Understanding the Redundancy of Software Systems

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Redundancy

Informally, a system is redundant when it is able to perform the same functionality by executing different code.
Software Redundancy

N-version

Recovery Blocks

Input → Checkpoint → Execute Version → Test → Output

Exception:

Fail

Yes

Alternatives?

No

Fail
Deliberate Redundancy

N-version

Recovery Blocks
Modern software systems contain a form of redundancy that is indeed intrinsically present.
Intrinsic Redundancy: Examples

**Joda-Time**

```java
DateTime t = new DateTime();
//...
//get the beginning of the day for time t
DateTime beginDay = t.millisOfDay().withMinimumValue();
```
Joda-Time

DateTime t = new DateTime();
//...
//get the beginning of the day for time t
DateTime beginDay = t.millisOfDay().withMinimumValue();
    = t.toDateMidnight().toDateTime();
    = t.withTimeAtStartOfDay();
Joda-Time

DateTime t = new DateTime();
//...
//get the beginning of the day for time t
DateTime beginDay = t.millisOfDay().withMinimumValue();
    = t.toDateMidnight().toDateTime();
    = t.withTimeAtStartOfDay();

Google Guava

MultiMap m = new MultiMap();
//...
//check if element is already in map
if (m.contains(x))
Intrinsic Redundancy: Examples

**Joda-Time**

```java
DateTime t = new DateTime();
//...
//get the beginning of the day for time t
DateTime beginDay = t.millisOfDay().withMinimumValue();
    = t.toDateMidnight().toDateTime();
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```

**Google Guava**

```java
MultiMap m = new MultiMap();
//...
//check if element is already in map
if (m.contains(x))
    if (m.elementSet().contains(x))
        if (m.count(x) > 0)
```
Intrinsic Redundancy: Examples

**Joda-Time**

```java
DateTime t = new DateTime();
//...
// get the beginning of the day for time t
DateTime beginDay = t.millisOfDay().withMinimumValue();
    = t.toDateMidnight().toDateTime();
    = t.withTimeAtStartOfDay();
```

**Google Guava**

```java
Multimap m = new Multimap();
//...
// check if element is already in map
if (m.contains(x))
    if (m.elementSet().contains(x))
        if (m.count(x) > 0)
```

2 LOC (~0.1%)

0 LOC (0%)
Using Intrinsic Redundancy

- Self-healing
- Test oracles
- Automatic repair
- Security
Modern software systems contain a form of redundancy that is indeed intrinsically present.
What is its essence?

"Modern software systems contain a form of redundancy that is indeed intrinsically present."
Studying Intrinsic Redundancy

What is its essence?
“Modern software systems contain a form of redundancy that is indeed intrinsically present.

How pervasive is it?
Modern software systems contain a form of redundancy that is indeed intrinsically present.
Modern software systems contain a form of redundancy that is indeed intrinsically present.
Modern software systems contain a form of redundancy that is indeed **intrinsically** present.
Modern software systems contain a form of redundancy that is indeed intrinsically present.
What Is Its Essence?
What Is Its Essence?

redundancy

=  

functional equivalence  

+  

execution diversity
What Is Its Essence?

redundancy =

functional equivalence + execution diversity

Observational Equivalence
[Hennessy et al.]
What Is Its Essence?

\[ \text{redundancy} = \text{functional equivalence} + \text{execution diversity} \]
What Is Its Essence?

redundancy = functional equivalence + execution diversity

put(K key, V value)  putAll(K key,Iterable values)
How Pervasive Is It?
How Pervasive Is It?

Joda-Time

<APACHE ANT>

eclipse

SWT

Lucene

GraphStream

guava-libraries

Guava: Google Core Libraries for Java 1.6+
How Pervasive Is It?

Joda-Time

4700+

equivalent method sequences

Lucene

GraphStream

eclipse

SWT

guava-libraries

Guava: Google Core Libraries for Java 1.6+
Intrinsic redundancy
What Is Its Essence?

redundancy = functional equivalence + execution diversity

Intrinsic redundancy
How Pervasive Is It?

redundancy =

functional equivalence

+ execution diversity

What Is Its Essence?

S_A

\[ a_1, a_2, a_3, \ldots \]

S_B

\[ a_1, a_2, a_3, \ldots \]

Intrinsic redundancy

What

How

Architecture

Python
Java

The C Programming Language

Second Edition

Innovative & Incremental Development
What Is Its Essence?

\[
\text{redundancy} = \text{functional equivalence} + \text{execution diversity}
\]

How Pervasive Is It?

How to Identify It?

```
Object o = s.peek();
int index = s.size();
index = index - 1;
s.remove(index);
return o;
```

Execution Scenarios
What Is Its Essence?

redundancy = 

functional equivalence + 

execution diversity

How Pervasive Is It?

Python

Java

Why?

Design for reusability

Non-functional requirements

Replicated Functionalities

Backward compatibility

How to Identify It?

Object o = s.peek();
int index = s.size();
index = index - 1;
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Execution Scenarios