Software Architecture

Marcel Weiher @mpweiher

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- You have no choice!
- Default architecture: Big Ball of Mud [Foote97]

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160k tonnes

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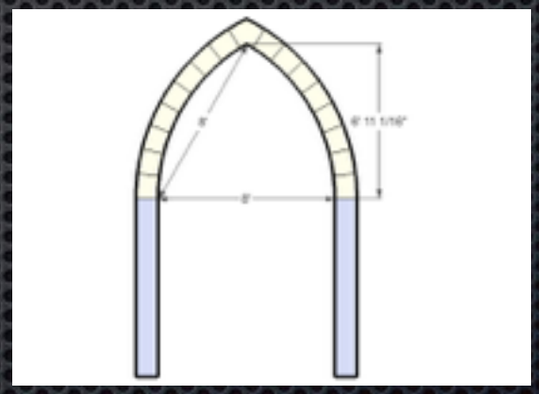
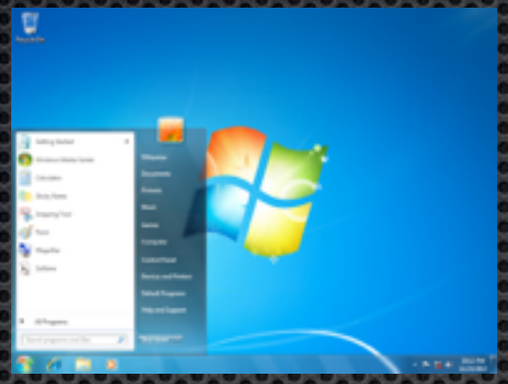
7.5 m tonnes



160k tonnes

Why Software Architecture?

- mono GUI
- Networking
- Word Processing
- 10 KLOC



- color GUI
- Internet
- Word Processing
- 100 MLOC

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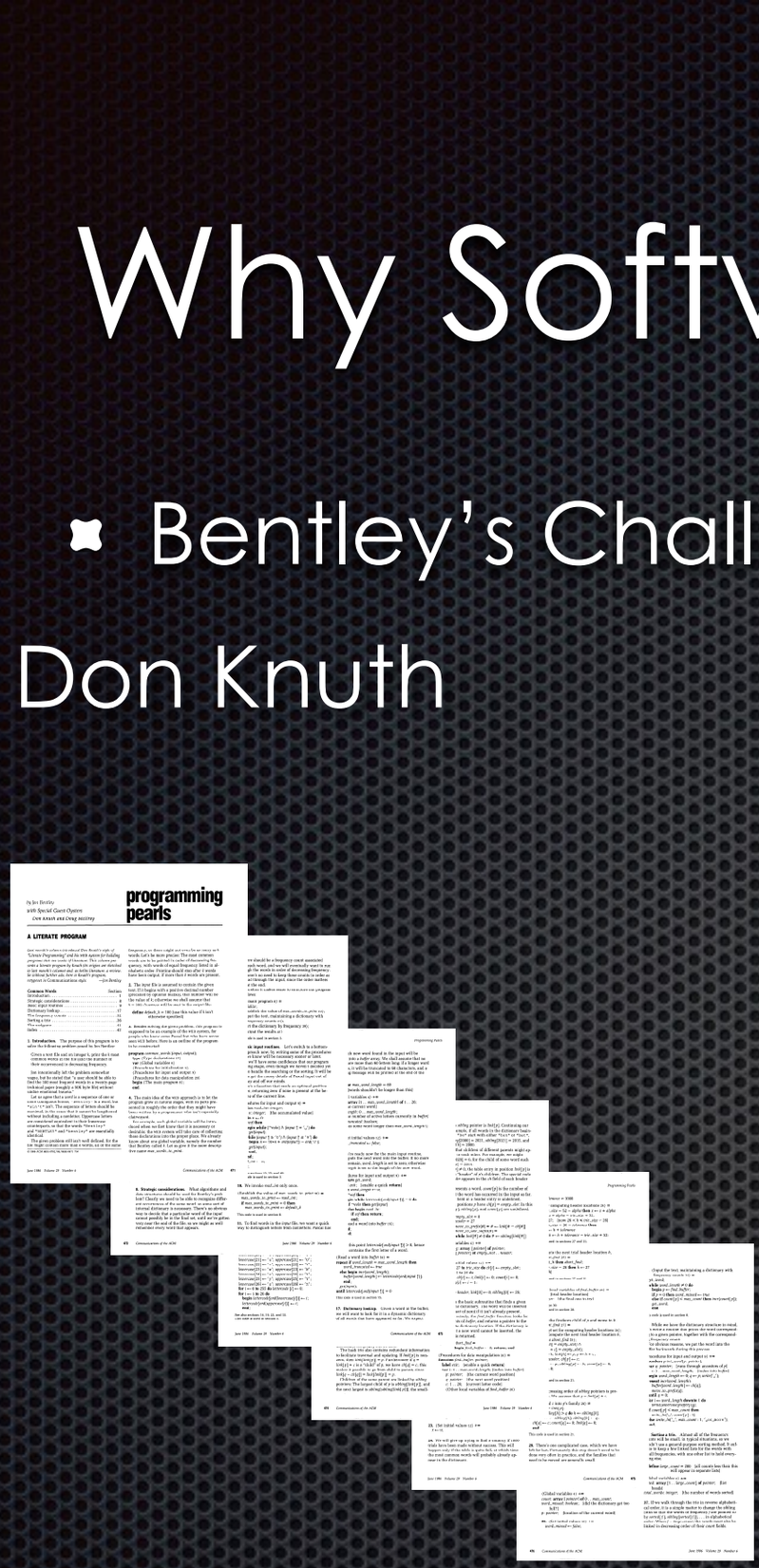
- Internet
- Word Processing
- 100 KLOC

Why Software Architecture?

- Bentley's Challenge: most frequent words

Don Knuth

Doug McIlroy




```
tr -cs A-Za-z '\n' |
  tr A-Z a-z |
  sort |
  uniq -c |
  sort -rn |
  sed ${1}q
```

Overview

- Theory: components, connectors, configurations, styles, adapters, ADLs
- Architectural elements in Cocoa
- Special architectural issues for UI software
- Linguistic Support
- Example: architecture in Wunderlist

Architecture: Theory

- Organizing software into interconnected parts
- Components: parts (computation,state)
- Connectors: communication/organization

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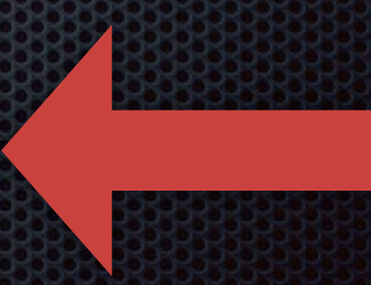


Architecture: Theory

- Organizing software into interconnected parts
- Components: parts (computation,state)

+

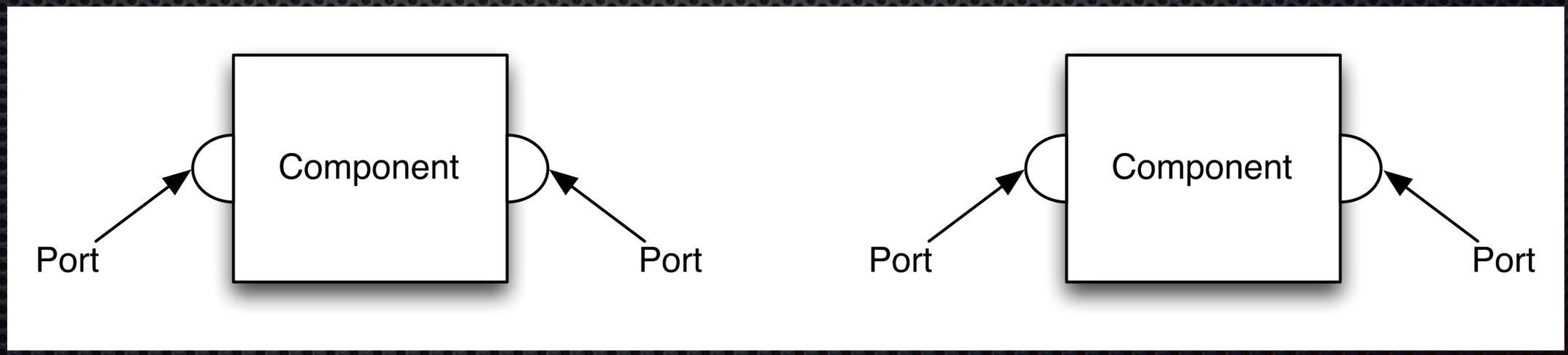
- Connectors: communication/organization

=

- Configurations: systems, programs, components
- Styles: classes/types of configurations

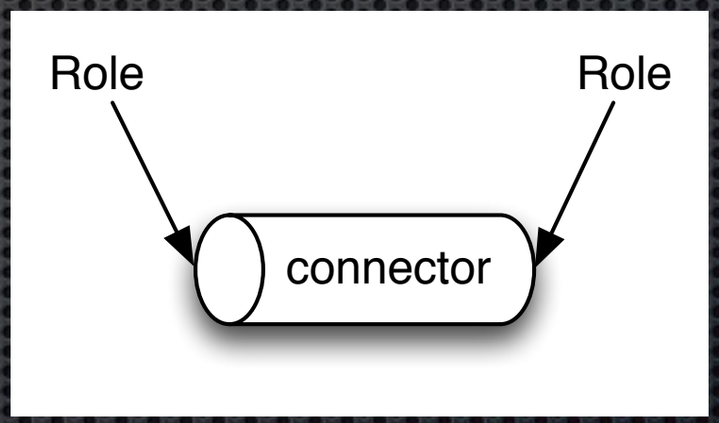
Component

- Computation
- Storage
- Attaches to Connectors via Ports



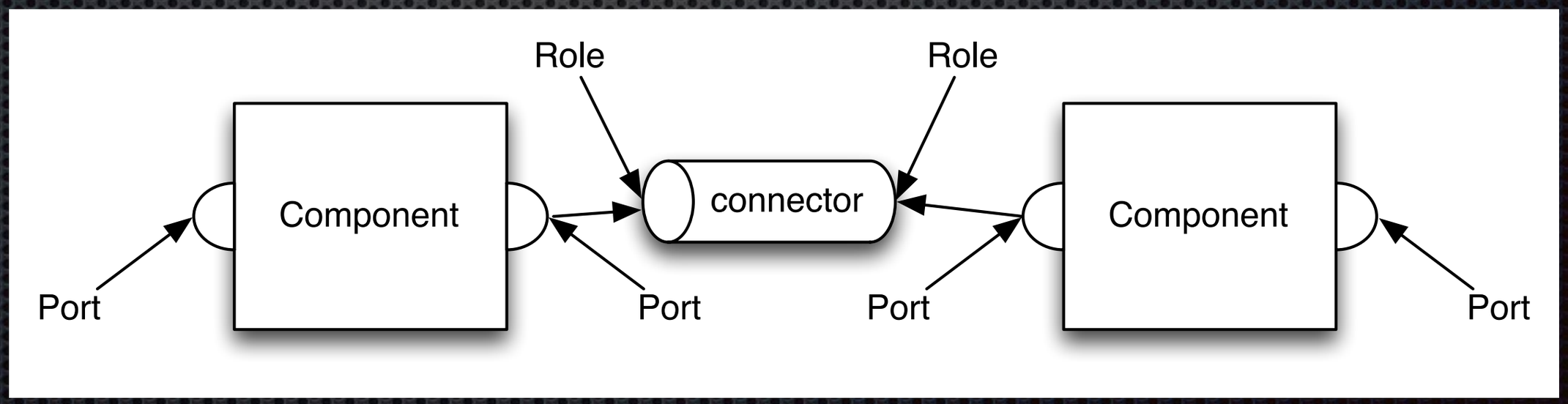
Connector

- Communication
- Interaction
- Attaches to Components via Roles



Configuration

- Also called “System”
- Components joined together via Connectors



Configuration

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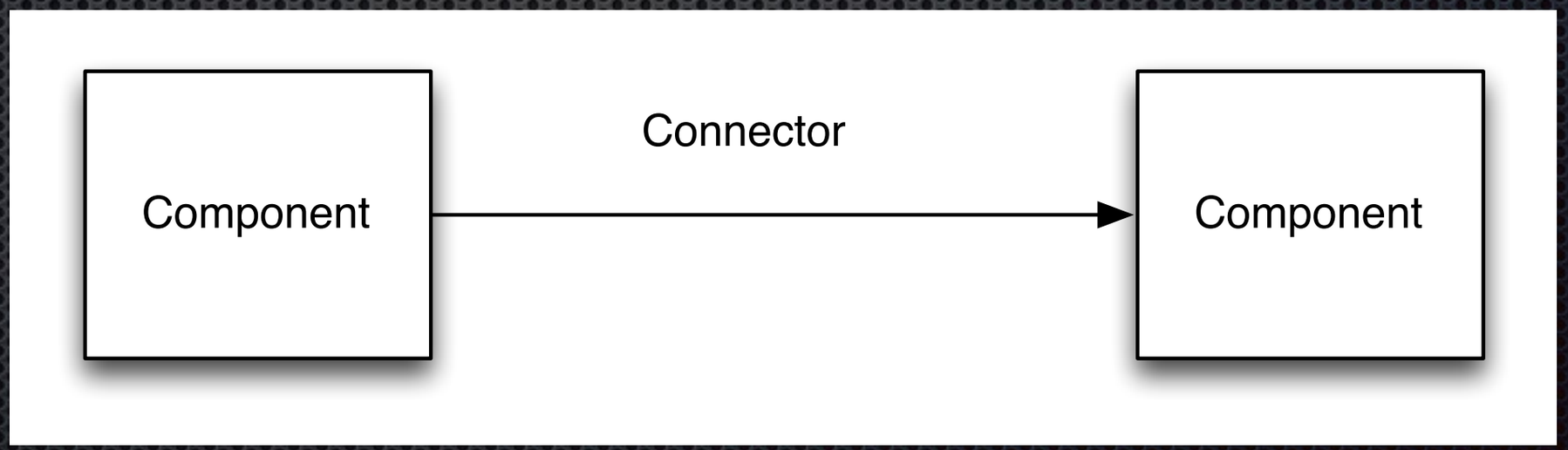


ADLs: ACME

```
System ls-wc {
    Component ls = {
        Port stdin,stdout;
    };
    Component wc = {
        Port stdin,stdout;
    }
    Connector pipe = {
        Role source,sink;
    }
}
```

ADLs: ACME

```
Attachments = {
    ls.stdout to pipe.source;
    wc.stdin  to pipe.sink;
  }
}
```

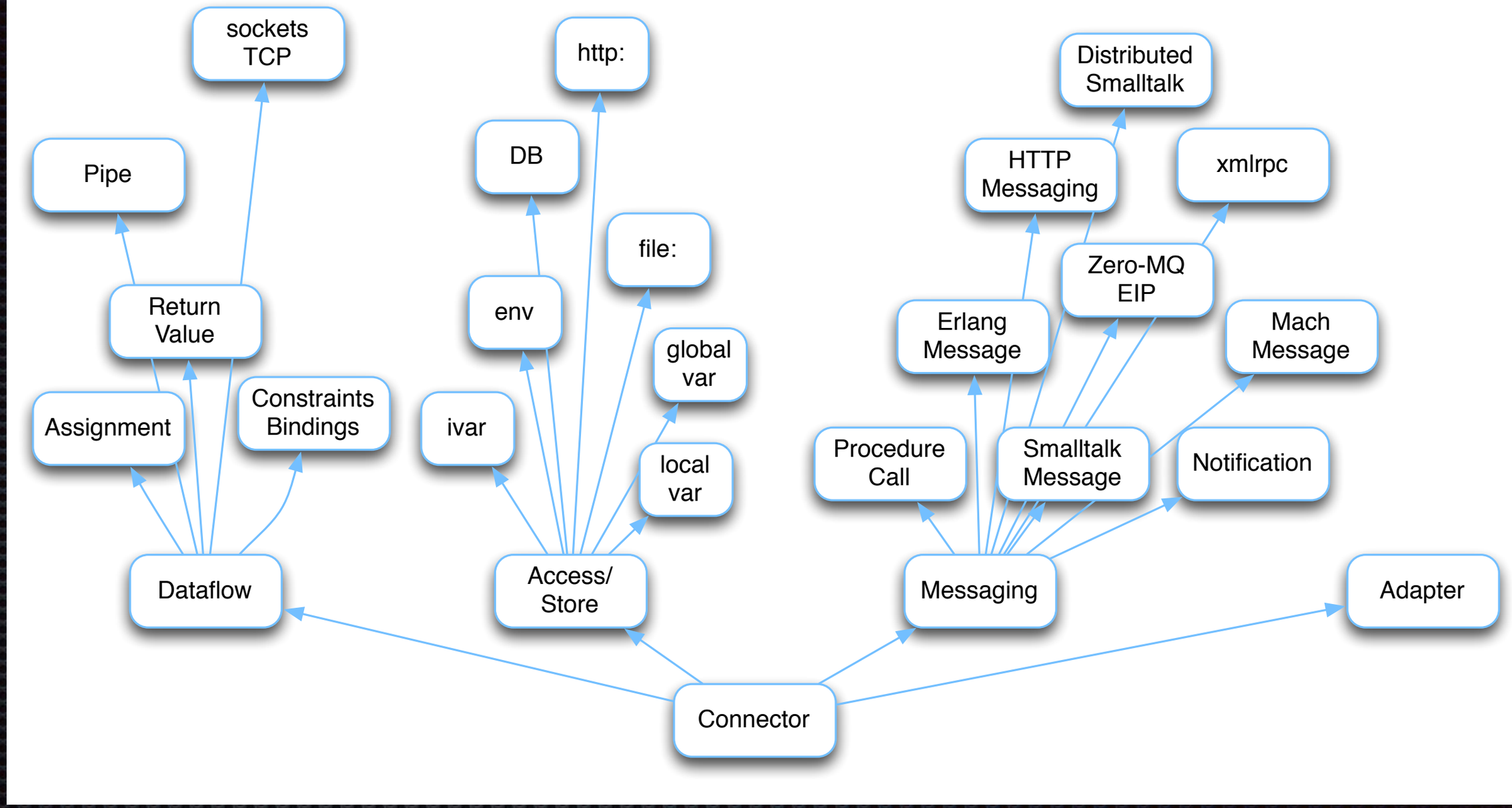
Unix shell:

```
ls | wc
```

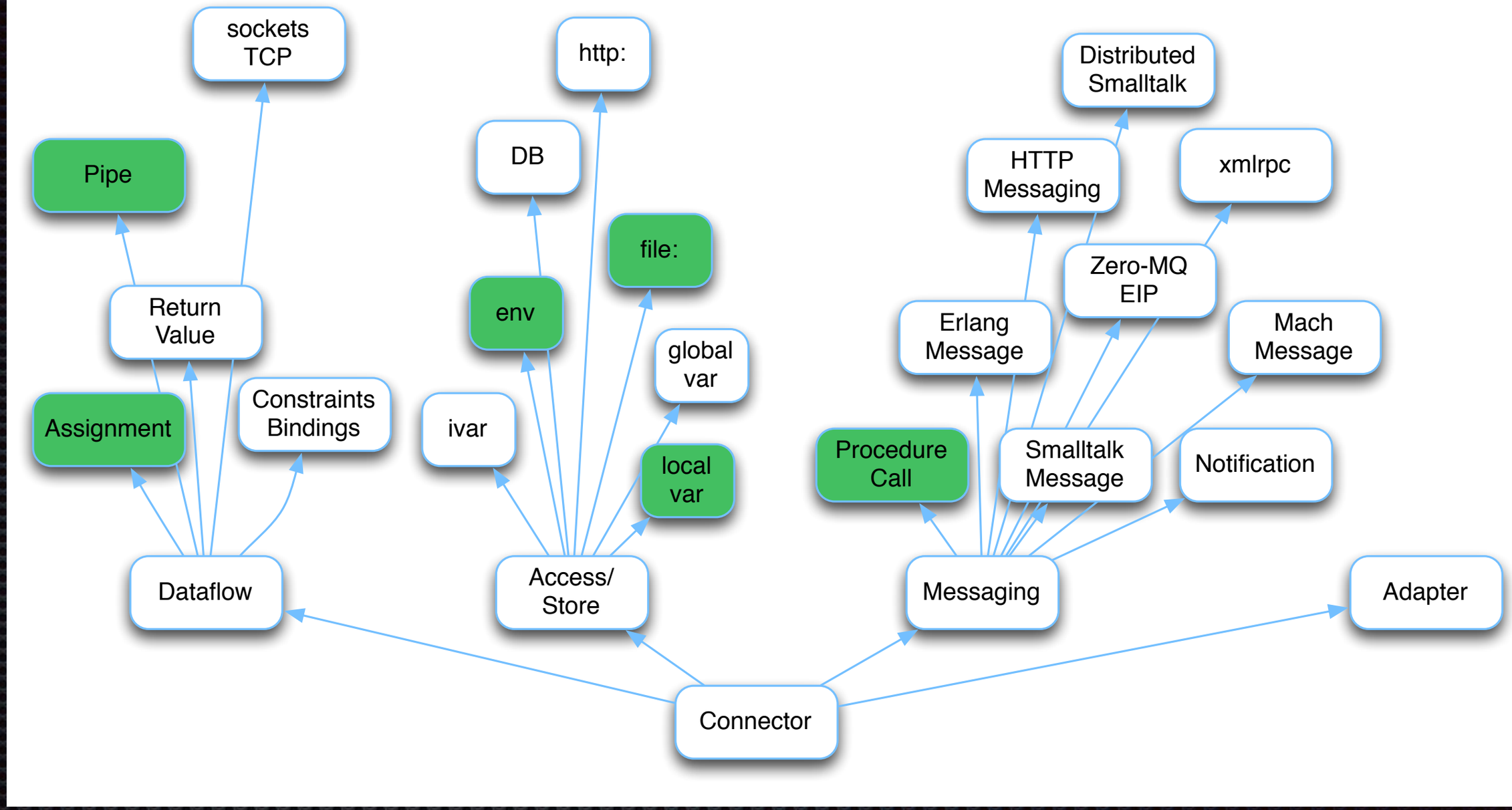
Connectors / Styles

- Call and return (procedural / OOP)
- Dataflow (Pipes/Filters, “reactive”, constraints)
- Implicit Invocation / Events
- Data access
- Messaging
- REST

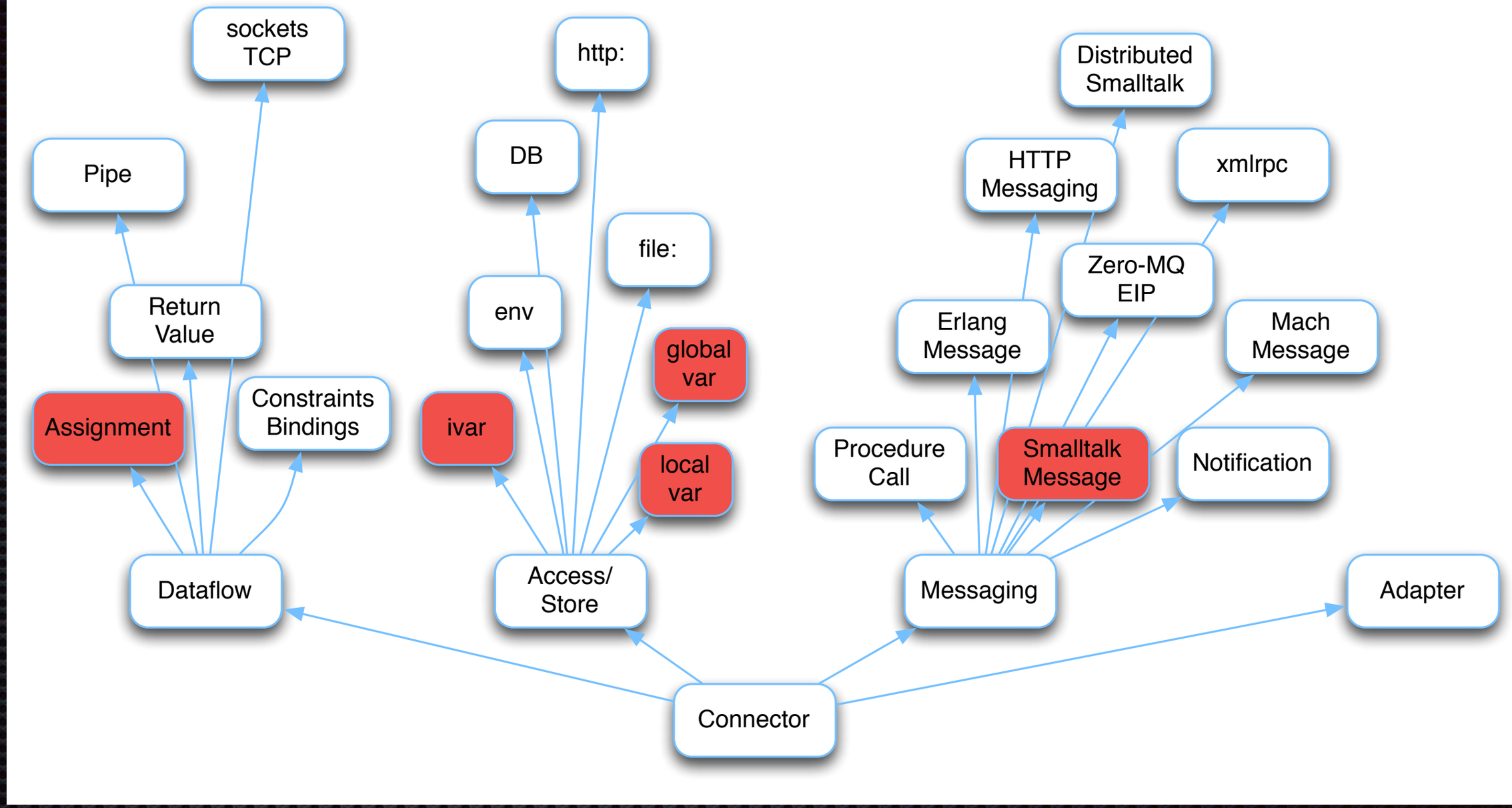
Connectors / Styles



Connectors / Styles



Connectors / Styles



Style: Messaging

- Kay: sorry I coined OO, it's about messaging
- synchronous / asynchronous
- local / remote
- call-based / reified
- early-bound / late-bound

Adapters

- stdio: adapts C call/return to Unix

```
#include <stdio.h>

int main(void) {
  int ch;
  while ((ch=getchar())!=EOF ) {
    putchar(toupper(ch));
  }
}
```

- Objective-C: adapts C to Smalltalk messaging
- Lots of UI-programming-specific adapters in Cocoa

Example: Obj-Streams

- -[NSArray description]

```
NSMutableArray *a;
a=[NSMutableArray array];
for (i=0; i<N; i++) {
   a=[NSMutableArray arrayWithObject:a];
}
NSLog(@“array: %@“,[a description]);
```

Example: Obj-Streams

- -[NSArray description]

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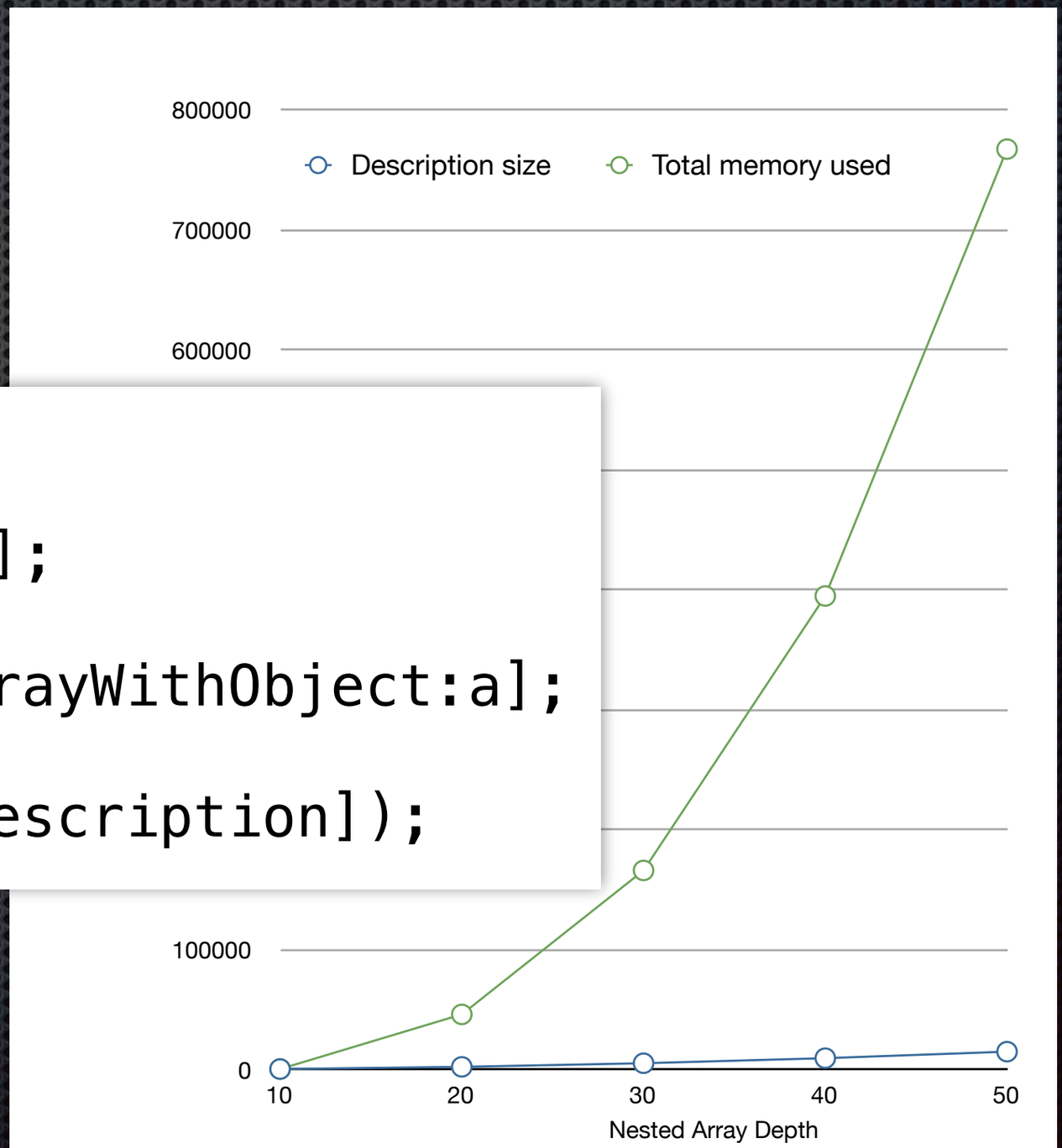

Example: Obj-Streams

```
-description {
 NSMutableString *s=[NSMutableString string];
 [s appendFormat:@“<%@:%p: “,[self class],self];
 for (id obj in self ) {
    [s appendFormat: @“ %@“,[obj description];
 }
 [s appendString:@“>”];
 return s;
}
```

Example: Obj-Streams

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 NSMutableString *s=[NSMutableString string];
 [s appendFormat:@“<%@:%p: “,[self class],self];
 for (id obj in self ) {
    [s appendFormat: @“ %@“,[obj description];
 }
 [s appendString:@“>”];
 return s;
}
```

Example: Obj-Streams

```
-(void)describe {
 printf(“<%s:“,[self className] UTF8String]);
 printf(“%p:“,self);
 for (id obj in self ) {
   [obj printDescription];
 }
 printf(“>”);
}
```

Example: Obj-Streams

```
-(void)describeOn:(FILE*)f {
 fprintf(f,“<%s:“,[self className] UTF8String]);
 fprintf(f,“%p:“,self);
 for (id obj in self ) {
   [obj printDescription:f];
 }
 fprintf(f,“>”);
}
```

Architectural Mismatch

Architectural Mismatch: Why Reuse Is So Hard

DAVID GARLAN, ROBERT ALLEN, and JOHN OCKERBLOOM
Carnegie Mellon University

◆ *Why isn't there more progress toward building systems from existing parts? One answer is that the assumptions of the parts about their intended environment are implicit and either don't match the actual environment or conflict with those of other parts. The authors explore these problems in the context of their own experience with a compositional approach.*

Future breakthroughs in software productivity may well depend on the software community's ability to combine existing pieces of software to produce new applications. The current build-from-scratch techniques that dominate most software production must eventually give way to techniques that emphasize construction from reusable building blocks. If not, software designers may hit a production ceiling in generating large, high-quality software applications.

The last decade has seen increased support for compositional approaches to software. There is considerable research and development in reuse; industry standards like CORBA have been created for component interaction; and many domain-specific architectures, toolkits, application generators, and other related products that support reuse and open systems have been developed.

Yet the systematic construction of large-scale software applications from existing parts remains an elusive goal. Why? Some of the blame can rightfully be placed on the lack of pieces to build on or the inability to locate the desired pieces when they do exist.

But even when the components are in hand, significant problems often remain because the chosen parts do not fit well together. In many cases these mismatches may be caused by low-level problems of interoperability, such as incompatibilities in programming languages, operating platforms, or database schemas. These are hard

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- Packaging doesn't match
- Subclassing required
- Thread of control
- Dependencies

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But even when the components are in hand, significant problems often remain because the chosen parts do not fit well together. In many cases these mismatches may be caused by low-level problems of interoperability, such as incompatibilities in programming languages, operating platforms, or database schemas. These are hard

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update 25th-anniversary top picks

Architectural Mismatch: Why Reuse Is *Still* So Hard

David Garlan, *Carnegie Mellon University*
Robert Allen, *IBM*
John Ockerbloom, *University of Pennsylvania*

In 1995, when we published "Architectural Mismatch: Why Reuse Is So Hard"[1] (an earlier version of which had appeared elsewhere[2]), we had just lived through the sobering experience of trying to build a system from reusable parts but failing miserably. Although the system had the required functionality, developing it took far longer than we had anticipated. More important, the resulting system was sluggish, huge, brittle, and difficult to maintain.

Why had things gone so awry? The usual explanations for reuse failure did not seem to apply. The parts had been engineered for reuse. We were reasonably skilled implementers. We had the source code and were familiar with all the parts' implementation languages. We knew what we wanted, and we used the parts in accordance with their advertised purposes.

In searching for answers, we realized that virtually all our problems had resulted from incompatible assumptions that each part had made about its operating environment. We termed this phenomenon "architectural mismatch," and our article tried to explore in more depth how and why it occurs.

In January 2009, I asked for follow-up pieces from several sets of authors whose insightful and influential *Software* classics made the magazine's 25th-anniversary top-picks list (Jan./Feb. 2009, pp. 9–11). Here, David Garlan, Robert Allen, and John Ockerbloom provide fresh perspectives on their winning article, addressing how their thinking has evolved over the years, what has changed, and what has remained constant.
—*Hakan Erdogmus, Editor in Chief*

The Problem

Specifically, we examined four general categories for assumptions that can lead to architectural mismatch:

- the nature of the components (including the control model),
- the nature of the connectors (protocols and data),
- the global architectural structure, and
- the construction process (development environment and build).

We also noted three facets of component interaction in which assumptions can lead to mismatch:

- the infrastructure on which the component relies,
- application software that uses the component (including user interfaces), and
- interactions between peer components.

Figure 1 illustrates these facets.

Finally, we argued that to make progress,

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Example: Obj-Streams

```
-(void)describeOn:(MPWStream*)s {
  [s printf:@“<%s:p:“,[self class],self];
  for (id obj in self ) {
    [s writeObject:obj];
  }
  [s printf:@“>”];
}
```

Example: Obj-Streams

```
-(void)describeOn:(MPWStream*)s {
  [s printf:@“<%s:p:“,[self class],self];
  [s writeArrayContents:self];
  [s printf:@“>”];
}
```

Example: Obj-Streams

```
-(void)describeOn:(MPWDescriptionStream*)s {
  [s writeObjectHeader:self];
  [s writeArrayContents:self];
  [s printf:@“>”];
}
```

Example: Obj-Streams

```
-(void)describeOn:(MPWDescriptionStream*)s {
 [s describeObject:self contents:^{
      [s writeArrayContents:self];
 }];
}
```

Example: Obj-Streams

```
-(void)describeOn:(MPWDescriptionStream*)s {
 [s describeObject:self contents:^{
      [s writeArrayContents:self];
 }];
}

-(NSString *)description {
  id s=[MPWDescriptionStream streamWithString];
  [s writeObject:self];
  return [s target];
}
```

Example: Obj-Streams

- [descriptionStream writeObject:array];
- [array describeOn:descriptionStream];
- partial results
- stack of objects already seen, no crash
- http://github.com/mpw/MPWFoundation

Architectural Mismatch II

Programs = Data + Algorithms + Architecture: consequences for interactive software

Stéphane Chatty

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7 avenue Edouard Belin, 31055 Toulouse Cedex, France
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IntuiLab, Prologue 1, La Pyrénéenne, 31672 Labège Cedex, France
http://recherche.enac.fr/~chatty
chatty@intuilab.com, chatty@enac.fr

Abstract. This article analyses the relationships between software architecture, programming languages and interactive systems. It proposes to consider that languages, like user interface tools, implement architecture styles or patterns aimed at particular stakeholders and scenarios. It lists architecture issues in interactive software that would be best resolved at the language level, in that conflicting patterns are currently proposed by languages and user interface tools, because of differences in target scenarios. Among these issues are the contravariance of reuse and control, new scenarios of software reuse, the architecture-induced concurrency, and the multiplicity of hierarchies. The article then proposes a research agenda to address that problem, including a requirement- and scenario-oriented deconstruction of programming languages to understand which of the original requirements still hold and which are not fully adapted to interactive systems.

1 Introduction

Niklaus Wirth, renowned computer science teacher and programming language designer, wrote in 1975 a reference book entitled "Algorithms + Data structures = Programs" [1] that has influenced thousands of programmers. It may be that his equation was incomplete though. Software architecture, that is the way of organising software into interconnected parts, has progressively become recognized as a central issue in programming and software engineering, to the point where students now spend more time learning about patterns and frameworks than data and algorithms. Yet, software architecture is still mostly considered a separate issue from programming languages. We contend that this is a serious issue for the software engineering of interactive systems. Short of being able to write "Programs = data + algorithms + architecture" and addressing architecture issues at the language level, the architecture of interactive software may be doomed to inconsistency and complexity.

The architecture of interactive software has been heavily studied and many influential results in software architecture were obtained by researchers with a background in interactive software, or derived from their work. Compare for example the authors and topics in the following list of publications: [2–10]. Still,

- Situation is a lot worse for interactive software
- Architectural style of languages doesn't match
- Our day-to-day slog
- Cocoa adapters help

Architectural Adapters in Cocoa

- NSRunLoop: Events -> Messages
- Target/Action: User Input -> Messages
- Notifications: Implicit Invocation
- Bindings: Dataflow (two-way constraints)
- performSelectorOn..   : Actors
- Nibs, Storyboards: Configurations

IB as an ADL

- Connectors make NIBs possible
- Having only a graphical ADL is limiting
- No abstraction, encapsulation, reuse
- Alternative: code without ADL abstractions
- Better: linguistic support for architecture

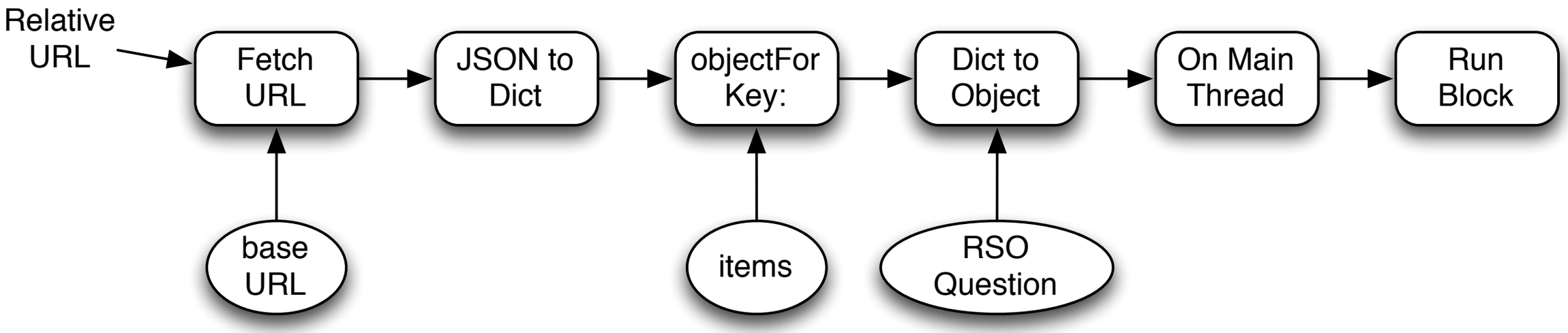
Swift

- Improvements for algorithmic code (compilers)
- Algorithmic code is rare in UI programs
- Restricts dynamic features...
- ... crucial for architectural adaptation...
- ... crucial for UI programming.

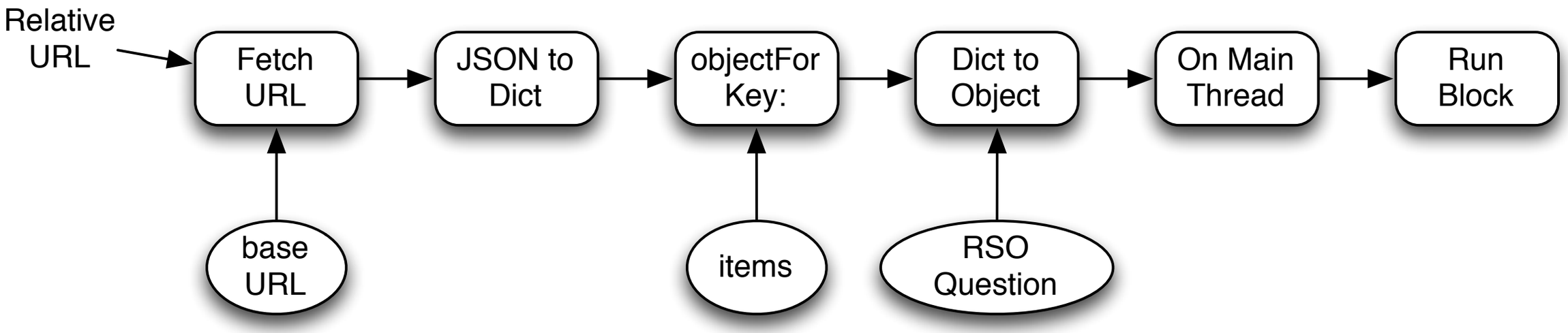
Linguistic support

- Objective-Smalltalk: compact ADL
- Flexibility of messaging for other connectors
- Dataflow
- Flexible data access (Polymorphic Identifiers)
- Dataflow constraints
- Tooling

Dataflow


Relative URL
Fetch URL
JSON to Dict
objectFor Key:
Dict to Object
On Main Thread
Run Block
base URL
items
RSO Question

Dataflow




```
URLFetchStream streamWithBaseURL: baseUrl |
                                parseJSON |
                       objectForKey:'items' |
    dict2objWithClass:(RSOQuestion class) |
                         onMainThreadStream |
                                onBlock:target.
```

Dataflow Constraints I

```
loginButton.enabled =
    [passwordField.stringValue isEqual:
       repeatField.stringValue];
```

Dataflow Constraints I

```
loginButton.enabled =
    [passwordField.stringValue isEqual:
       repeatField.stringValue];
```

```
loginButton/enabled :=
     passwordField/stringValue =
       repeatField/stringValue.
```

Dataflow Constraints I

```
loginButton/enabled :=
     passwordField/stringValue =
       repeatField/stringValue.
```

Dataflow Constraints I

```
loginButton/enabled |=
     passwordField/stringValue =
       repeatField/stringValue.
```

Dataflow Constraints I

```
RAC(self, createEnabled) = [RACSignal
    combineLatest:@[ RACObserve(self, password),
                     RACObserve(self, passwordConfirmation) ]
    reduce:^(NSString *password, NSString *passwordConfirm) {
        return @([passwordConfirm isEqualToString:password]);
    }];
```

```
loginButton/enabled |=
     passwordField/stringValue =
       repeatField/stringValue.
```

Polymorphic Identifiers

- Full URIs as programming language identifiers

  html := http://www.amazon.com/

  file:/tmp/{name} := ‘Hello World’.

- Unified composite references

  textField/intValue := defaults:celsius

- First class references without strings

  ref:textField/intValue

Dataflow Constraints II

```
celsius    |= fahrenheit * 5/9 - 32.
fahrenheit |= (celsius + 32) * 9/5.
```

Dataflow Constraints II

```
celsius     |= fahrenheit * 5/9 - 32.
fahrenheit  |= (celsius + 32) * 9/5.

celsiusTextField/intValue =|= celsius.
fahrenheitTextField/intValue =|= fahrenheit.
```

Dataflow Constraints II

```
celsius     |= fahrenheit * 5/9 - 32.
fahrenheit  |= (celsius + 32) * 9/5.

celsiusTextField/intValue    =|= celsius.
fahrenheitTextField/intValue =|= fahrenheit.

celsius                 := defaults:degreesC.
defaults:degreesC       |= celsius.
```

Wunderlist

```
  <model invariants>

ui              =|= memory-model.

memory-model :=  persistence.
persistence   |= memory-model.

backend       =|= memory-model.
```

Example: Wunderlist 3

- Real MVC
- Hexagonal (Ports/Adapters)
- In-Process REST
- Network: callback hell (replace with dataflow)

Example: Wunderlist 3

- Real MVC
- Hexagonal (Ports/Adapters)
- In-Process REST
- Network: callback hell (replace with dataflow)

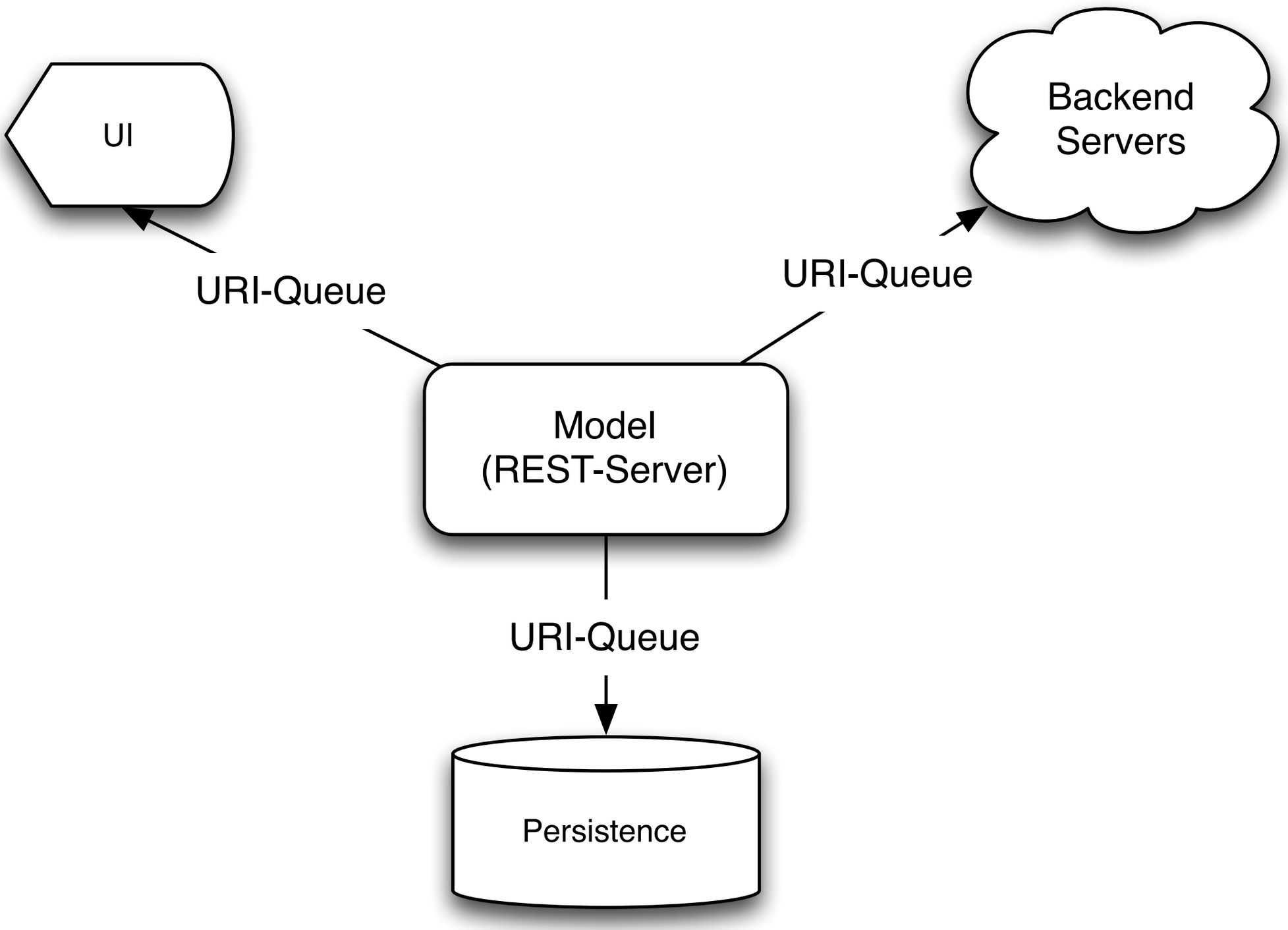
In-Process REST

- Use URIs (StoreReference) to refer to model
- URIs can be persisted
- URIs are structured:

  wlstore:<entity>/container/<id>/object/<id>

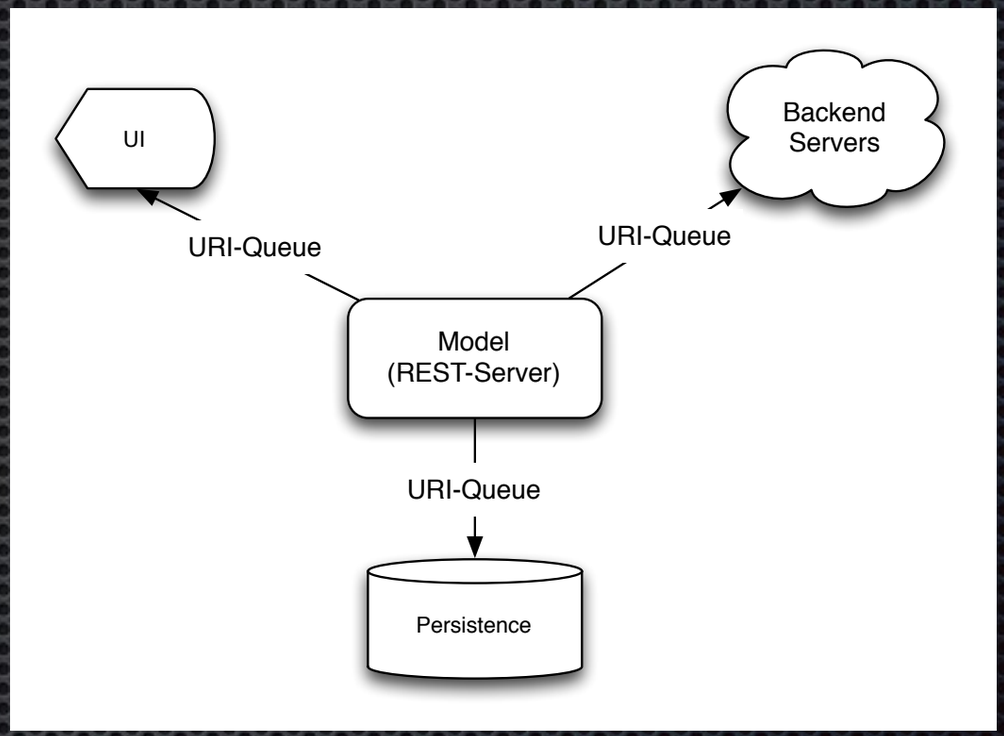
- URIs can refer to single objects or groups

Overall Structure



URI Queues

- A queue of references
- Asynchronous
- Persistable (network)
- Uniqued (network)
- “Bucketized” (storage)
- Dynamic coalescing/throttling (UI)



The Humble Architect

- "Best Practices"
- If you see the architecture, destroy it!
- Useful architectures are discovered
- Architectural abstraction is a toolbox

The Humble Architect

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Conclusions + Q&A

- Software Architecture key to success
- Connecting the pieces
- Linguistic support: http://objective.st
- Practical toolbox for the humble architect