

# Algorithmic Architecture

### Performant Architecture in Evolving Regulatory Environments

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Source: <a href="http://blog.jetbrains.com/clion/2015/09/cpp-annotated-summer-edition/">http://blog.jetbrains.com/clion/2015/09/cpp-annotated-summer-edition/</a>

regulations and change
 problems, people and software
 architecture and performance









Regulations are currently seen as the best way to protect the markets and their participants from themselves

### But Regulations are a Moving Target

**Regulations Change** 

for many reasons but ultimately they change

**\*stuff\*** happens and regulations are often seen as the answer

regulations create loop-holes that need plugged

regulations create industries that themselves need regulated

To Infinity and...

### Explosive Growth in Regulatory Burden



### **There are often Hard Constraints**

#### minimum throughput?

availability?

disaster recovery?

average latency?

worst case latency? And The States proof of compliance? 1.2 CARACT audit trails? a life on the state accuracy of data capture?

many constraints driven by regulations

### Let's simplify this...



### **Addressing Difficult Problems**



### "We fail more often because we solve the wrong problem than because we get the wrong solution to the right problem"

— Ackoff 1974

# How can we classify problems?

Rittel & Webber 1973, Ackoff 1974, Roth & Senge 1996, Hancock 2004, Ritchey 2013

### **Tame Problems**

may be simple orhighly complex definitive stopping point consensus on how to proceed

can be broken down into parts and solved /solutions can be determined to be successful ...or not

Gather Data

Analyse Data

Formulate Solution

Implement Solution

### Messes

#### Organised complexity

• clusters of interrelated or interdependent problems

Systems of problems

• problems that cannot be solved in relative isolation from one another

Messes are puzzles - we don't solve them instead we **resolve their complexities** 



### Messes are... a Mess

- not sufficient to just break the system into parts and fix components
- instead look for **patterns** of interactions between parts
- beware of identifying a mess as a tame problem—the evolving mess can be even more difficult to deal with
- interactive complexity—what can go wrong?
- coupling—the degree to which we cannot stop an impending disaster once it starts













# Refactoring?



- \* Conflicting **social** ethics and beliefs
- \* Smart, informed people **disagree**
- \* **Divergent** problems with no promise of a solution
- **Evolving** set of Interlocking
  Issues and Constraints
- \* Constraints **change over Time**
- \* Many Stakeholders

Wickedness

### Know your demons...

- No definitive Problem == No definitive Solution
- Cannot be solved by a Linear or "Waterfall" process
- Studying followed by Taming does not work
- No stopping rules
- Finished when we Exhaust Resources
- Solutions not Right or Wrong but **Better** or **Worse**
- Poor choices create more Wicked Problems



# Let's consider the question of Healthy Markets

#### The markets involve people

#### The markets involve systems





#### Lots of People and Lots of Systems

#### Characteristics of a Healthy Market?

Volatility?

Data Access?

Transparency?

What represents "good liquidity"?

Tighter Spreads?

High Behavioural Complexity

• Order Book Depth?

What about "phantom" Orders?

Liquidity?

High Dynamic System Complexity

Wicked Mess

**Regulations Developed to Promote Healthy Markets** 



#### **Regulatory Solutions are Too Slow to React Effectively**

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Algorithmic Architecture

# Triggered and Skewed by Events: Flash Crash and HFTs?

# ACCEPTED WISDOM Boundaries for **qualitative assessment** by Expert Stakeholders



Sounds a lot like Agile Development?

# Agile and We're Done?

## Remember our focus is on Architecture in the context of Wicked Messes

### What do we mean by Architecture?

 The product of Design and Implementation – what you see when you step back and look at your system
 Encoded in the Architecture are the choices made and compromises reached

> Whose choices? Whose compromises?

**ECTURE** 

LUKE HOHMAN

### **Another view on Architecture**

Marketecture vs Tarchitecture?

Marketecture: Anything that is concerned with how revenue is generated for a product or how it is marketed as working, or how it is sold

Marketecture impacts Tarchitecture

### **Dangers in evolution**

- Marketecture is often driven by decisions that have
  no regard for the technical impact
- Stakeholders change
- Goal posts move
- Power without responsibility"
- Poor choices baked in early
- What's most important?



### **Architecture General Truths**

- ➤ Is often an observed **sketch** of the system
- > Actual architecture exists based on the **source code**
- Pinpointing which aspects contribute to any characteristic of the system can be difficult
- ➤ Changing it is usually hard






- ► Hard choices early so later choices are easier
- > Evolving to an appropriate architecture
- > Deferring choices to last responsible moment
- ► Natural calcification along the way

Agile Architecture is a good starting point—evolving to an appropriate architecture Can we do better? Let's look at a real world example as a starting point Following the Flash Crash the SEC launched an investigation into the causes



The SEC were presented with architectural overviews of how the systems involved behaved, and how they were evolved

Their focus was on Market Data Publication Slow and delayed quoting was experienced during the Flash Crash

What can we tell from looking at this picture?



Data flow Networking Queuing Decisions Processors Data stores

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Bus

Clients

MDB

Requirement!!! Trades must not be lost and must not be duplicated

CTS

COS



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4



5

# There are a lot of things we **cannot** tell from looking at the diagrams

#### What about...?

- How are stale quotes handled during a recovery?
- When and why are zero quotes published?
- Are the recovery requirements reasonable?
- Which version was in production at the time?
- Did the system behave correctly?
- Is there information to make that determination?
- How was memory managed?
- How many cores did deployment machines have?
- Details, details, details...

#### Reasons why ...?

- Risk Averse Business
- Correctness the highest priority, then performance
- Ultimate priority was performance
- Worst case performance requirements
- Architecture should evolve to improve performance
- There were 2 versions live in production

## A Story... Not the Whole Story

### Nice diagrams typically do not reflect the reality of a code-base



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It would be nice if it did

Some things we can conclude > Performance improved by doing the right thing > Not by optimising existing behaviour Local optimisation only done

when solution good enough

Let's look at some possible future systems that all do the same thing...



Algorithmic Architecture

6



Algorithmic Architecture



Algorithmic Architecture

The same thing in a different way with different trade-offs: Performance trade-offs



Prefer to optimise at the highest level possible The fastest way to do something is not do it at all

#### **Environmental Influences**

- > Architecture for wicked problems typically a "**mess**"
- Many stakeholders and evolving problem domain over time adds "wickedness"
- Decomposing and understanding interactions difficult
- Such architecture, good or bad, is often hard to reason about in a way that maps directly to code
- ► Favours Task Optimisation

#### We want to reason about this...



# But we can only see this...

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#### What we really want is an Architecture that

- favours algorithmic optimisation
- has a clear mapping to code
- allows an optimal solution
- is adaptive to a changing environment

#### an "Algorithmic Architecture"

Relies on being able to decompose the Architecture into discrete elements treating them as Building Blocks

#### We Achieve This By

- > Exposing a Vocabulary *that can map to code and is*
- ➤ Decomposable
- ► Composable
- ➤ Independently Orderable
- ► Compactible
- > Substitutable



#### Expose a vocabulary

the first step in moving towards an algorithmic architecture is to identify a vocabulary suitable for the domain

implies decomposabilityimplies extensibility



#### Must be a **common** vocabulary

A common vocabulary's primary concern is not ensuring the best use in the description of a possible solution—rather it is focused on ensuring that all stakeholders can communicate sufficiently their position within it—it is **shared** 

#### Must be **domain specific**

The vocabulary must support natural domain specific terms as understood by most stakeholders—it is not sufficient to simply adopt a general vocabulary based on general design patterns (but they help)

#### Identify concepts

Focus on identifying **concepts** over specific realisations. Refinement to more concrete terms is best reserved for supporting substitutable elements in an architecture

#### **Vocabulary Checklist**

- > must add in clarity of communication
- should have consensus on basic meanings
- ➤ does not need to be complete
- but should be sufficient to model basic systems
- > may capture concepts at **different** levels in a system
- ► should be possible to describe a system
- vocabularies can grow and evolve



#### Decomposable

it should be possible to decompose the architecture into vocabulary elements that communicate the intent of the system

➤ implies partitioning interfaces



#### Composable

composable components can be assembled together to complete more complex tasks

implies common approach to communication





Independently orderable

it should be possible to re-order components of the architecture that do not have an ordering relationship

➤ implies loose coupling




# Compactible

it should be possible to compact the architecture such that placeholder vocabulary elements can be optimised away

implies facilities to offset the cost of abstraction



### Substitutable

vocabulary elements should be replaceable by differing implementations with differing performance trade-offs

implies consistent, clean interfaces

# Define building block vocabulary elements

```
template<class DataT>
void process( const DataT& Data );
```

```
template<class DataT>
void push( const DataT& Data );
```

```
template<class ProcessorT>
void connect( ProcessorT Processor );
```



Define building block vocabulary elements
Avoid shared state



Processor 2

- Define building block vocabulary elements
- Avoid shared state
- Favour message passing



- Define building block vocabulary elements
- Avoid shared state
- Favour message passing
- Make synchronisation points explicit in the architecture



Synchronisation points are not composable. If you hide them you run the risk of concurrency hazards such as livelocks, starvation, deadlocks, and convoying

- Define building block vocabulary elements
- Avoid shared state
- Favour message passing
- Make synchronisation points explicit in the architecture



Support **push** and **pull** models

```
enum class read_policy{ on_data, poll };
template<class ProcessorT>
void connect( ProcessorT Processor, read_policy Read );
```

- Define building block vocabulary elements
- Avoid shared state
- Favour message passing
- Make synchronisation points explicit in the architecture
- Support push and pull models
- Separate Data and Command paths
- Static Polymorphism for Performance



# Simple Example



# **Different Performance Trade-offs**



### **Code Mapping Example**



```
© 2016 Jamie
                                                                                         Inbound Packet Bus
             void process ( const shared inbound packet & InboundPacket )
                                                                                                                                     Per Channel Gap Filter
                 if ( InboundPacket->seq num() == ExpectedSeqNum )
                     ExpectedSeqNum = InboundPacket->seq num() + InboundPacket->header().num msgs();
                     GapHandler .update_expected_seq_num( ExpectedSeqNum, ChannelId );
                                                                                                                                           Packet Filter
                     if(
                             InboundPacket->header().num msgs()
                         && InboundPacket->header().delivery flag() == format::delivery flag::original message )
                     {
                                                                                                                                       Message Extractor
                         while ( shared message t Message = InboundPacket->pop front() )
                                                                                                                                          Packet Framer
                             if (FramingStrategy ->incoming message triggers send (OutboundPacket ->size(), Message->size()))
     SS
                                 SeqNum += NumMsgsInPrevPacket ;
                                 LastFrameTime = clock t::now().time since epoch();
                                 OutboundPacket ->assign seq num( SeqNum );
                                                                                                                                      Outbound Packet Bus
                                 OutboundPacketBus ->push( OutboundPacket );
     roce
                                 NumMsgsInPrevPacket = OutboundPacket ->header().num msgs();
                                 OutboundPacket = std::make shared<outbound packet t>( format::delivery flag::original message );
                             OutboundPacket ->push back( Message );
                             if (FramingStrategy ->packet requires immediate send (OutboundPacket ->size(), Message->last message in packet() ) )
                                 SeqNum += NumMsgsInPrevPacket ;
                                 LastFrameTime = clock t::now().time since epoch();
                                 OutboundPacket ->assign seq num( SeqNum );
                                                                                                                                      Outbound Packet Bus
    acket
                                 OutboundPacketBus ->push( OutboundPacket );
                                 NumMsgsInPrevPacket = OutboundPacket ->header().num msgs();
                                 OutboundPacket = std::make shared<outbound packet t>( format::delivery flag::original message );
                     else
    Π
                         // send command::category::notification - packet discarded
                 else if ( InboundPacket->seq num() > ExpectedSeqNum )
                     ExpectedSeqNum = GapHandler .handle unexpected packet( InboundPacket, ExpectedSeqNum, ChannelId );
                 else if( InboundPacket->seq num() < ExpectedSeqNum )
                     // log and ignore
```



#### **Publish Packets**



Vocabulary elements map directly to code

- Code still lives in separate 'modules'
- Maintained and tested separately
- Communication through building block interfaces
- Abstraction cost removed but clarity retained
- Easy to change, fix, replace

# Additional Benefits of a Common Vocabulary

# **Common Vocabulary** $\rightarrow$ **Tiered Structure**

Source code is arranged in tiers facilitating a layered development structure and allowing critical code to retain high quality and performance

Projects, Deployments and Configuration

**Product Libraries** 

**Domain Specific Libraries** 

Domain Agnostic Libraries

Standard & Thirdparty Libs

New York Equities Platform

matching\_engine, gateway

gap\_handler, format, session

multicast, bus, concurrency

boost, std, asio

### **Stable Foundations**

Tiers form a pyramid of code with the foundations formed by re-usable components and libraries of well tested code



### **Developer Growth**

- Allows different experience and skillsets to be catered to throughout the team
- Provides clear opportunities for progression and personal growth minimising turnover and helping attract the best developers

Projects, Deployments and Configuration

**Product Libraries** 

Domain Specific Libraries

Domain Agnostic Libraries

Standard & Thirdparty Libs



# **Contrast with Disparate Vocabulary**



**Disparate Vocabulary** Hurts Development

- Product Siloed Development
- Competing underlying frameworks
- Explosion of Code



- Possible to adopt a Core Framework
- Product Building Focused more on Assembly
- Scales across Teams and Geographies
- Developer and Business share the vocabulary



### **Accelerated Development**



Products based on shared framework

- Development rate increases over time
- Framework stabilises over time
- Developer turnover less impact

Minimal Toolchain possible

- Hiring Easier
- Maintenance Easier
- Faster Learning

C++ (core language, high perf, servers), **Python** (web-server, scripting, builds, test), Javascript (web-clients), SCSS (presentation), Postgresql (data storage) Favour a more holistic view of development — one that puts people as a central aspect of architecture

### **Final Thoughts**

In a highly regulated, ever-changing, environment with extreme performance constraints it is increasingly difficult to avoid full system rewrites to meet changing requirements

Algorithmic architecture is primarily about adhering to certain principles and concepts where the goal is to facilitate clear understanding within complex and changing problem domains

The goal of those principles is to allow optimisation (and general improvement) of an architecture to occur at the highest level possible—the architecture itself—allowing adaptivity and evolution

Algorithmic Architecture



# Thank you for Listening





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