Graph Coverage Criteria

CS 4501 / 6501
Software Testing

[Ammann and Offutt, “Introduction to Software Testing,” Ch. 7]
Structures for Criteria-Based Testing

Four structures for modeling software

- **Input space**
  - **Graph**
    - Source
    - Design
    - Specs
    - Use cases
  - Applied to: ---R

- **Logic**
  - Source
  - Specs
  - FSMs
  - DNF
  - Applied to: RI-R

- **Syntax**
  - Source
  - Models
  - Integration
  - Inputs
  - Applied to: RIPR

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Today’s Objectives

• Understand the concepts of simple paths and prime paths

• Understand how to use graph to define criteria and design tests
  • Complete Path Coverage (CPC)
  • Prime Path Coverage (PPC)

• Touring, sidetrips, and detours

• Dealing with infeasible test requirements
Complete Path Coverage (CPC)

CPC: TR contains all paths in G

Node $N = \{1, 2, 3, 4, 5, 6, 7\}$

Edge $E = \{(1,2), (1,3), (2,3), (3,4), (3,5), (4,7), (5,7)\}$

List all test paths:
- Test path $p1 = [1, 2, 3, 4, 7]$
- Test path $p2 = [1, 2, 3, 5, 7]$
- Test path $p3 = [1, 3, 4, 7]$
- Test path $p4 = [1, 3, 5, 7]$
CPC: Graph with Loop

Node $N = \{1, 2, 3, 4, 5, 6, 7\}$

Edge $E = \{(1,2), (1,3), (2,3), (3,4), (3,5), (4,7), (5,7), (5,6), (6,5)\}$

List all test paths:

- $[1, 2, 3, 4, 7]$, $[1, 2, 3, 5, 7]$, $[1, 3, 4, 7]$, $[1, 3, 5, 7]$, $[1, 2, 3, 5, 6, 5, 7]$, $[1, 2, 3, 5, 6, 5, 6, 5, 7]$, $[1, 2, 3, 5, 6, 5, 6, 5, 6, 5, 7]$, ...

Impossible if a graph has a loop
$\approx$ infinite number of paths
$\approx$ infinite number of test requirements
Handling Loops in Graphs

Attempts to deal with loops:

- 1970s: Execute cycles once ([5, 6, 5] in previous example)
- 1980s: Execute each loop, exactly once
- 1990s: Execute loops 0 times, once, more than once
- 2000s: Prime paths (touring, sidetrips, and detours)
Simple Paths

Path from node \( n_i \) to \( n_j \) that is no internal loops

- A loop is a simple path

List simple paths: 31 simple paths

\[
[1,2,3,4,7], [1,2,3,5,7], [1,2,3,5,6],
[1,2,3,4], [1,2,3,5],
[1,3,4,7], [1,3,5,7], [1,3,5,6],
[2,3,4,7], [2,3,5,7], [2,3,5,6],
[1,2,3], [1,3,4], [1,3,5],
[2,3,4], [2,3,5],
[3,4,7], [3,5,7], [3,5,6],
[5,6,5],
[6,5,6], [6,5,7],
\]

Subpaths of other simple paths ⇒ avoid these

[1,2], [1,3], [2,3], [3,4], [3,5],
[4,7], [5,7], [5,6], [6,5]
Prime Paths

Simple path that is not subpath of any other simple path

List prime paths: 9 prime paths

- [1,2,3,4,7], [1,2,3,5,7], [1,2,3,5,6],
- [1,3,4,7], [1,3,5,7], [1,3,5,6],
- [5,6,5], [6,5,6], [6,5,7]

Execute loop 0 time

Execute loop once

Execute loop more than once
Prime Path Coverage (PPC)

- Keep the number of test requirements down
- For a given infeasible prime path that consists of some feasible simple paths, replace the infeasible prime path with relevant feasible subpaths

PPC: TR contains each prime path in graph G
Note on PPC

- PPC does not subsume EPC
- If a node $n$ has an edge to itself ("self edge"), EPC requires $[n, n, m]$ and $[m, n, n]$
- $[n, n, m]$ and $[m, n, n]$ are not simple paths (prime paths)

List EPC requirements:

$$TR = \{ [1,2,3], [1,2,2], [2,2,3], [2,2,2] \}$$

List PPC requirements:

$$TR = \{ [1,2,3], [2,2] \}$$
Touring, Sidetrips, and Detours

Touring the prime path \([1, 2, 3, 5, 6]\) without sidetrips or detours

Touring with a sidetrip

Touring with a detour

[AO, Figures 7.8, 7.9]
Infeasible Test Requirements

- An infeasible test requirement cannot be satisfied
  - Unreachable statement (dead code)
  - Subpath that can only be executed with a contradiction ($X > 0$ and $X < 0$)

- Most test criteria have some infeasible test requirements
- It is usually undecidable whether all test requirements are feasible
- When sidetrips are not allowed, many structural criteria have more infeasible test requirements
- Always allowing sidetrips weakens the test criteria

**Practical recommendation—Best Effort Touring**
- Satisfy as many test requirements as possible without sidetrips
- Allow sidetrips to try to satisfy remaining test requirements
Graph Coverage Criteria Subsumption

- Complete Path Coverage (CPC)
- Prime Path Coverage (PPC)

- Complete Round Trip Coverage (CRTC)
- Simple Round Trip Coverage (SRTC)

- Edge-Pair Coverage (EPC)
- Edge Coverage (EC)
- Node Coverage (NC)

- All-DU-Paths Coverage (ADUP)
  - All-uses Coverage (AUC)
  - All-defs Coverage (ADC)

- Graph Coverage Criteria

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