软件架构之何去何从

Whither Software Architecture?

Jeff Kramer

Imperial College London

software architecture

lots and lots and lots of publications and books

"... **software architecture** is a set of **architectural** (or, if you will, **design**) **elements** that have a particular **form**." (Perry,Wolf 1992)

"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." (SEI 2010)

"A **software system's architecture** is the set of principal **design decisions** made during its development and any subsequent **evolution**." (Taylor,Medvidovic,Dashofy 2010)

Image: Tina Phillips / FreeDigitalPhotos.net

Whither software architecture

- how did we get here?
- impact?
- where are we going?

a "soap opera" based on my personal research experience

unintentional stepping on toes

my formative project

CONIC – "configuration programming"

the CONIC project

Computer Control & Monitoring of underground systems in coal mining.

The investigators:

Guess Who and Morris Sloman

The research assistant:

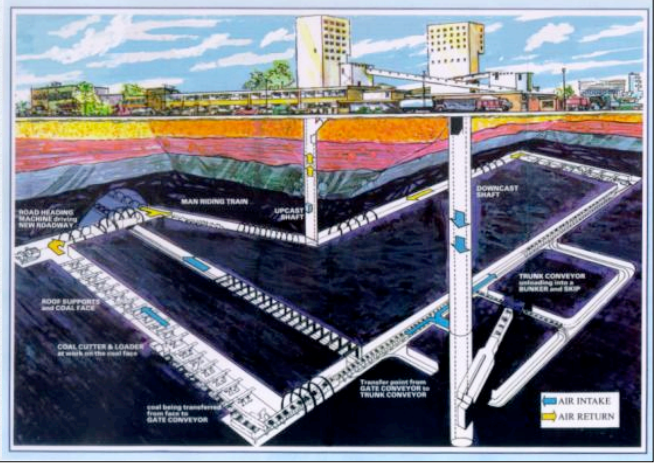
Jeff Magee

coal mines

Underground, coal mines consist of a number of **interacting subsystems**:

- coal cutting
- transport
- ventilation
- drainage
- ...

... **changes** as the mine topography changes.



requirements elicitation

- ➡ complex
  large number of interconnected devices, sensors, actuators, controllers, ...
- ➡ highly distributed
  over the mine site, both above and below ground
- ➡ evolving
  new coal faces open, old faces close
- ➡ robust
  against failures

Software structure should mirror the physical mine

engineering distributed software

- **Information Hiding**

  Encapsulation of design behind an interface

  David Parnas, CACM, 1972

- **Abstraction**

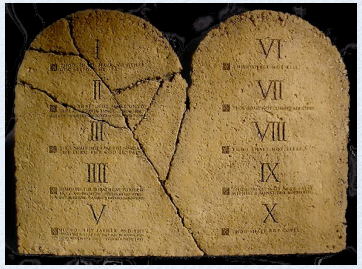
  Programming-in-the-small Vs
  Programming-in-the-large

  deRemer and Kron, TSE 1975

- **Composition**

  "Having divided to conquer, we must reunite to rule"

  Michael Jackson, CompEuro 1990

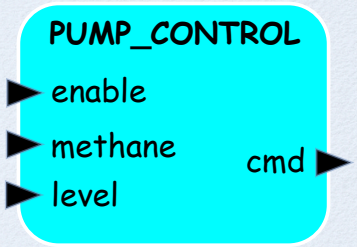


1. distributable components

Key property of **context independence**

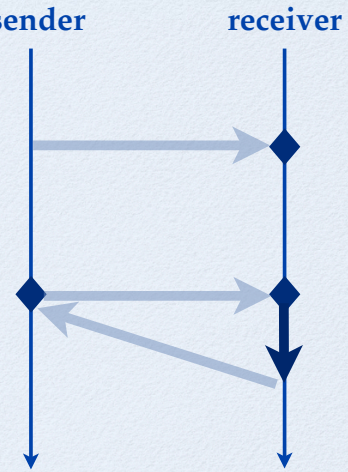
* communication via a well-defined interface.
* supports third party instantiation and binding
* reuse

- **input** and **output** ports (indirection)
- parameterised component types



2. interaction

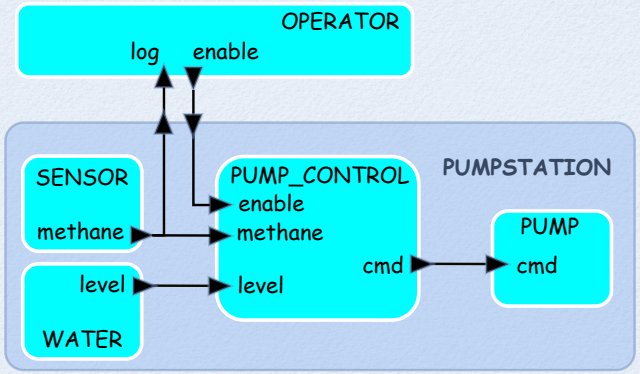
- unidirectional
  - asynchronous
- bidirectional
  - rendezvous



transparent local/remote communication.

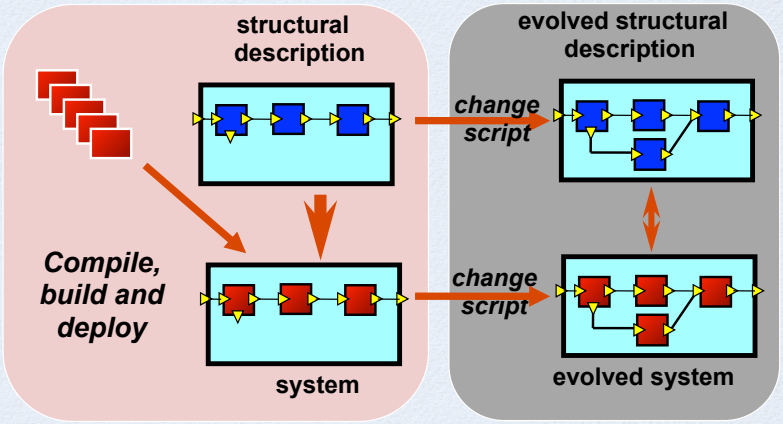
3. configuration (static)

Separate explicit description of the **structure** of the system in terms of the **composition** of component **instances** and **connections** (ie. third party instantiation and binding).



Hierarchical composition helps to hide complexity.

3. configuration (... & dynamic)



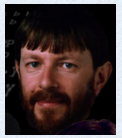
"configuration programming"

TSE 1985

CONIC

- Reusable components
  The control software for a particular coal mine could be assembled from a set of components.
- On-line change
  Once installed, the software could be dynamically modified without stopping the entire system to deal with new coalfaces.

Research team:


Kevin Twidle


Naranker Dulay


Keng Ng

CONIC

- The Iron Lady effect!

However ....

- Wider application than coal mining.
- Distributed worldwide to academic and industrial research institutions.
- Exciting and a lot of fun

TSE 1989

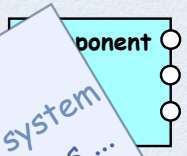
CONIC was not general

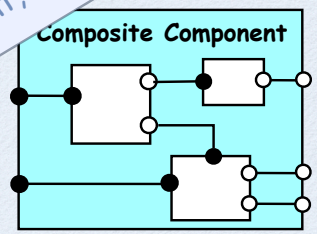
- .... was programming language dependent (Pascal)
- .... had fixed communications primitives
- .... had simple single message interfaces for bindings

Structural view provides a useful level of abstraction.

Darwin - a general purpose ADL

- **Component types** have one or more interfaces. An **interface** is simply a set of names **provided** or **required** by the component, referring to action **specification** or services **implementation**.
- **System types** by comp interface





Tool support
graphical design and software system generation, deployment, as well as ...

ESEC/FSE 1995, FSE 1996

... associated Modelling support

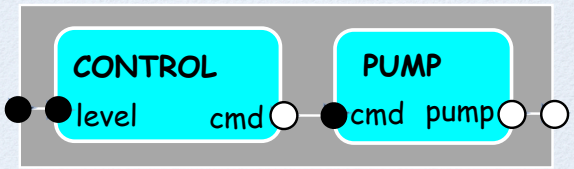
* model component behaviour
* compose behaviours using the same structural information as the software architecture

... compositional reasoning using model checking

Process Calculus - FSP

component behaviour

```
PUMP = STOPPED,
STOPPED = ( cmd.start -> STARTED),
STARTED = ( pump -> STARTED
          | cmd.stop -> STOPPED
          ).
```



model architecture

```
||PUMP_CONTROL =(c:CONTROL || p:PUMP)
               /{c.cmd/p.cmd,
                 level/c.level,
                 pump/p.pump}.
```

Analysis - LTSA

```
fluent RUNNING = <start,stop>
fluent METHANE = <methane.high, methane.low>

assert SAFE = [](tick->(METHANE -> !RUNNING))
```

ESEC/FSE 2005

... in collaboration as always ...

Jeff Magee

Shing-Chi Cheung
- LTS, CRA & Safety

Dimitra Giannakopoulou
- Liveness & Fluent LTL

Nat Pryce
- Animation

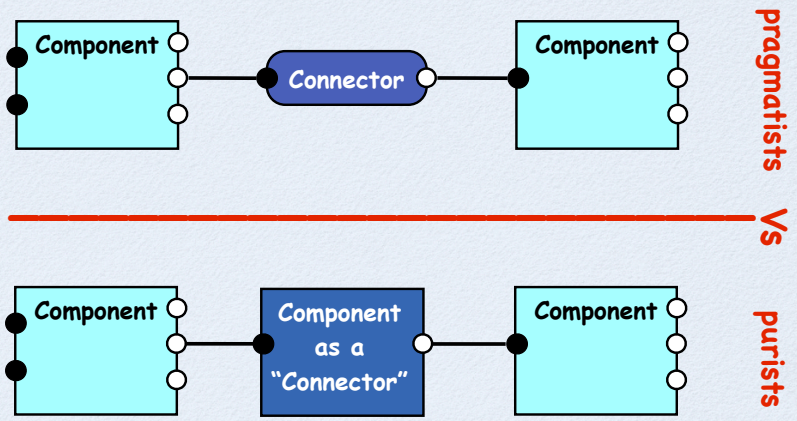
Emmanuel Letier
- AFLTL

Sebastian Uchitel
- Synthesis

ICSE 1996, FSE 1999, ICSE 2000, ESEC/FSE 2003, ESEC/FSE 2005, and Wiley 1999 & 2006

connector wars

connector wars



connector wars

impact?

Image: Salvatore Vuono / FreeDigitalPhotos.net

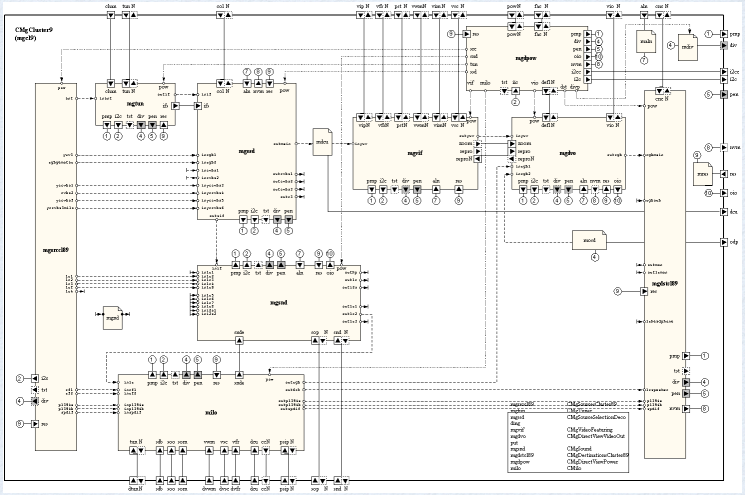
Koala

In the ARES project
Rob van Ommering saw potential of
Darwin in specifying television
product architectures and
developed Koala, based on Darwin,
for Philips.

First large-scale industrial application of an ADL.

Computer 2000

Koala - example

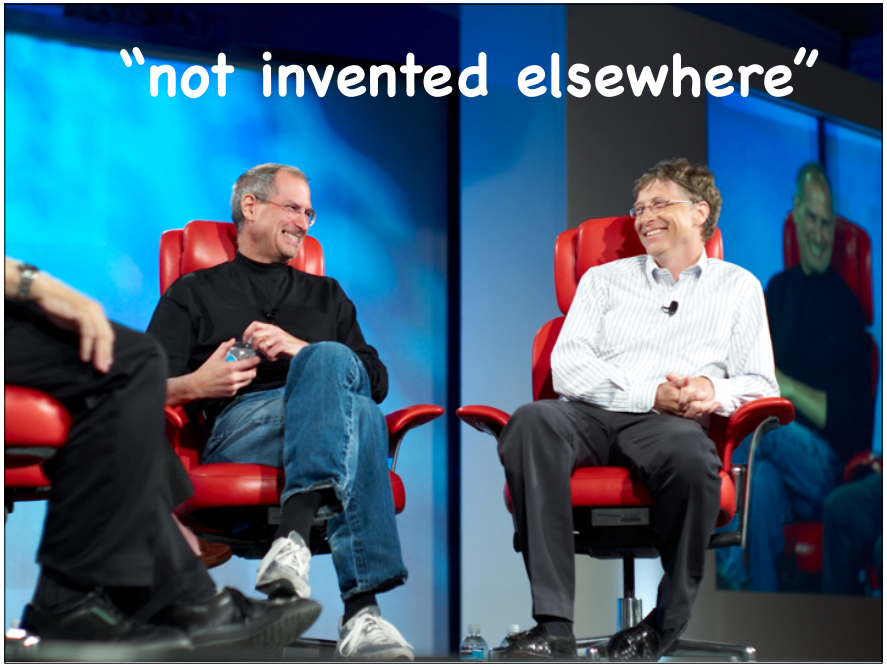


Koala

Not more widely adopted, even in Philips!

- … despite right level of abstraction
- … despite compiler + code generation
- … despite support for diversity

WHY???



Is Koala the only ADL in use?

ROOM
MetaH
~~AADL~~
UNICON
WRIGHT
ACME
Rapide
C2
xADL
ArchJava
SADL
UML2?
…

ADLs have not been widely adopted!

Disappointed but not downhearted …

" All hat and no cattle! "

Architecture research is a success

The abstractions pioneered in software architecture research have actually been very influential.

- qualitative aspects
- reviews/style guides
- architectural patterns
- provides and requires
- UML2
- modelling and analysis

Garlan and Shaw (ESEC/FSE 2011)

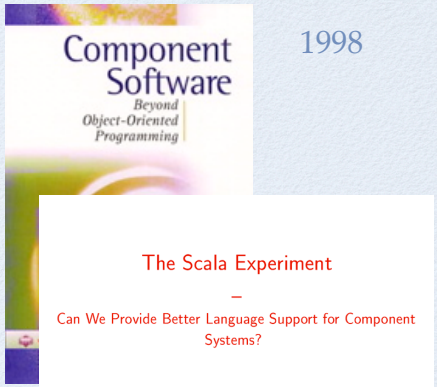
Why were ADLs not widely adopted?

Object-Oriented Programming became ma

- focus on hierarchy
- implicit structure
- implicit interfaces
- objects rather than components

components vs objects

- benefits of a component oriented view are recognised
- we can gain the benefits even with objects.



1998

2006

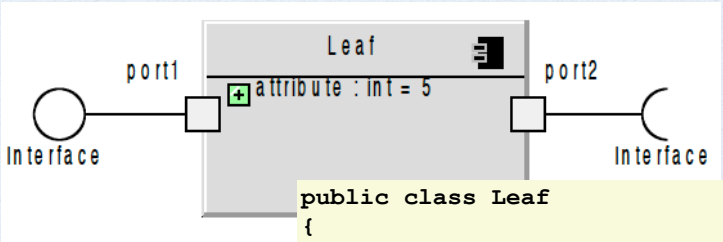
components from objects

provided methods/services

required methods/services

- component type as an OO class
- **dependency injection** (or inversion of control):
  - "**new**" and connections are no longer in the component code
  - supports 3rd party instantiation and binding

components from objects

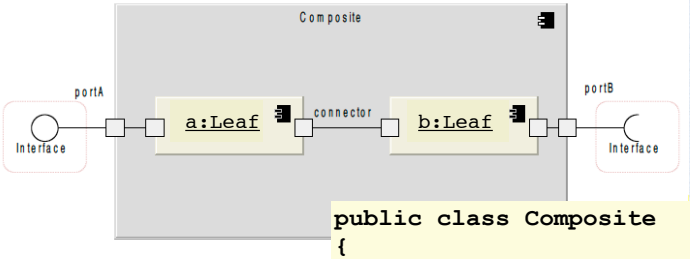


provides →

requires →

```
public class Leaf
{
  public int attribute = 5;
  private Interface port1 =
                      new Interface();
    {...Interface methods ...};
  public Interface getPort1()
    { return port1(); }
  private Interface port2;
  public void setPort2(Interface i)
  { port2 = i; }
}
```

composite components



instantiation →

"connector" →

provides →

requires →

```
public class Composite
{
  private Leaf a = new Leaf();
  private Leaf b = new Leaf();
  public Composite()
    { a.setPort2(b.getPort1()); }
  public Interface getPortA()
    { return a.getPort1(); }
  public void setPortB(Interface i)
    { b.setPort2(i); }
}
```

dependency injection

Permits separation of configuration from use

- **current EJB** (CDI) - "... server-side component architecture for Java"
  - **Spring** - "... application development framework for enterprise Java"
    - **Guice** - ..."lightweight dependency injection framework for Java 5 and above"
      - **Autofac** - ... "IOC container for .NET classes by treating them as components.

rays of hope for ADLs

☑ some current practice in programming languages and some application domains

☑ research on change:

1. software maintenance and evolution
2. adaptive software

1. ADLs for software evolution

Change is intrinsic in the architecture definition

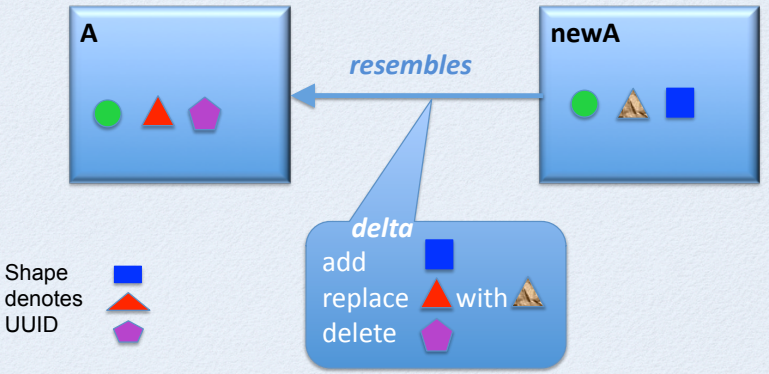
- add three basic constructs to a Darwin-like ADL (Backbone) to support arbitrary extension:
  resemblance, replacement, strata
- **Evolve Tool** uses UML2 graphical notation

Andrew McVeigh

Jeff Magee

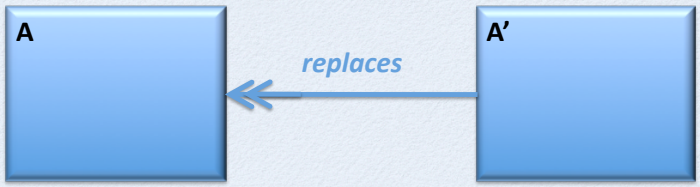
SAVCBS 2006, ICSE 2011

resemblance

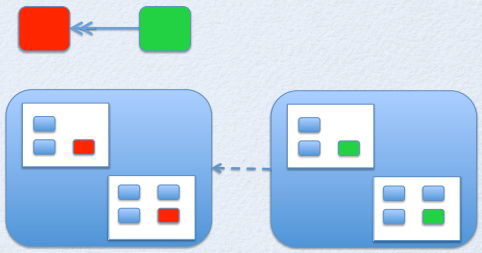


define new components as a delta from the structure of one or more existing components (ie. reuse)

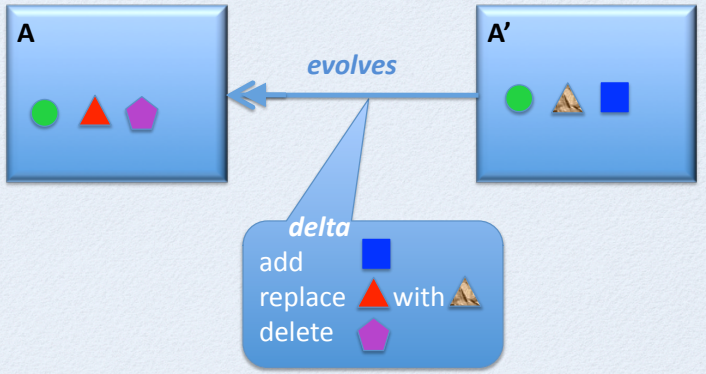
replacement



A' globally replaces A in the architecture.

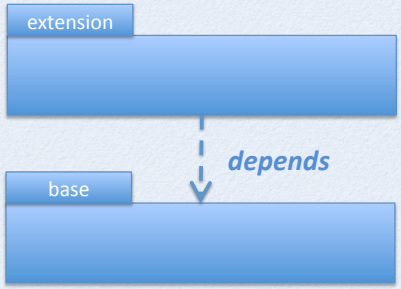


evolution



combines resemblance and replacement

stratum

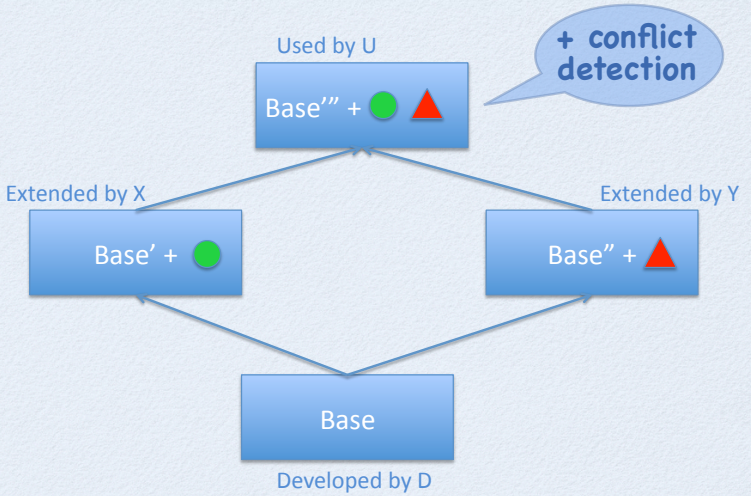


include both strata to give extended system

include base stratum to give original system

* packages the definitions
* unit of ownership
* controls visibility

decentralised development

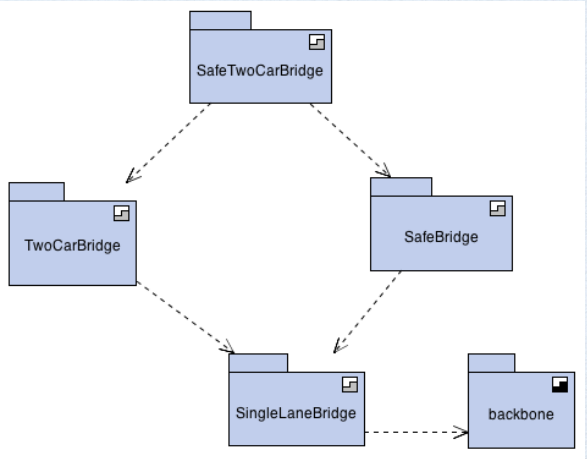


incremental extension properties

* **ALTER**
  Allows any possible extension even if unplanned
* **NO IMPACT**
  Others are not impacted by extensions they don't want
* **DECENTRALIZED**
  Supports a fully decentralized environment
* **COMBINE**
  Extensions / upgrades can be combined, problems rectified
* **NO SOURCE**
  Works even without source code!

Evolve demo

- Evolve design tool
- Backbone ADL



ICSE demo 2011

http://www.intrinsarc.com/evolve

conformance

- "What are the prospects for showing conformance between architecture and code?"

question posed by Garlan and Shaw (ESEC/FSE 2011)

Generate it!

... and store it in the code ("exoskeletal software")

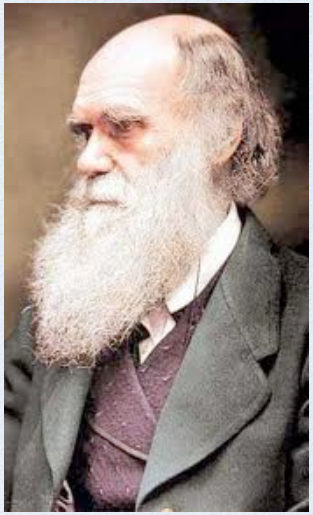
2. ADLs for adaptive software

from **change** in the form of

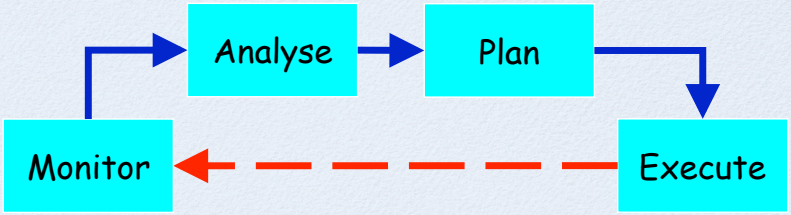
- maintenance and evolution

to

- self-managed software adaptation

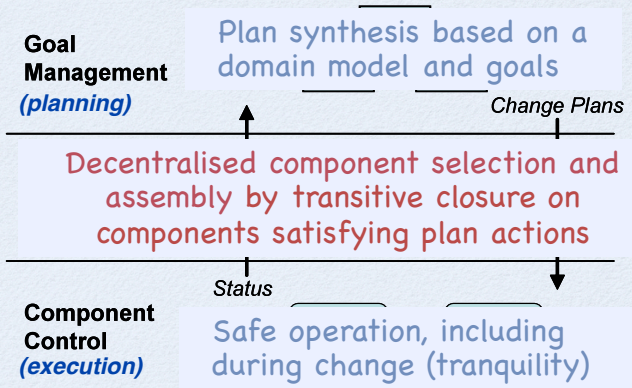


MAPE cycle



- a single feedback loop?
- response times?
- complexity?

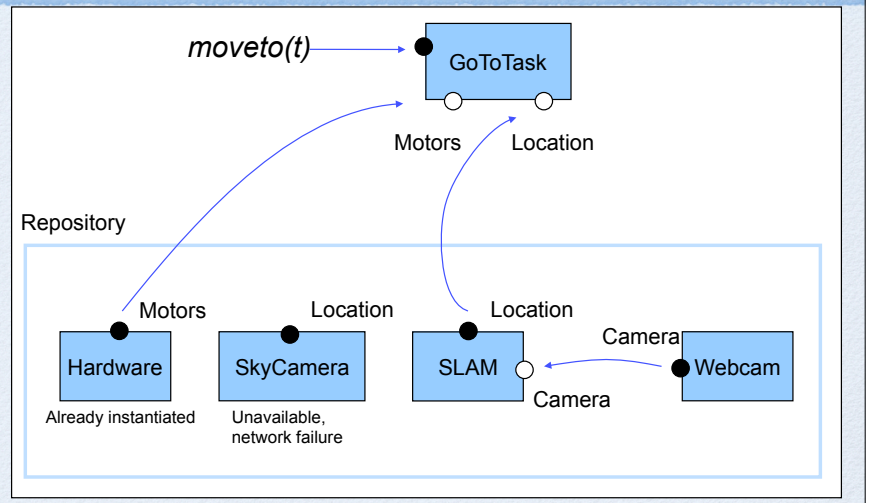
three layer architecture model



a separation of timescales and concerns

ICSE FOSE '07, SEAMS 2008, SEAMS 2011

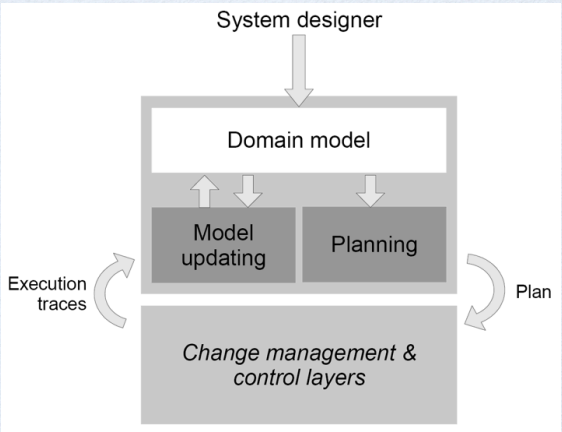
generating the architecture



generating revised plans

- Plan revision through model revision using observations and probabilistic rule learning

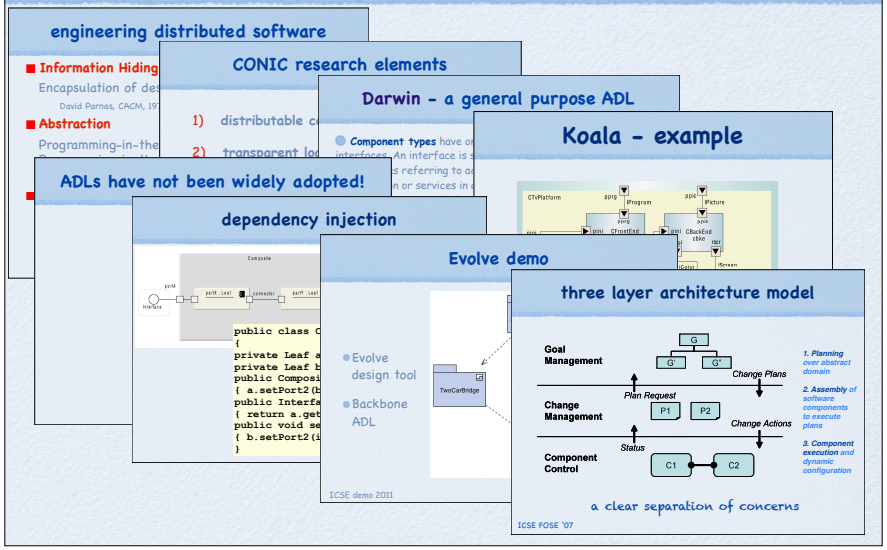
Learning through experience!



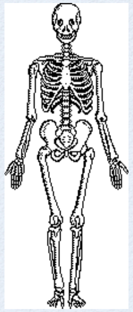
ICSE 2013

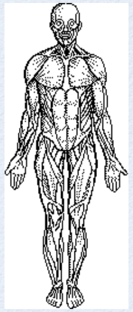
In conclusion...

Previously: What does it mean to "evolve software architecture"



Architecture as an Abstraction





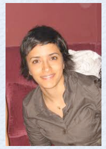
... the same architectural description can be used as the structural framework for the requirements, to compose behaviours for analysis, to compose component implementations for systems, ...

continuing research...

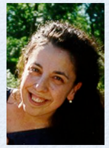
Sebastian Uchitel

- partial component model synthesis from goals and scenarios for architectural fragments,
  - ➡ merge overlapping models,
  - ➡ compose component models according to the system architecture

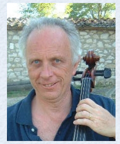
- requirements elaboration and revision using a combination of model checking and machine learning



Dalal Alrajeh



Alessandra Russo



Axel van Lamsweerde

FSE 2004, ICSE 2009, ICSE 2012

a life of collaborative research

colleagues

interesting

challenging

serendipity

rewarding

fun

Whither Software Architecture?

Jeff Kramer

Imperial College London