Building Scalable, Highly Concurrent & Fault-Tolerant Systems: Lessons Learned

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Typesafe

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Lessons Learned through...

Lessons Learned through... Agony

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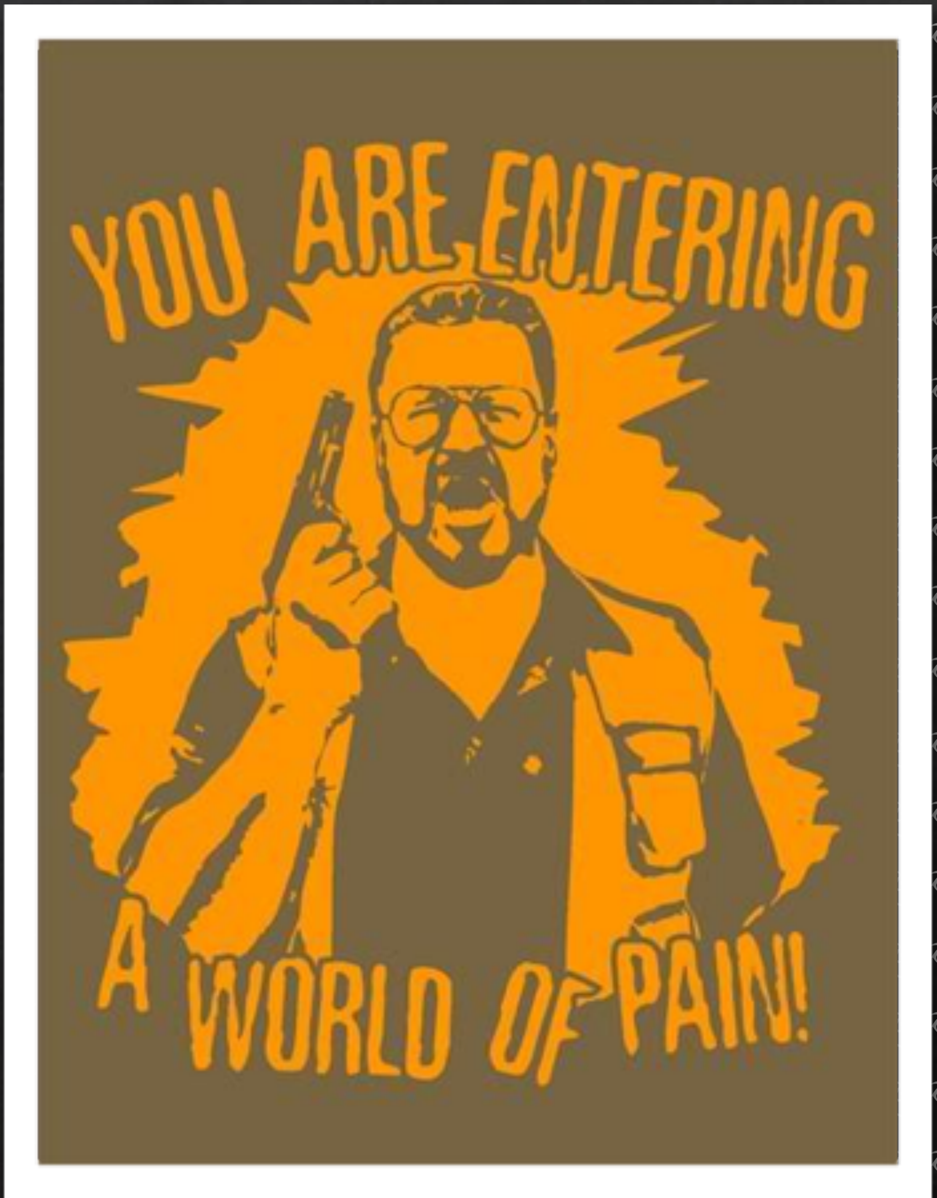

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Lessons
Learned
through...
Agony
and Pain
lots of
Pain

Agenda

- It's All Trade-offs
- Go Concurrent
- Go Reactive
- Go Fault-Tolerant
- Go Distributed
- Go Big


There is no
Free Lunch.

It's all

Trade-offs

Performance

vs

Scalability

Latency

vs

Throughput

Availability

vs

Consistency

Go Concurrent

Shared mutable state

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Together with threads...

Shared mutable state

Together with threads...

...leads to

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Together with threads...

...leads to

...code that is totally INDETERMINISTIC

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...and the root of all EVIL

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Please, avoid it at all cost

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Shared mutabl e

Together

...leads to

ERMINISTIC

VIL

Pl oid it at all cost

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The problem with locks

- Locks do not compose
- Locks breaks encapsulation
- Taking too few locks
- Taking too many locks
- Taking the wrong locks
- Taking locks in the wrong order
- Error recovery is hard

You deserve better tools

- Dataflow Concurrency
- Actors
- Software Transactional Memory (STM)
- Agents

Dataflow Concurrency

- Deterministic
- Declarative
- Data-driven
  - Threads are suspended until data is available
  - Lazy & On-demand
- No difference between:
  - Concurrent code
  - Sequential code
- Examples: Akka & GPars

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Actors

- Share NOTHING
- Isolated lightweight event-based processes
- Each actor has a mailbox (message queue)
- Communicates through asynchronous and non-blocking message passing
- Location transparent (distributable)
- Examples: Akka & Erlang

STM

- See the memory as a transactional dataset
- Similar to a DB: *begin*, *commit*, *rollback* (ACI)
- Transactions are retried upon collision
- Rolls back the memory on abort
- Transactions can nest and compose
- Use STM instead of abusing your database with temporary storage of "stratch" data
- Examples: Haskell, Clojure & Scala

Agents

- Reactive memory cells (STM Ref)
- Send a update function to the Agent, which
  1. adds it to an (ordered) queue, to be
  2. applied to the Agent asynchronously
- Reads are "free", just dereferences the Ref
- Cooperates with STM
- Examples: Clojure & Akka

If we could start all over...

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1. Start with a *Deterministic*, *Declarative* & *Immutable* core

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3. Add *Mutability* selectively - *only where needed*

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4. Finally - *only if really needed*
    - Add *Monitors (Locks)* and explicit *Threads*

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Go Reactive

Never block

- ...unless you *really* have to
- Blocking kills scalability (and performance)
- Never sit on resources you don't use
- Use non-blocking IO
- Be reactive
- How?

Go Async

Design for reactive event-driven systems

1. Use asynchronous message passing
2. Use Iteratee-based IO
3. Use push *not* pull (or poll)

- Examples:
    - Akka or Erlang actors
    - Play's reactive Iteratee IO
    - Node.js or JavaScript Promises
    - Server-Sent Events or WebSockets
    - Scala's Futures library

Go Fault-Tolerant

Failure Recovery in Java/C/C# etc.

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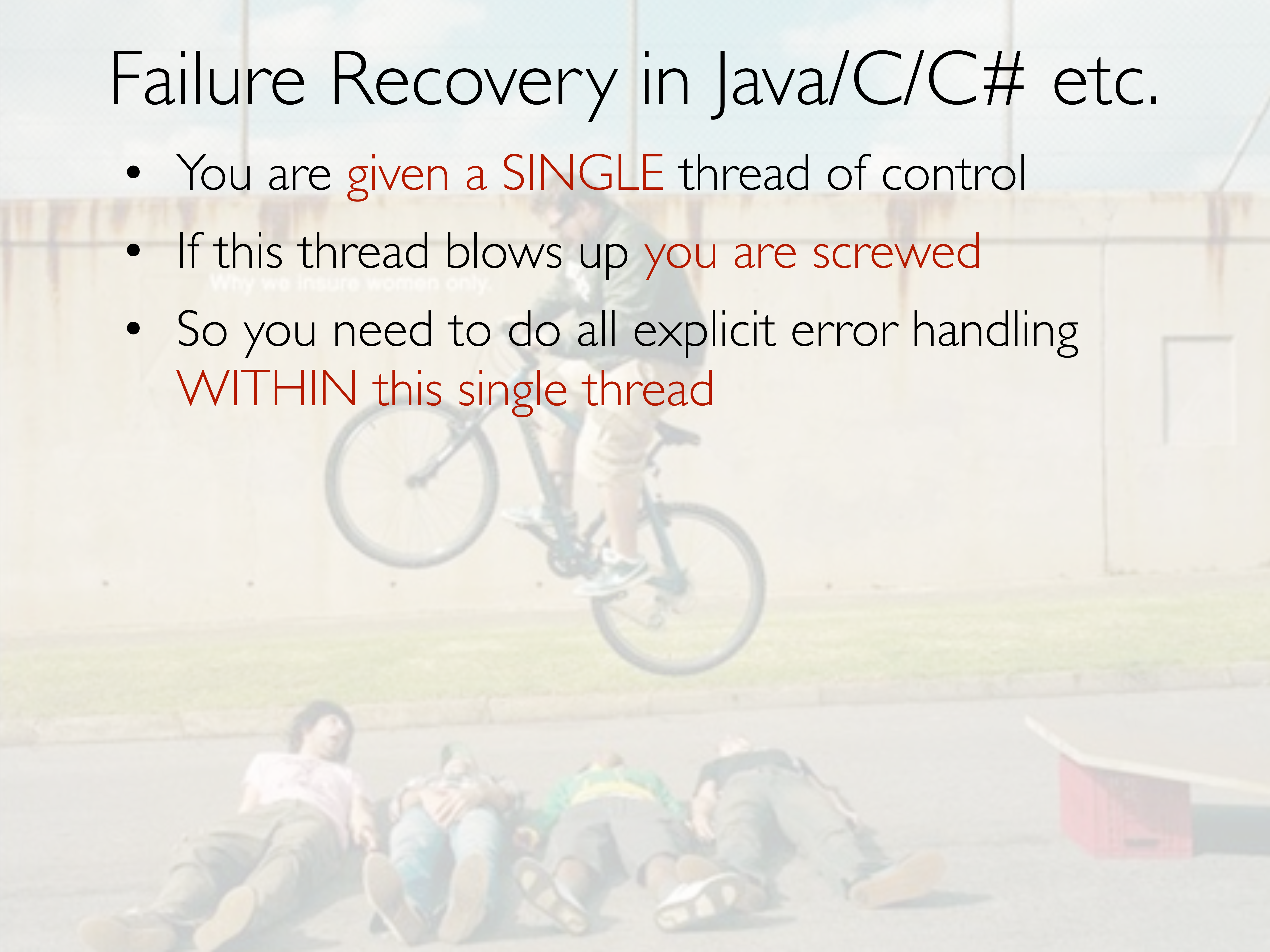

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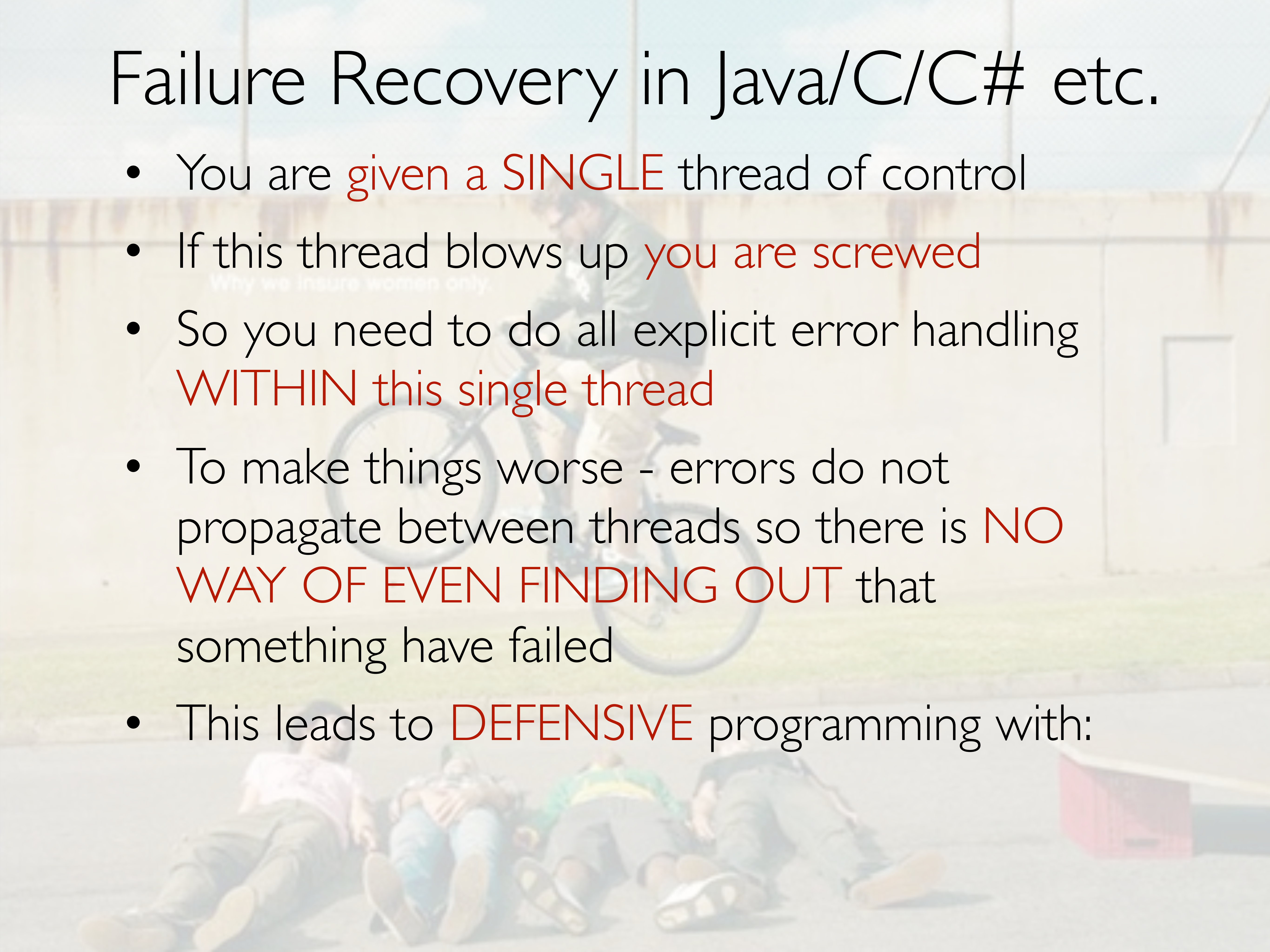

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Just

Let It Crash

The right way

1. Isolated lightweight processes
2. Supervised processes
   - Each running process has a supervising process
   - Errors are sent to the supervisor (asynchronously)
   - Supervisor manages the failure

- Same semantics *local* as *remote*
- For example the Actor Model solves it nicely

Go Distributed

Performance

vs

Scalability

How do I know if I have a performance problem?

How do I know if I have a performance problem?

If your system is
slow for a single user

How do I know if I have a scalability problem?

How do I know if I have a scalability problem?

If your system is
fast for a single user
but slow under heavy load

(Three) Misconceptions about Reliable Distributed Computing
- Werner Vogels

1. Transparency is the ultimate goal
2. Automatic object replication is desirable
3. All replicas are equal and deterministic

Classic paper: *A Note On Distributed Computing* - Waldo et. al.

Fallacy 1

Transparent Distributed Computing

- Emulating Consistency and Shared Memory in a distributed environment
- Distributed Objects
  - *"Sucks like an inverted hurricane"* - Martin Fowler
- Distributed Transactions
  - ...don't get me started...

Fallacy 2
RPC

- Emulating synchronous blocking method dispatch - across the network
- Ignores:
  - Latency
  - Partial failures
  - General scalability concerns, caching etc.
- *"Convenience over Correctness"* - Steve Vinoski

Instead

Instead

Embrace the Network

Use Asynchronous Message Passing

and be done with it

Guaranteed Delivery

Delivery Semantics

- No guarantees
- At most once
- At least once
- Once and only once

It’s all lies.

It’s all lies.

The network is inherently unreliable and there is *no such thing* as 100% *guaranteed delivery*

It's all lies.

Guaranteed Delivery

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The question is what to guarantee

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1. The message is - *sent out on the network?*

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Guaranteed Delivery

The question is what to guarantee

1. The message is - *sent out on the network?*
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3. The message is - *put on the receiver's queue?*

Guaranteed Delivery

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Guaranteed Delivery

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Guaranteed Delivery

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4. The message is - *applied to the receiver?*
5. The message is - *starting to be processed by the receiver?*
6. The message is - *has completed processing by the receiver?*

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Ok, then what to do?

1. Start with 0 guarantees (0 additional cost)
2. Add the guarantees you need - one by one

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Different USE-CASES

→ Different GUARANTEES

→ Different COSTS

Ok, then what to do?

1. Start with 0 guarantees (0 additional cost)
2. Add the guarantees you need - one by one

Different USE-CASES

→ Different GUARANTEES

→ Different COSTS

For each additional guarantee you add you will either:

- decrease performance, throughput or scalability
- increase latency

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Just

Just

Use ACKing

Just

Use ACKing

and be done with it

Latency
vs
Throughput

You should strive for

maximal throughput

with

acceptable latency

Go Big

Go Big Data

Big Data

Imperative OO programming *doesn't cut it*

- Object-Mathematics Impedance Mismatch
- We need functional processing, transformations etc.
- Examples: Spark, Crunch/Scrunch, Cascading, Cascalog, Scalding, Scala Parallel Collections
- Hadoop have been called the:
  - *"Assembly language of MapReduce programming"*
  - *"EJB of our time"*

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Big Data

Batch processing *doesn't cut it*

- Ala Hadoop
- We need *real-time* data processing
- Examples: Spark, Storm, S4 etc.
- Watch "*Why Big Data Needs To Be Functional*" by Dean Wampler

Go Big

DB

When is a RDBMS **not** good enough?

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Scaling reads to a RDBMS is hard

Scaling writes
to a RDBMS
is impossible

Do we

really need

a RDBMS?

Do we

really need

a RDBMS?

Sometimes...

Do we really need a RDBMS?

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Do we
really need
a RDBMS?

But many times we don’t

Atomic

Consistent

Isolated

Durable

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Availability

vs

Consistency

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Brewer's

CAP

theorem

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You can only pick 2

- ☐ Consistency
- ☐ Availability
- ☐ Partition tolerance

At a given point in time

Centralized system

- In a centralized system (RDBMS etc.) we don't have network partitions, e.g. P in CAP
- So you get both:

☑ Consistency

☑ Availability

Distributed system

- In a distributed (scalable) system we will have network partitions, e.g. P in CAP
- So you get to only pick one:

  ☐ Consistency

  ☐ Availability

Basically Available

Soft state

Eventually consistent

Think about your data

Then think again

- When do you need ACID?
- When is Eventual Consistency a better fit?
- Different kinds of data has different needs
- You need full consistency less than you think

How fast is fast enough?

- Never guess: Measure, measure and measure
- Start by defining a baseline
  - Where are we now?
- Define what is "good enough" - i.e. SLAs
  - Where do we want to go?
  - When are we done?
- Beware of micro-benchmarks

...or, when can we go for a beer?

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SO

GO

...now home and build yourself

Scalable,

Highly Concurrent &

Fault-Tolerant

Systems

Thank You

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