Call	Producre call connectors model the flow of control among components through various invocation techniques. They are thus **coordination connector**. [Examples: fork and exec]
Data Access	Data access connectors allow components to access maintained by a data store component. Therefore they provide **communication services**. [Example: JDBC → java SQL driver]
Event	An even as the instantaneous effect of the termination of the invocation of an operation on an object, which occurs at that object's location. [Example: windows with GUI inputs]
Stream	Streams are used to preform transfer of large amounts of data between autonomous processes. Thus they provide **communication services** in a system. [Examples: UNIX pipes, TCP/UDP sockets, client-server protocols]
Distributor	Distributor connectors perform the identification of interaction paths and subsequent routing of communication and coordination information among components along these paths. They provide **facilitation** services. *[Distributor connectos never exist by themselves, but provide assistance to other connectors, such as steams or procedure calls)*
Arbitrator	When components are aware of the presence of other components but cannot make assumptions about their needs and state, arbitrators streamline system operation and resolve any conflicts (providing **facilitation**). They also redirect the flow of control (providing **coordination**)
Adaptor	Adaptor connectors provide facilities to support interaction between components that have not been designed to interoperate. *(adopters involve matching communication polices and interaction protocols among components, thus providing **conversion** services.*

11 Patterns

12 Modelling The Life-cycle

13 Dev-Ops

14 Product Line Architecture

15 Analysis