TT- fortest. (15)

Testability Transformation

seminar for ForTest Network

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Overview

- Test Data Generation
- Problems for Evolutionary Test Data Generation
- Testability Transformation
- Two Examples

Automatic Test Generation

Generating good quality test data is hard

Knowing what **good quality** means is hard

I do not propose to answer that question today

Starting point: structural test adequacy criterion

Specifically that some path or branch is to be **covered**

Structural Test Data Generation

There are five possible methods:

- Human analysis
- Random Testing
- Symbolic Execution
- Constraint Solving
- Evolutionary Testing

This talk focuses on Evolutionary Testing

But testability transformation applies elsewhere too

Evolutionary Testing

To execute a branch:

Define a **fitness function** for the predicate

Fitness function guides a **search** for test input

This has been shown to work well

... but there are problems

Problems with Evolutionary Testing

Program **structure** inhibits the fitness function formation

Examples of structure problems include:

- Side effects
- Unstructured control flow
- Flag variables

Paradox

We are testing to cover **structure**

… but the **structure is the problem**

So we **transform** the program

… and this **alters the structure**

So a question arises:

Are we **still testing according to the same criterion**?

We need to **co-transform the test adequacy criterion**

Informally

A **transformation** is a partial function on programs

We need to pair the program and test adequacy criterion

- call this the **test pair**

A **testability transformation** is a partial function on test pairs

such that...

Testability Transformation

Test data

which

is

adequate for the **transformed** test pair

is

adequate for the **original** test pair

Trivial Example

Informally, this is already done:

"Branch coverage is MC/DC coverage when we expand out *if* statements"

```
if (a && b)
    s1;
else s2;
```

→

```
if (a)
    if (b)  s1;
    else  s2;
else s2;
```

More Formally

Definition 1 (Testing-Orientated Transformation)

Let **P** be a set of programs and **C** be a set of testing criteria. A program transformation is a partial function in $\mathbf{P} \rightarrow \mathbf{P}$. A *Testing-Orientated Transformation* is a partial function in $(\mathbf{P} \times \mathbf{C}) \rightarrow (\mathbf{P} \times \mathbf{C})$.

Definition 2 (Testability Transformation)

A Testing-Orientated Transformation, τ is a *Testability Transformation* iff for all programs, p and criteria c, if $\tau(p, c) = (p', c')$ then for all test sets T, T is adequate for p according to c if T is adequate for p' according to c'.

Reversible Testability Transformations

A testability transformation only guarantees that **sufficient** test data will be generated to meet the original test adequacy criterion.

A Reversible Testability Transformation guarantees that test data generated is necessary and sufficient:

Definition 3 (Reversible Testability Transformation)
A testability transformation, τ is a *Reversible Testability Transformation* iff its inverse is a testability transformation.

Examples

We now look at two examples

The first is particular to Evolutionary Testing

The second is a general problem in test data generation

The first illustrates how the **adequacy criteria** may need to **change** during Testability transformation

The second illustrates the way Testability Transformation may lead to **novel transformations**

The Flag Problem

Flag variables → ‘coarse fitness landscape’

- Possibly a large **plateau** of low equal fitness
- Possibly a **small plateau** of high equal fitness
- **No guide** from low to high
- **Can not find high plateau**

Worst case:

Evolutionary testing degenerates to random testing

Flag Removal Transformation

```
…
n' = n;
flag = (n' %2==0)?0:(n' <4);
…
if (a[i] != '0' &&  (n' %2==0)?0:(n' <4))
     …
```

Nothing New

These are all **standard transformations**

But we require a **change** in the **adequacy criterion**

Depends upon the interpretation of 'node of the CFG'

But test data :

which is adequate for **MC/DC on the transformed**

is adequate for **branch on the original**

Unstructuredness

Unstructured control flow presents problems

Seek **transformation to single-entry/single-exit**

Such a transformation is **always possible**

(Note: Due to Cooper **not** Böhm and Jacopini)

Unfortunately the approach is to **introduce flags**

... and to **massively alter the structure**

Equivalence

Definition 4 (Functional equivalence)

Program *p* is ***functionally equivalent*** to program *q* if they always produce the same output for the same input.

Definition 5 (Path equivalence)

Program *p* is ***path equivalent*** (or strongly equivalent) to program *q* if, for all inputs, the sequences of test and actions performed by the two programs are identical.

For us, **path equivalence seems a natural choice**

Path Equivalence is restrictive

Knuth and Floyd: ‘regular expression flowchart semantics’

Regular expression captures possible paths through flowchart

gotos cannot always be removed under path equivalence

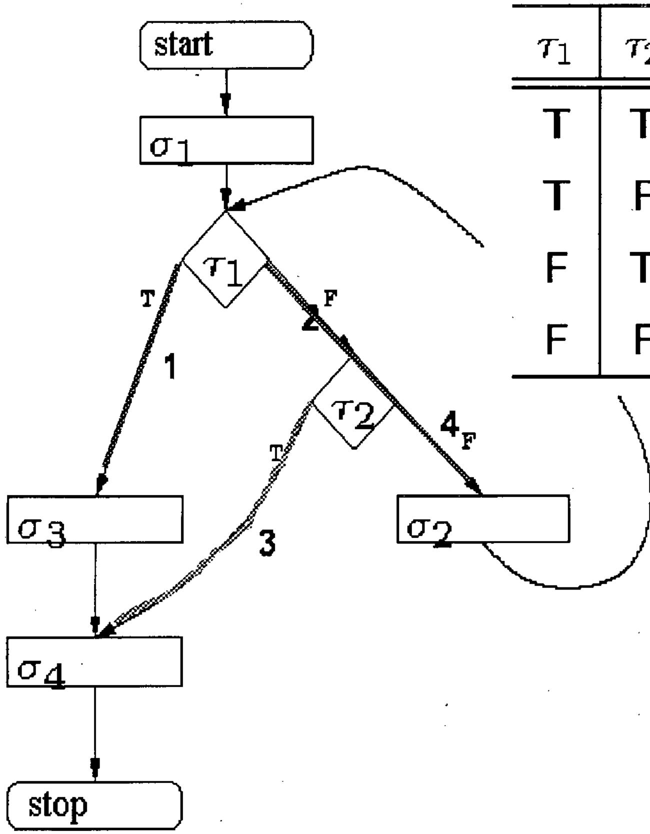
R describes paths through structured programs

Hopcroft showed that

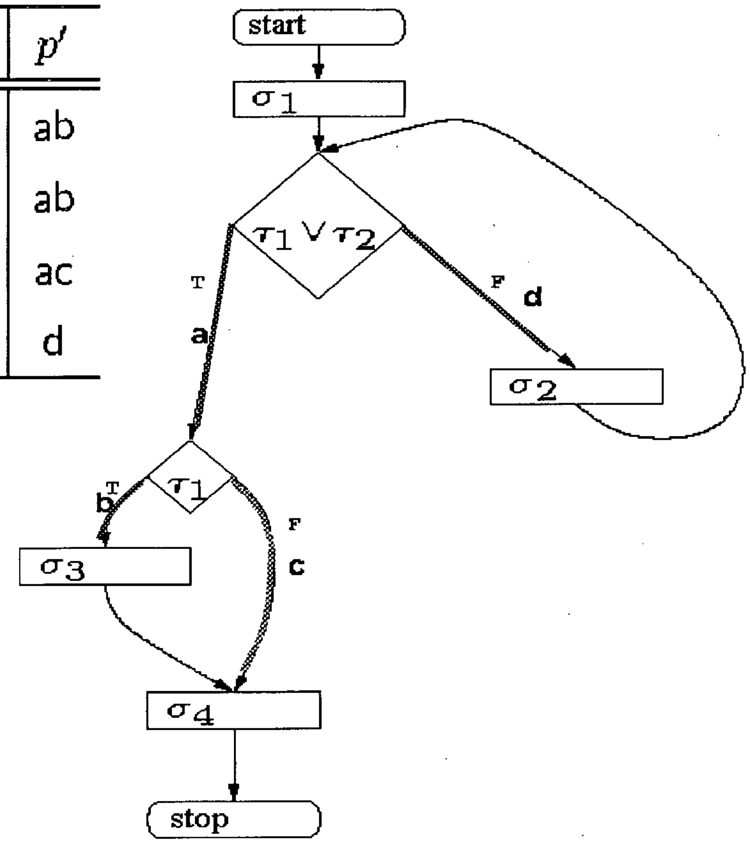
$$\sigma_1(\tau_{1F}\tau_{2F}\sigma_2)^*(\tau_{1T}\sigma_3 \mid \tau_{1F}\tau_{2T})\sigma_4$$

is not in *R*.

Diagrammatically



τ_1	τ_2	p	p'
T	T	1	ab
T	F	1	ab
F	T	23	ac
F	F	24	d



This does not preserve (strict) path equivalence

Connection

This means that branch coverage of the transformed program corresponds to branch coverage for the original

So here we do not need to co-transform the adequacy criterion but new concepts of equivalence and new transformations

Conjecture:
In theory, we **never** need to co-transform the adequacy criterion

Disposable Transformations

We generate test data using the transformed program

because it is easier

… then **throw away the transformed program**

Transformation as a **means to an end** not an end in itself

Do the transformations even need to **preserve meaning?**

Conclusion

Test data generation is hard

…anything which helps is good

Test data generation can be impeded by structure

... so **transform the structure**

To avoid throwing baby out with bath-water

... also **transform adequacy criterion**

This allows the **application of transformation to testability**

... and the **generation of new transformations**

Future Work

Other non-meaning preserving transformation

- Transformation as a **means to an end**
  - Would like **branch coverage preserving** transformation
  - Variable dependence preserving too
  - Other Preserving?

Implementation

- flags - some results
- side effects - done but no results
- restructuring - to do

Testability Transformation Conjecture: post transform to preserve adequacy?