WELCOME TO
SOFTWARE ENGINEERING TESTING!

(DARK MODE)

Lecture 3: Graphs I

We will be discussing:

- Graph and testing terminology... a lot of it
- Structural Coverage for Graphs

We'll get started shortly after 10am to give folks a chance to join.

Curtin University

LECTURE 3: GRAPHS (PART 1)

Software Engineering Testing (CMPE3008/CMPE4001/CMPE5000)

Created by Arlen Brower

OUTCOMES

You should be able to do the following:

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- Create control flow graphs from source code

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  - All-DU-Paths, All-Uses, All-defs coverage
- Identify test paths for the above

DEFINITION OF A GRAPH

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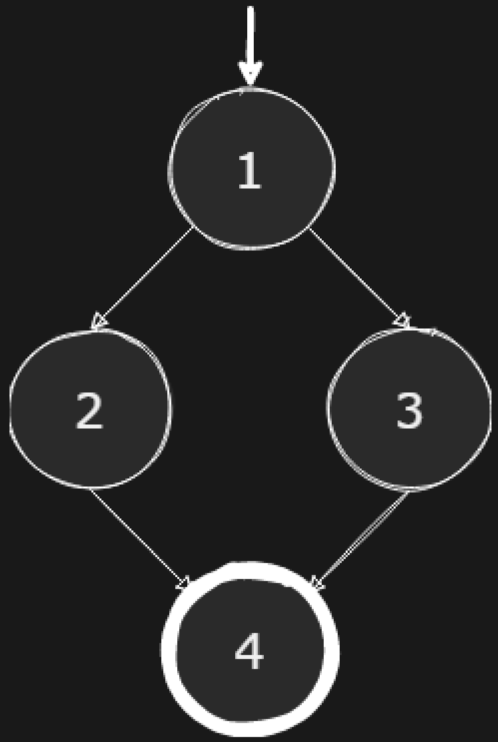
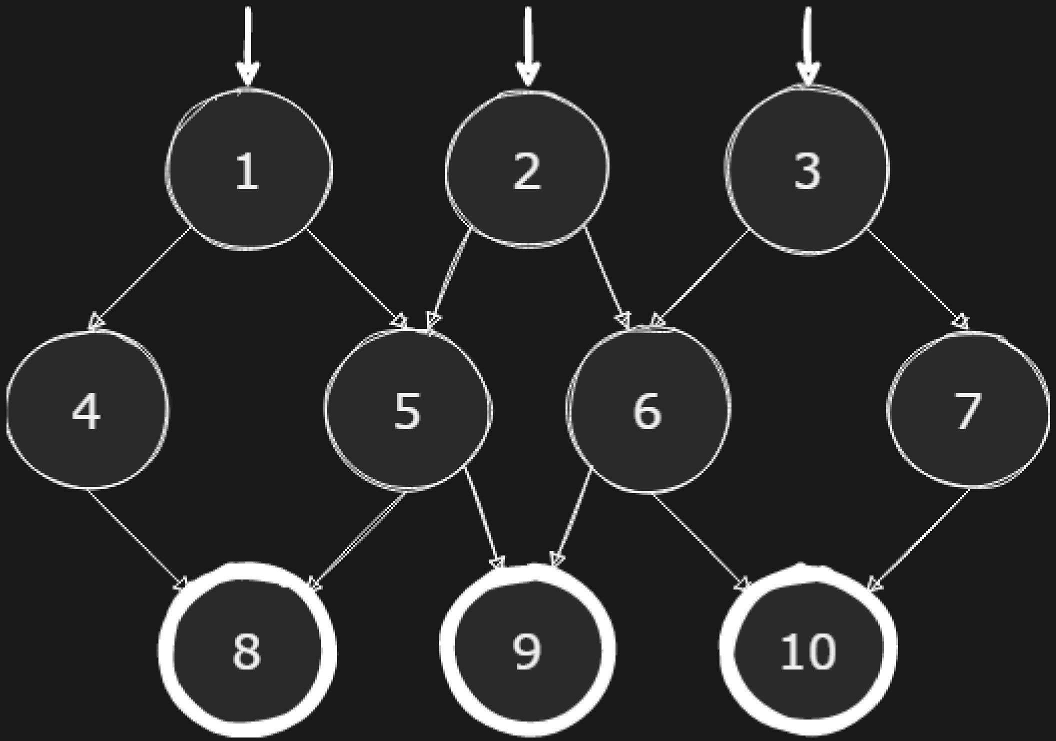
These sets must not be empty.


1
2
3
4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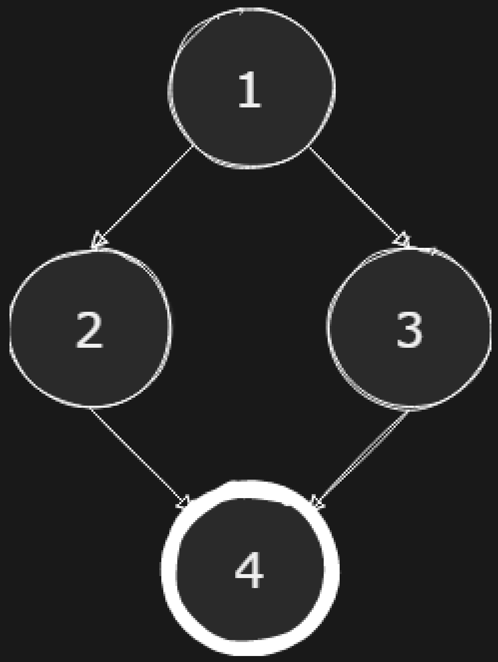
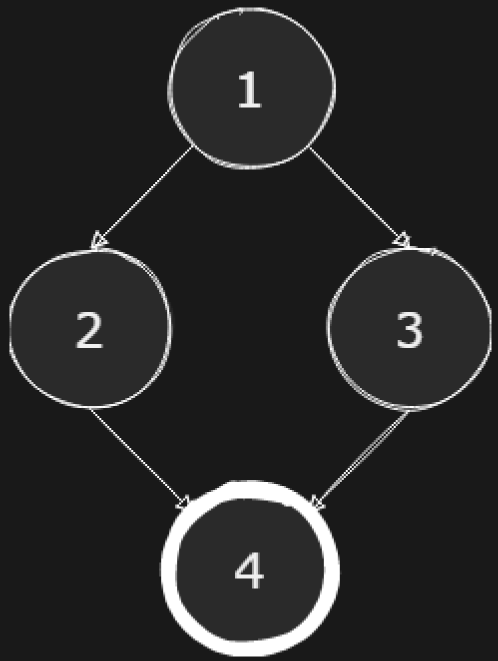
10

NOT A VALID GRAPH



Why?

NOT A VALID GRAPH



Why?

$$N_0 = \{\}$$

GRAPH TERMINOLOGY

GRAPH TERMINOLOGY

- Path: A sequence of nodes
- Length: The number of edges in a path
- Subpath: A path that makes up part of a larger path

GRAPH TERMINOLOGY

- Test Path: A path that starts at an initial node and ends at a final node

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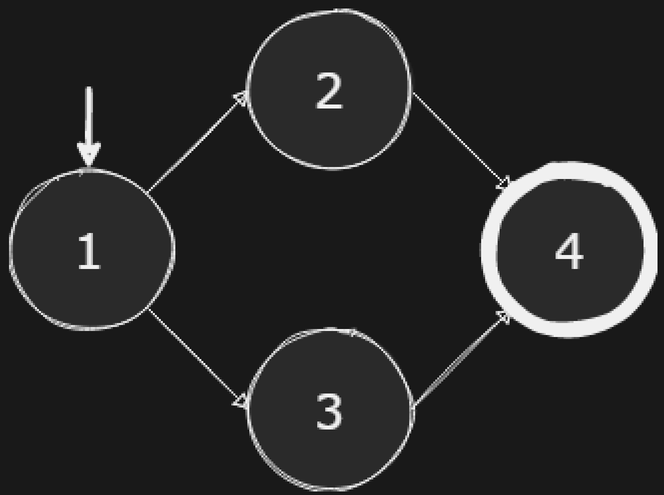

GRAPH TERMINOLOGY

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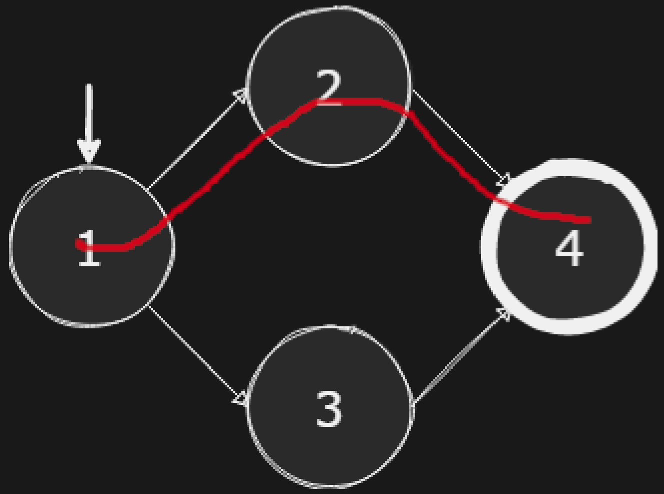
- (1,2,4) is a valid test path.



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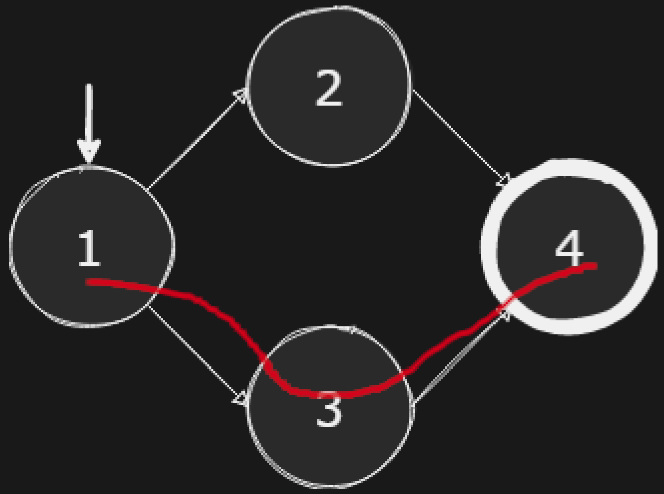

GRAPH TERMINOLOGY

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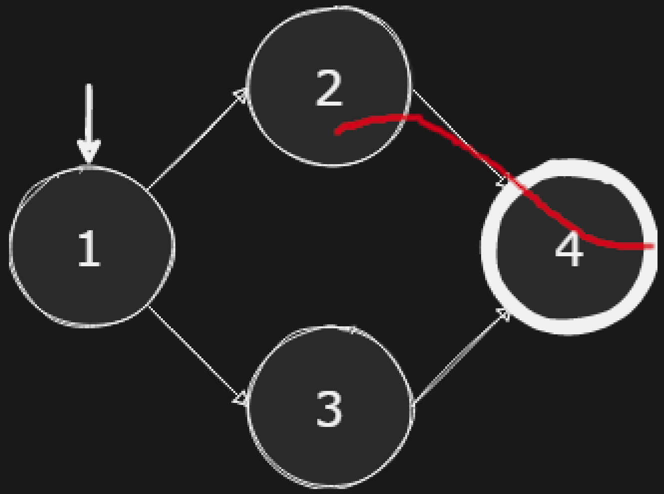
- (2,4) is NOT a valid test path.



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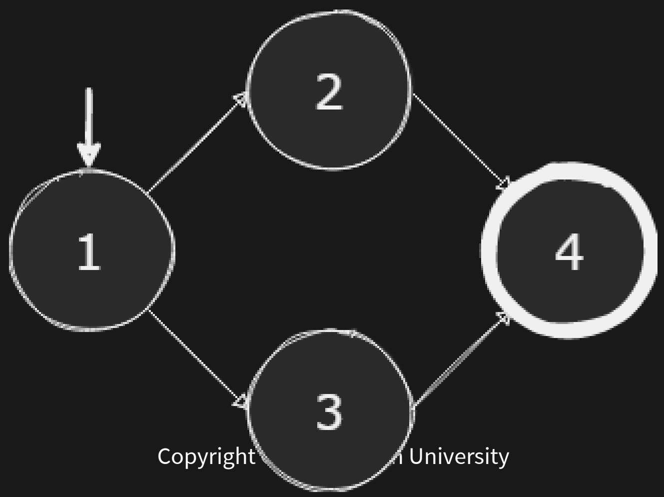
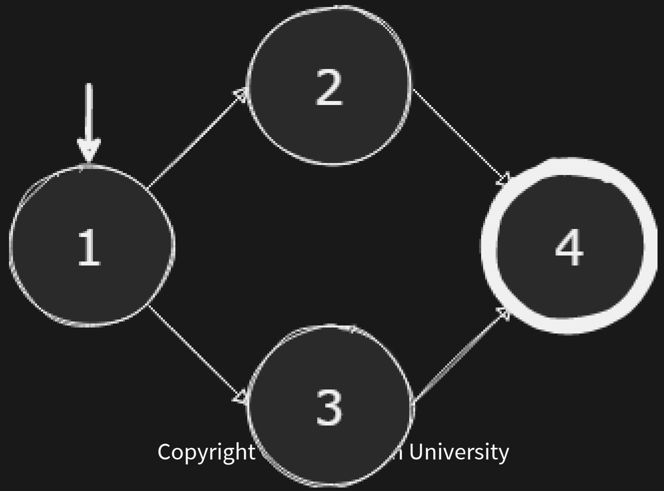
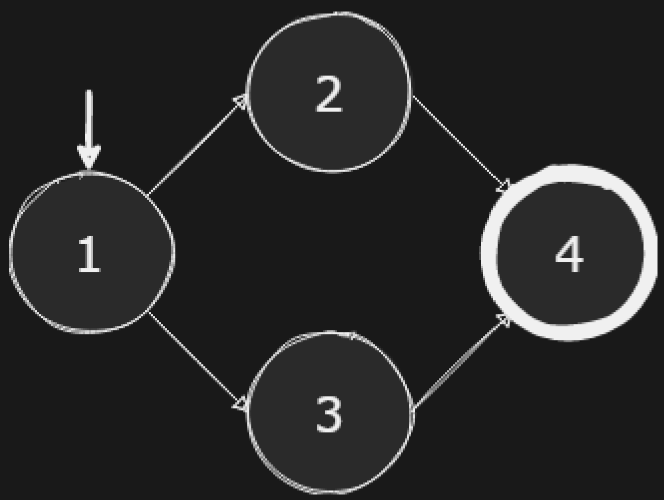


GRAPH TERMINOLOGY

- <u>Test Path</u>: A path that starts at an initial node and ends at a final node
- Whenever you execute your code, it will run through a test path.
- A single test path may satisfy multiple test requirements.

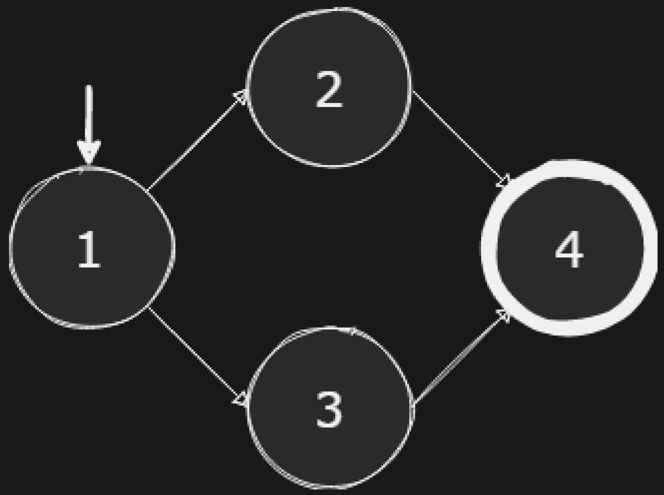


GRAPH TERMINOLOGY



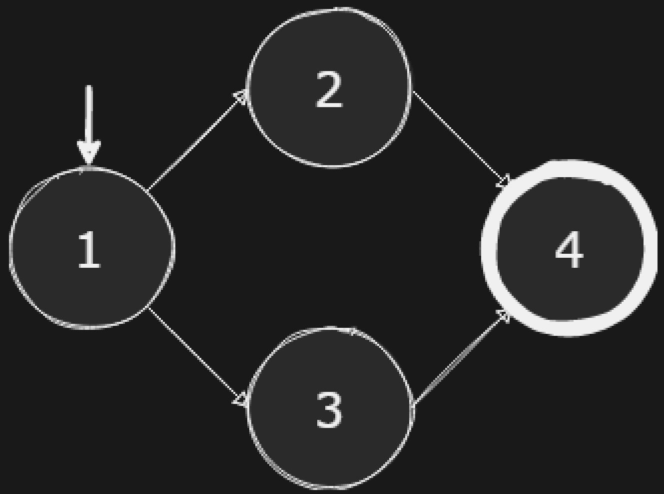
GRAPH TERMINOLOGY

- Visit: If node/edge N exists in a test path, that test visits that node/edge



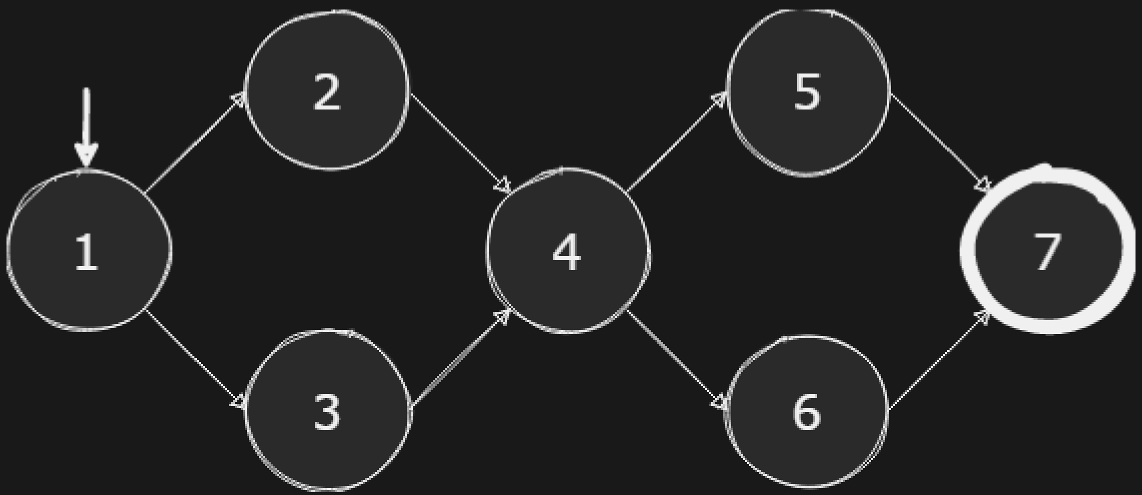
GRAPH TERMINOLOGY

- Visit: If node/edge N exists in a test path, that test visits that node/edge
- Tour:A subpath that is part of a test path is toured by that test path.



GRAPH TERMINOLOGY

Test Path [1,2,4,5,7]



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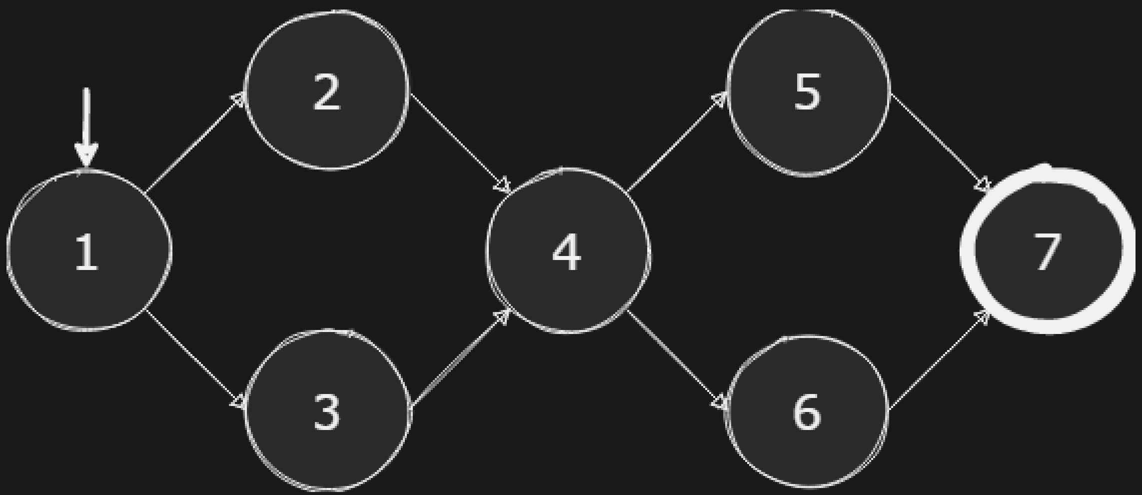

GRAPH TERMINOLOGY

Test Path [1,2,4,5,7]

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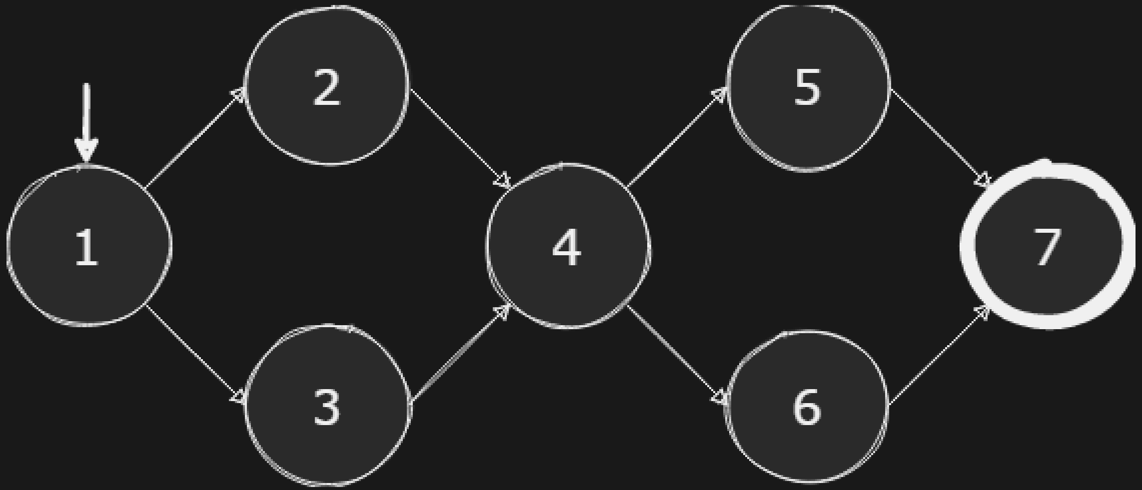
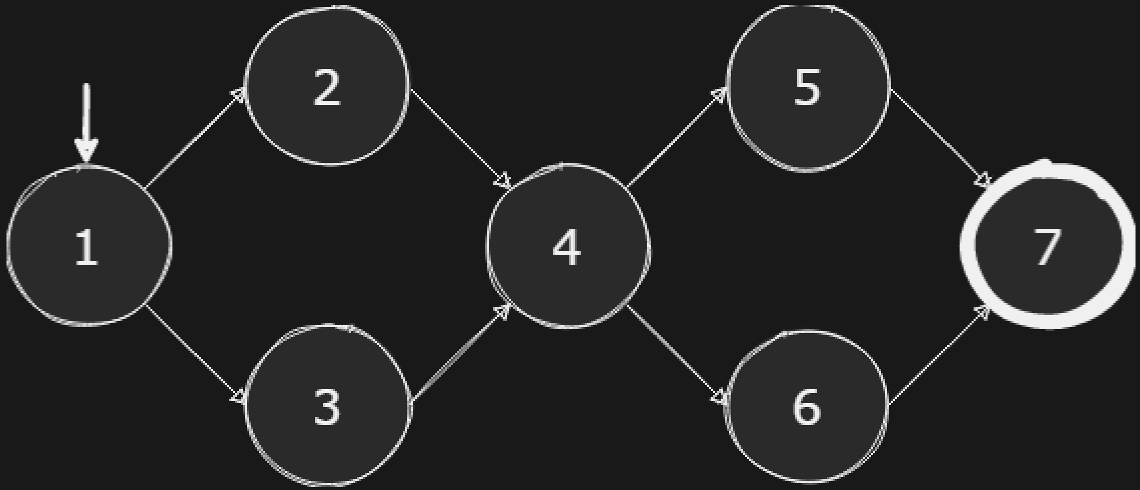
- Visits edges (1,2) (2,4) (4,5) (5,7)



GRAPH TERMINOLOGY

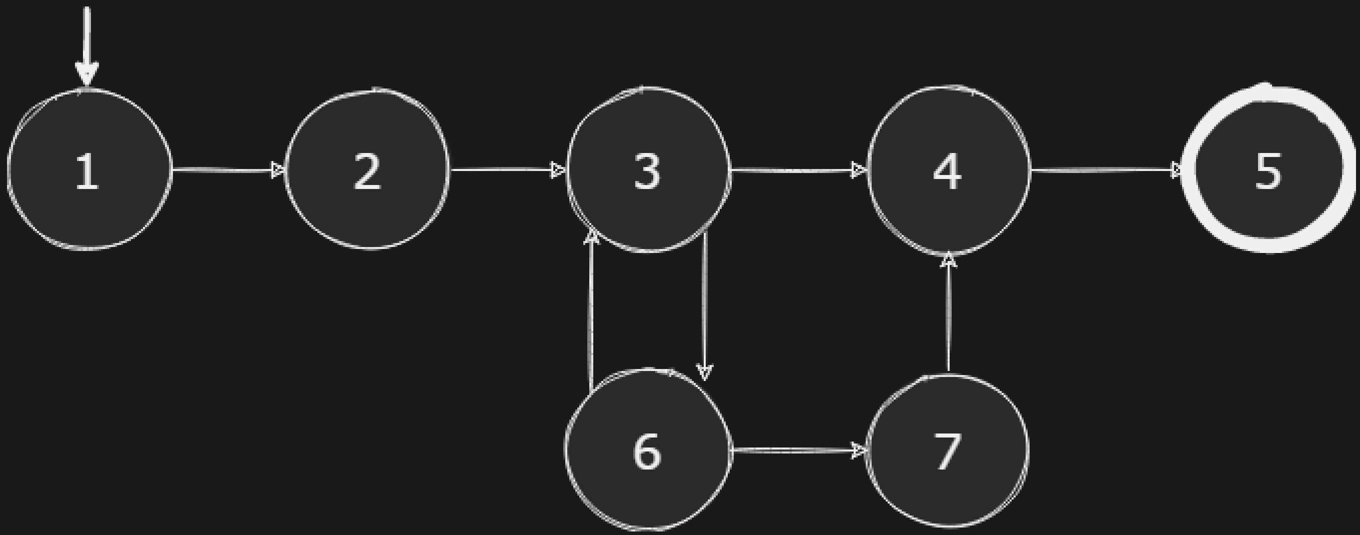
Test Path [1,2,4,5,7]

- Visits nodes 1,2,4,5,7
- Visits edges (1,2) (2,4) (4,5) (5,7)
- Tours subpaths (1,2,4) (2,4,5) (2,4,5,7)



TOURING, SIDE-TRIPS, DETOURS

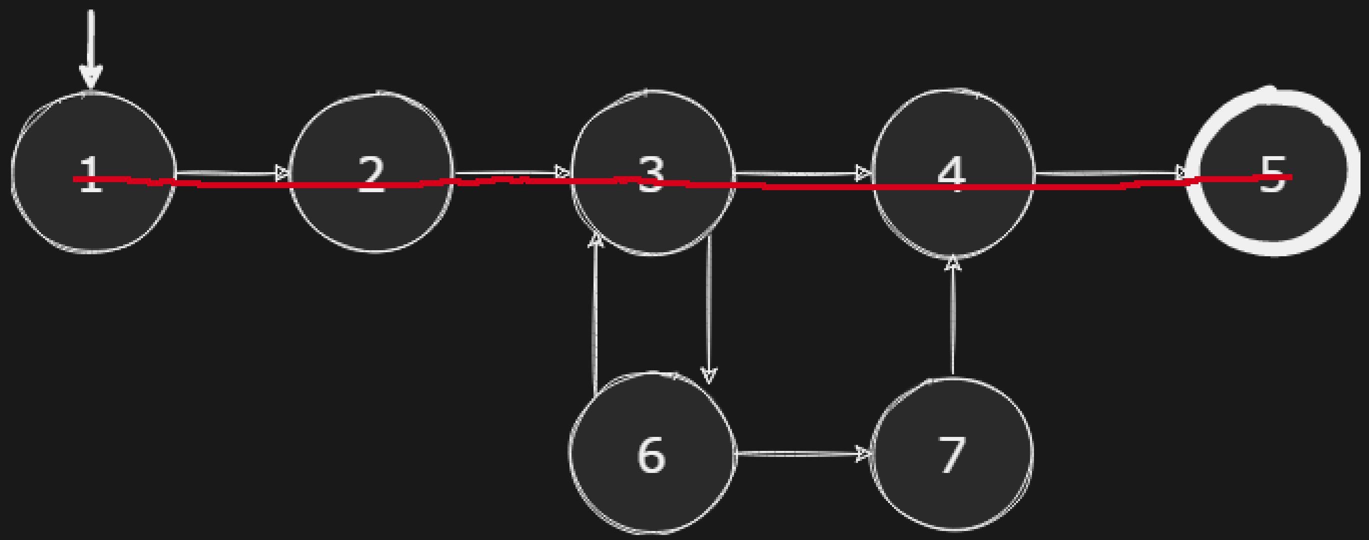
Let's say we have a test requirement: [1,2,3,4,5]



TOURING, SIDE-TRIPS, DETOURS

Test Requirement [1,2,3,4,5]

If our test path was also [1,2,3,4,5], it <u>tours</u> our requirement.



TOURING, SIDE-TRIPS, DETOURS

Test Requirement [1,2,3,4,5]

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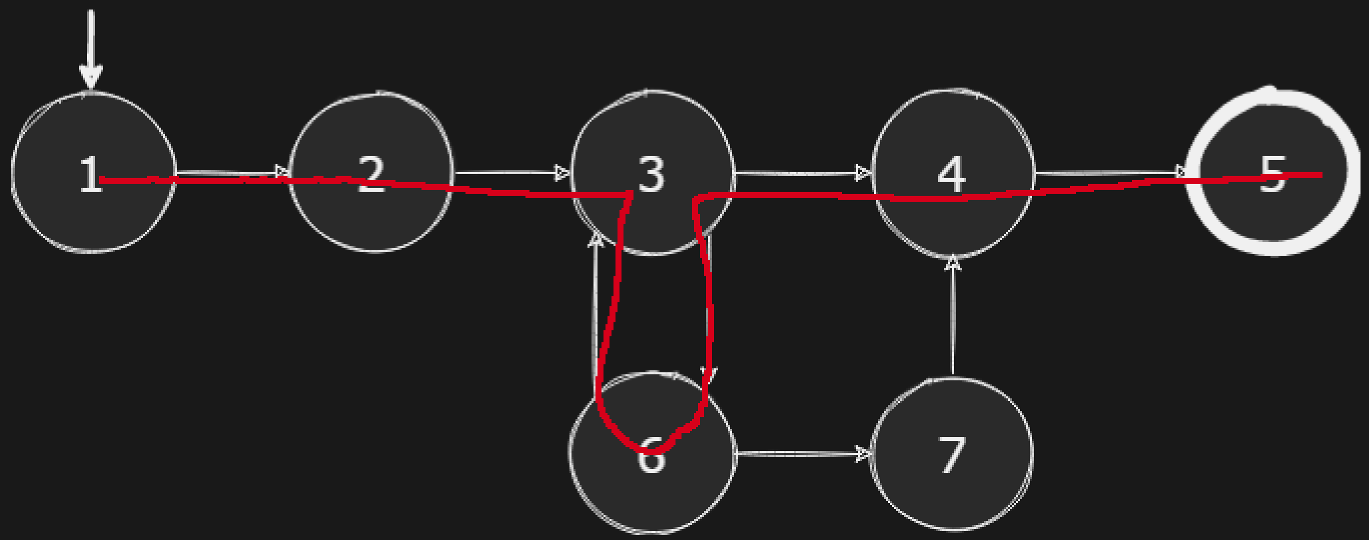

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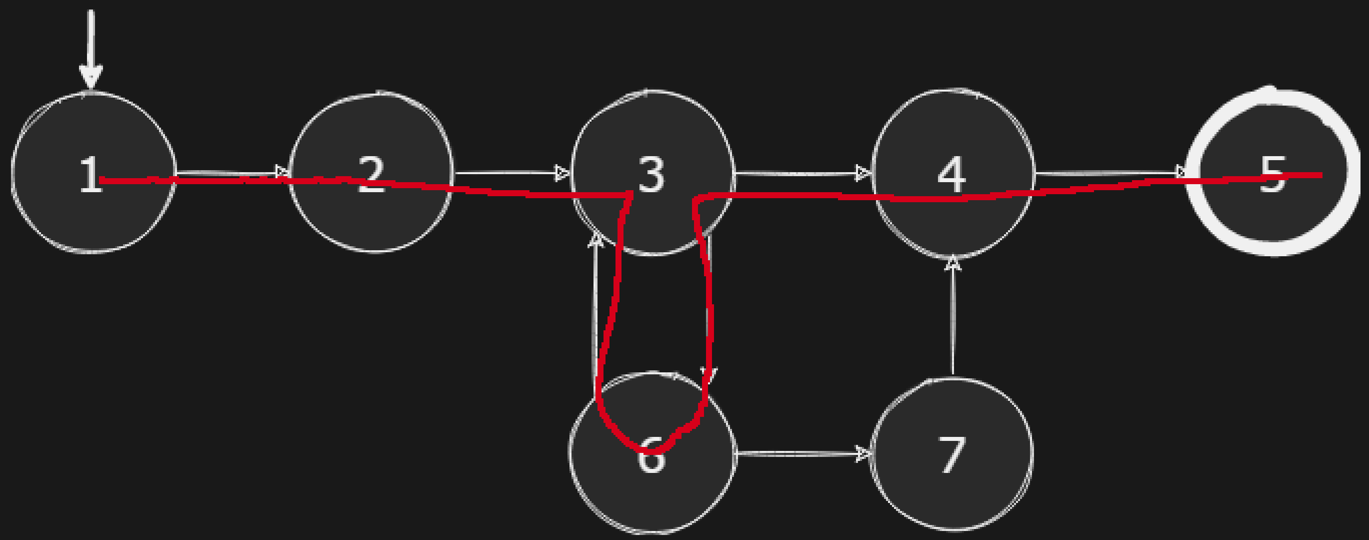

TOURING, SIDE-TRIPS, DETOURS

Test Requirement [1,2,3,4,5]

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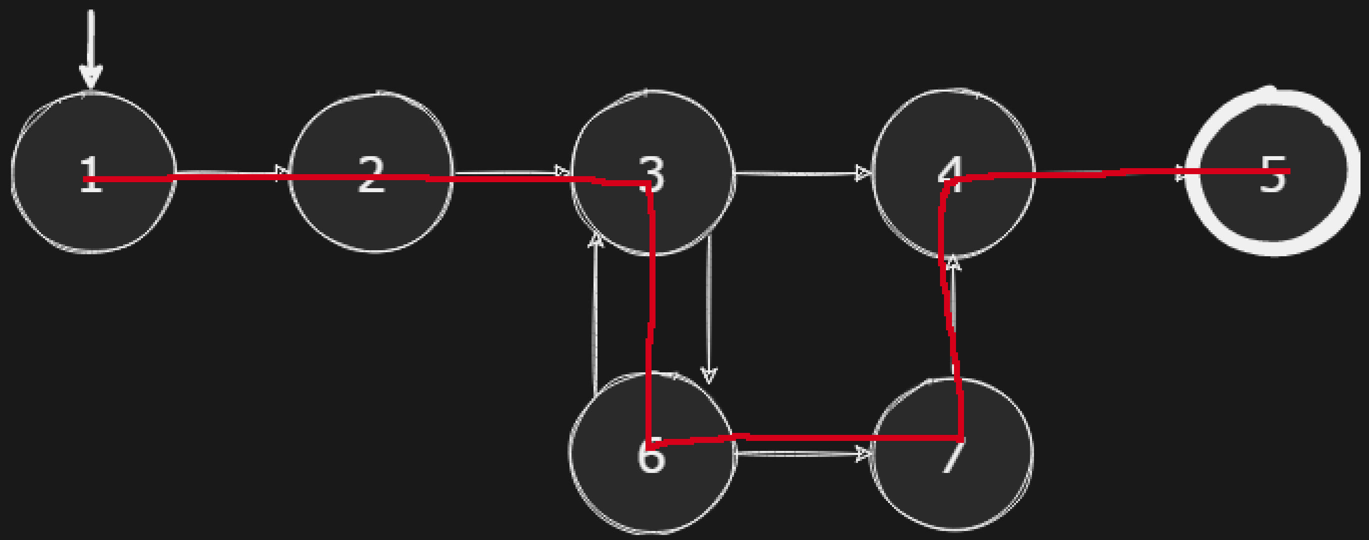

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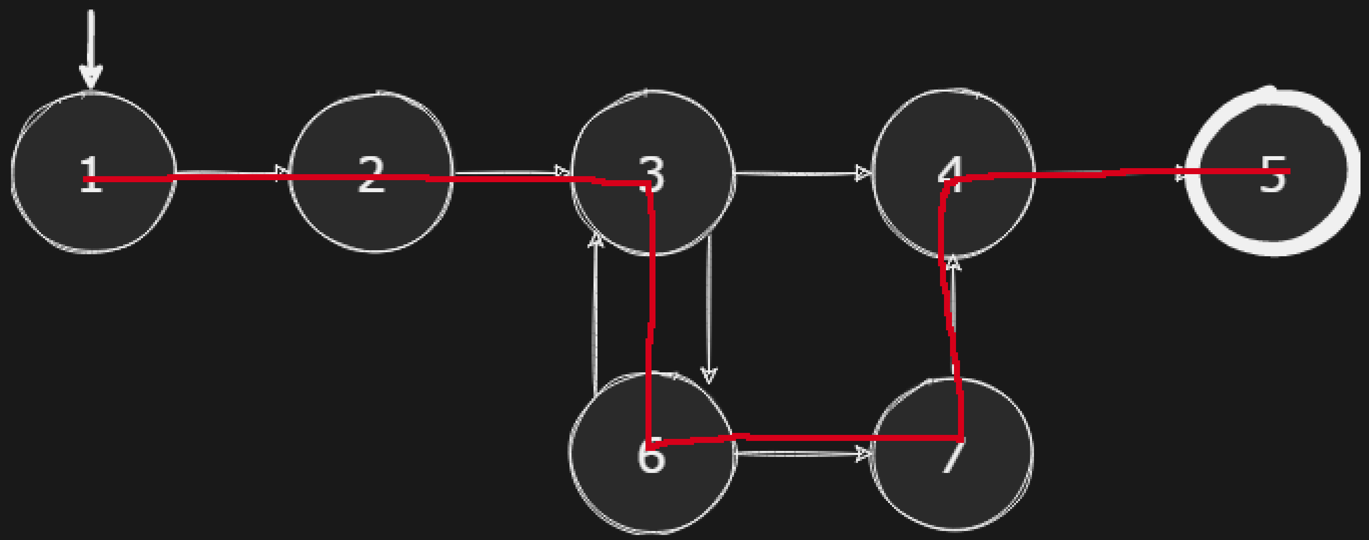

MORE GRAPH TERMINOLOGY

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- Upper case (i.e. 'T') denotes an entire set.

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- Path (t): A test path executed by test t
- Path (T): The set of test paths executed by test set T
- Each test executes one and only one test path

SOME TESTING TERMINOLOGY

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- Test Criterion: The rules by which we design our tests

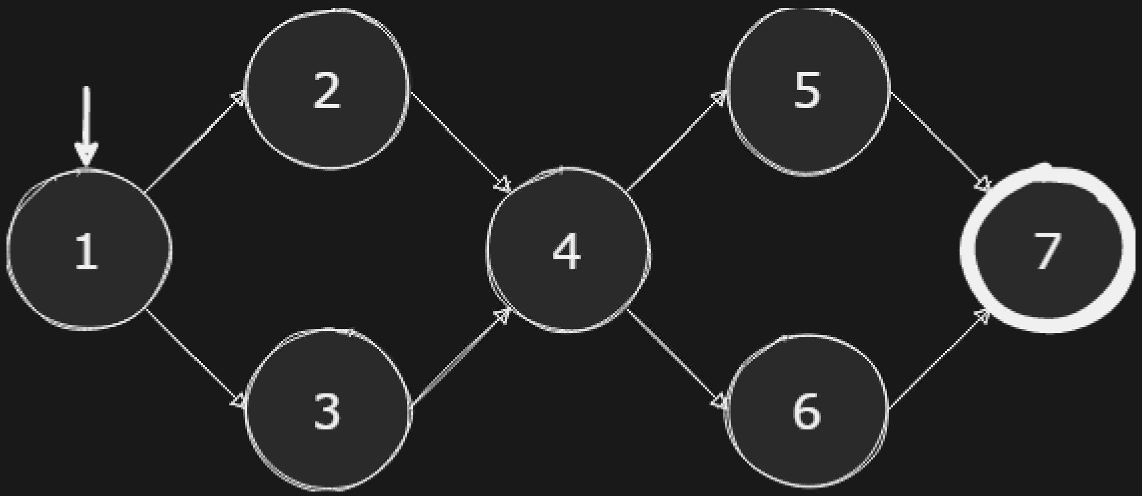
SOME TESTING TERMINOLOGY

- Test Criterion: The rules by which we design our tests
- Test Requirements (TR): A set of paths that test paths should ideally cover, based on a criterion

SOME TESTING TERMINOLOGY

Let's consider a simple criterion:

- Test Criterion: Node Coverage
- Test Requirements: [1],[2],[3],[4],[5],[6],[7]



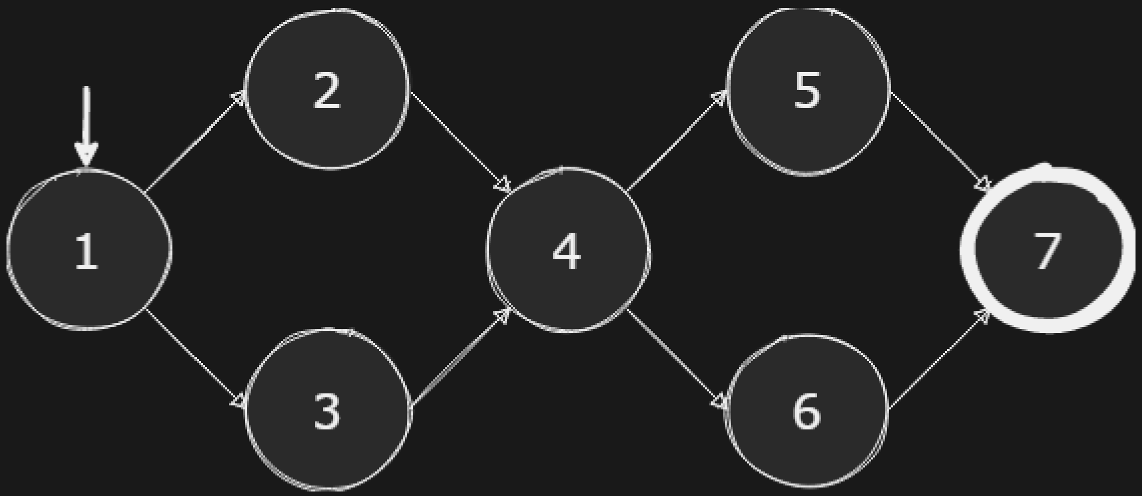
SOME TESTING TERMINOLOGY

Formal...

SOME TESTING TERMINOLOGY

Less formal

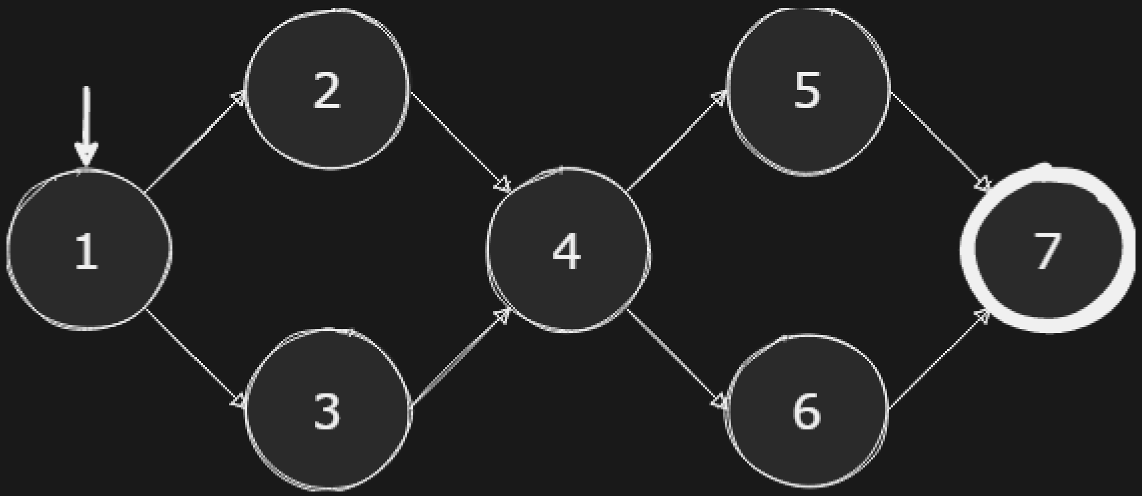
- Satisfaction: Make sure you have test paths that cover all the test requirements for a given criteria.



SOME TESTING TERMINOLOGY

Node Coverage Satisfaction

- Test Requirements: [1],[2],[3],[4],[5],[6],[7]
- Path(T): [1,2,4,6,7], [1,3,4,5,7]



TYPES OF CRITERION FOR GRAPHS

In general, we have two categories for Graph Coverage:

- Structural: criteria that investigate the structure of the graph and the paths
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Today we're looking at Structural Criteria.

NODE COVERAGE

Test set *T* satisfies node coverage on Graph G iff for every syntactically reachable node *n* in *N*, there is some path *p* in path*(T)* such that *p* visits *n*.

NODE COVERAGE

... Make sure that your Test Requirements contain all reachable nodes for a given graph.

EDGE COVERAGE

TR contains each reachable path of length up to 1, inclusive, in a given graph.

We say "up to 1" to account for graphs with only one node.

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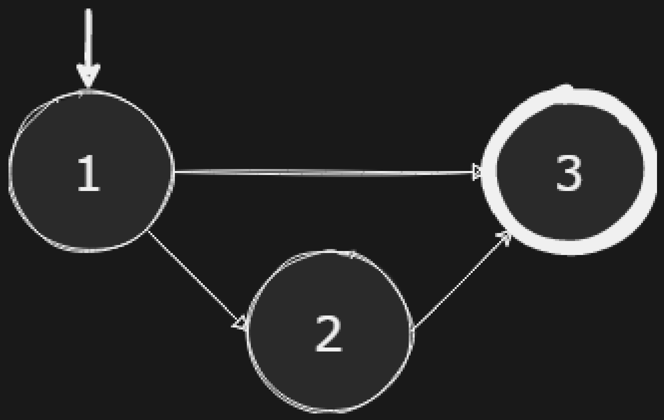
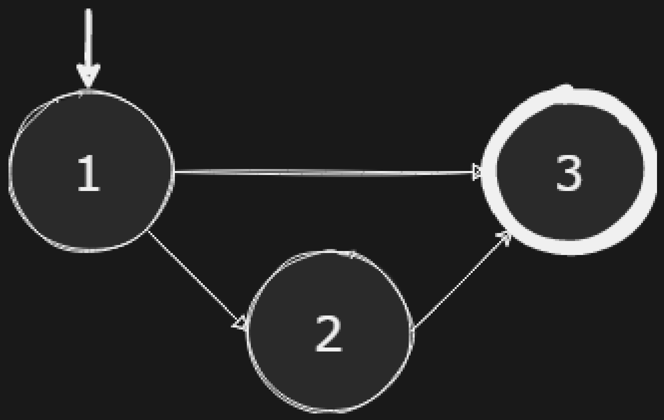


- TR: [1,3], [1,2], [2,3]
- Path(T): [1,3], [1,2,3]

EDGE-PAIR COVERAGE

TR contains each reachable path of length up to 2, inclusive, in G.



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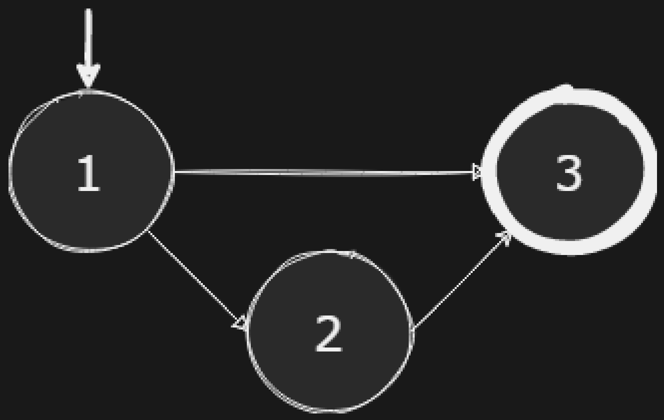

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COMPLETE PATH COVERAGE

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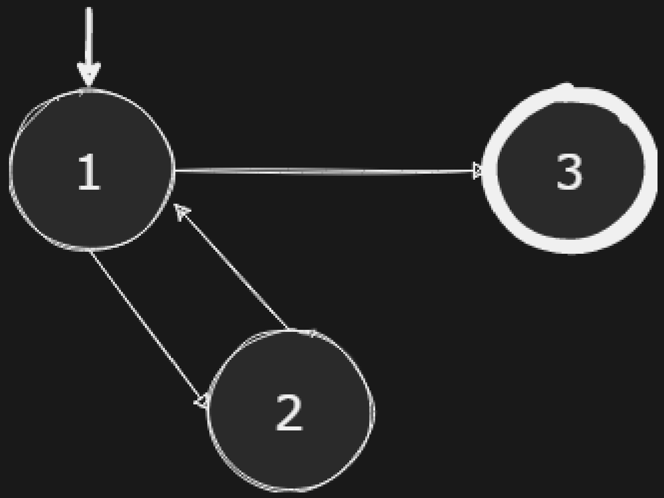

SPECIFIED PATH COVERAGE

TR contains a set S of test paths, where S is supplied as a parameter.

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- Unfortunately, this is very subjective.

SO... LOOPS.

How do we deal with them?

1. Specify a specific path? Not formal...
2. Go through each loop exactly once? More formal, but not so useful.
3. Go through a loop zero times, one time, more than once? Not formal...

SIMPLE PATHS & PRIME PATHS

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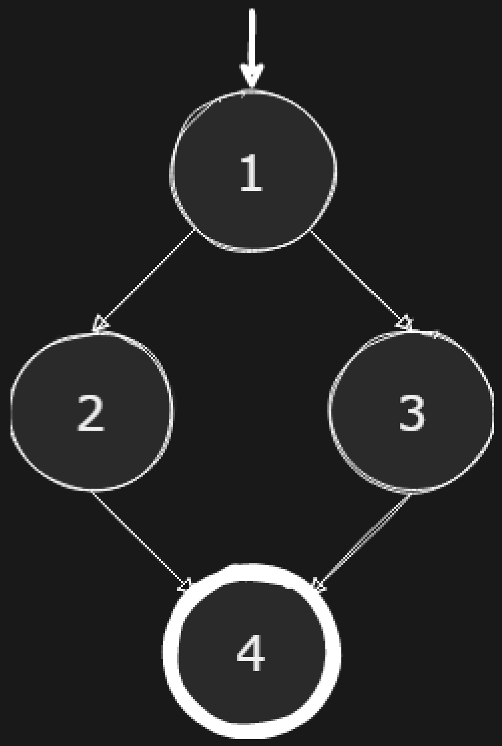
PRIME PATHS

An example...



- Prime Paths: [1,2,4], [1,3,4]

PRIME PATHS

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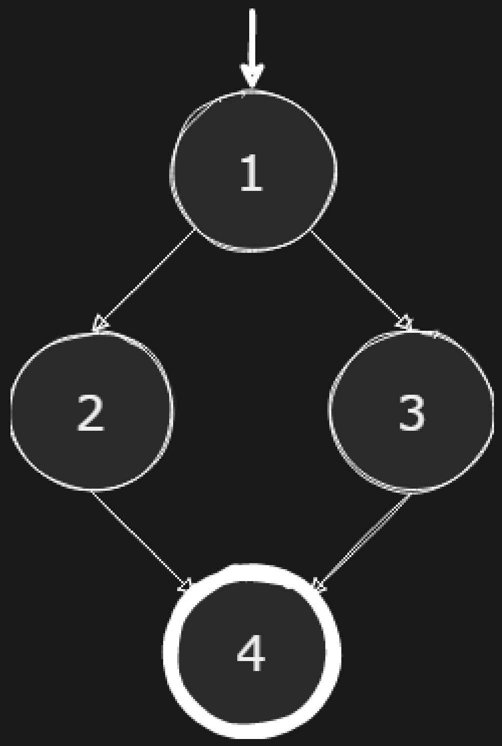
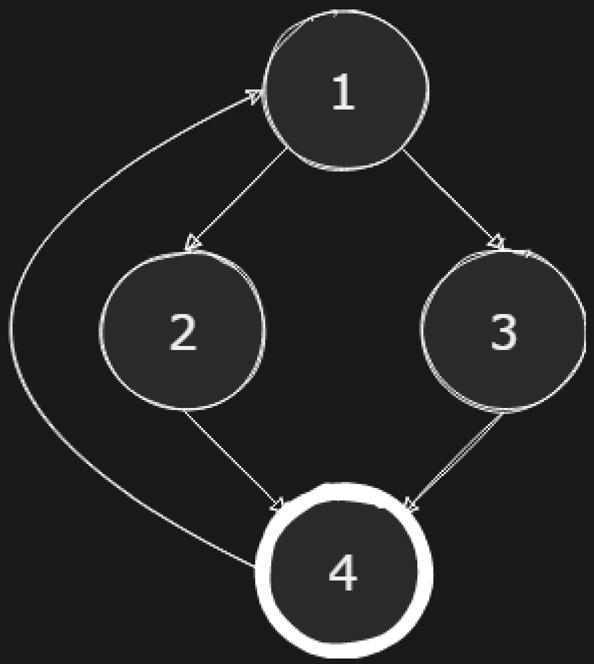


- Prime Paths: [1,2,4], [1,3,4]
- Not too bad, right?

PRIME PATHS

That wasn't even my final form!



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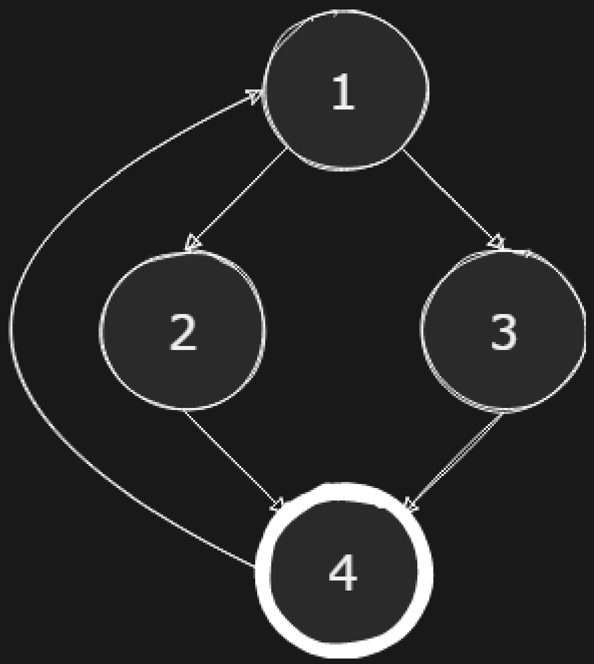

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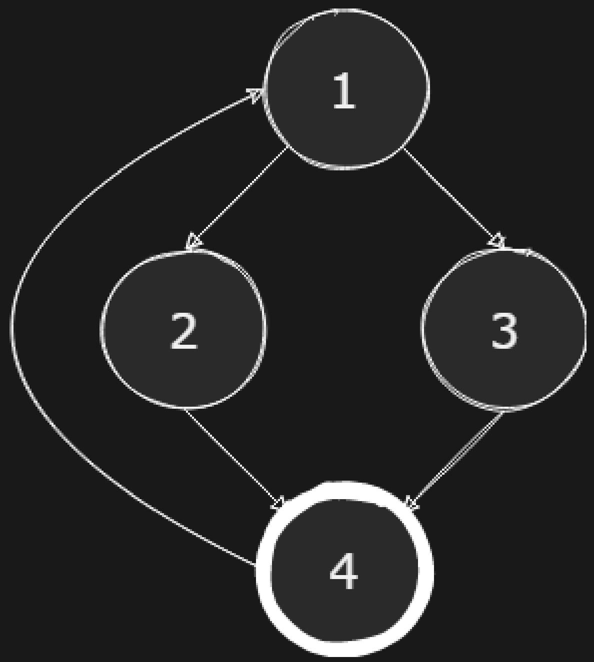

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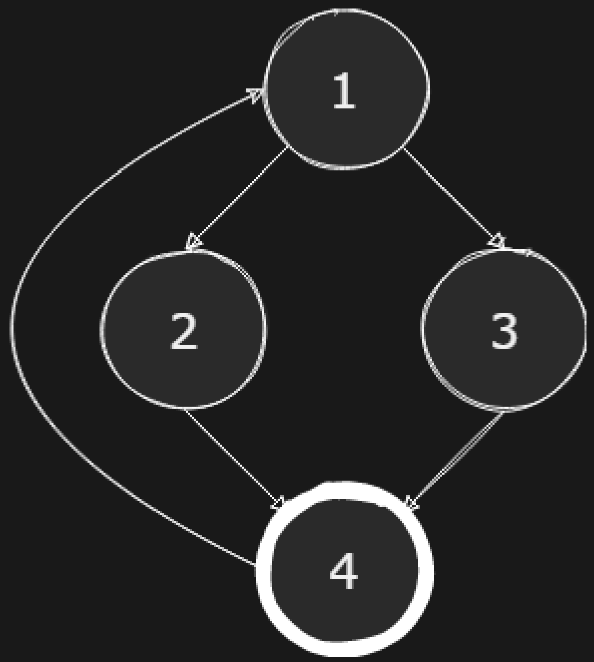

PRIME PATHS

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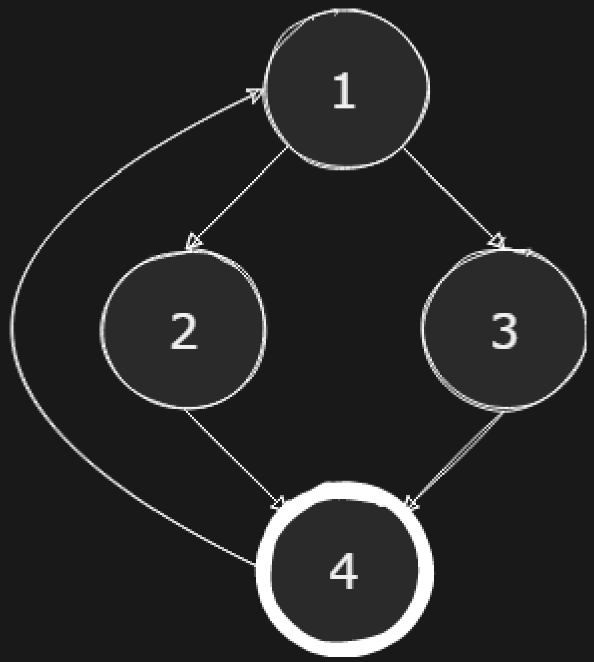
- Prime Paths: There are eight of them now.



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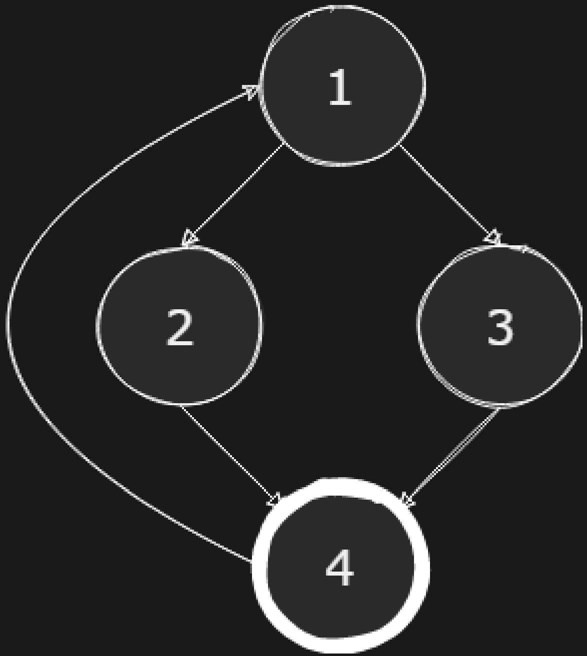

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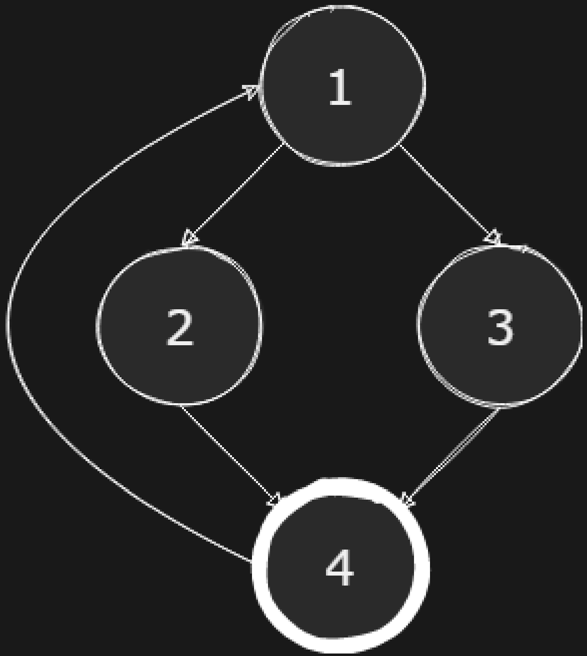
- Prime Paths: [1 2 4 1]



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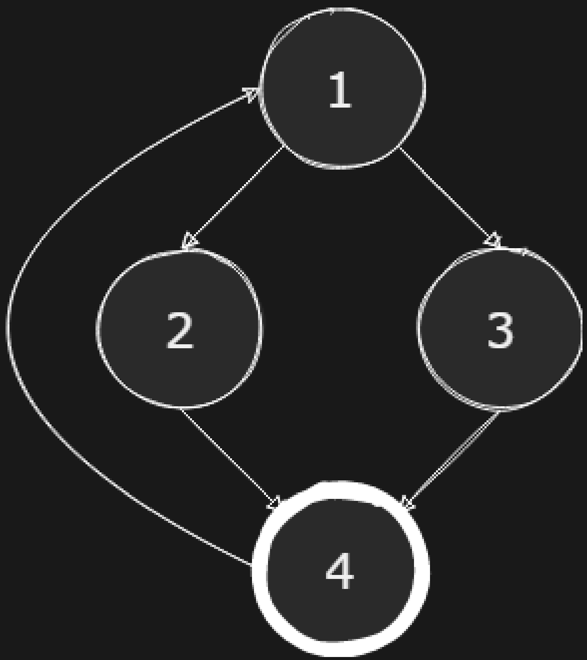

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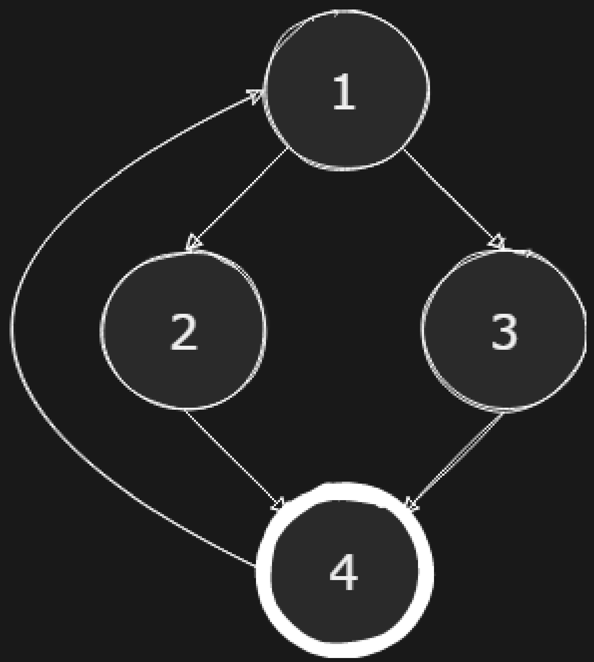
- Prime Paths: [1 2 4 1] [1 3 4 1] [2 4 1 2]



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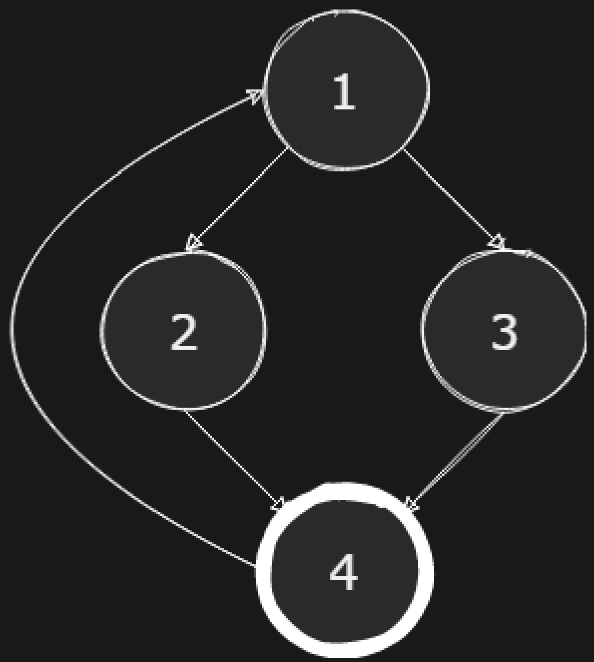

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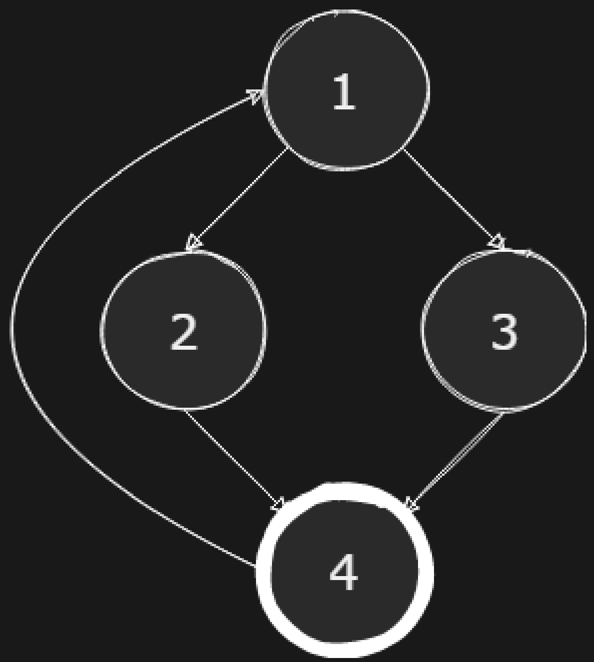

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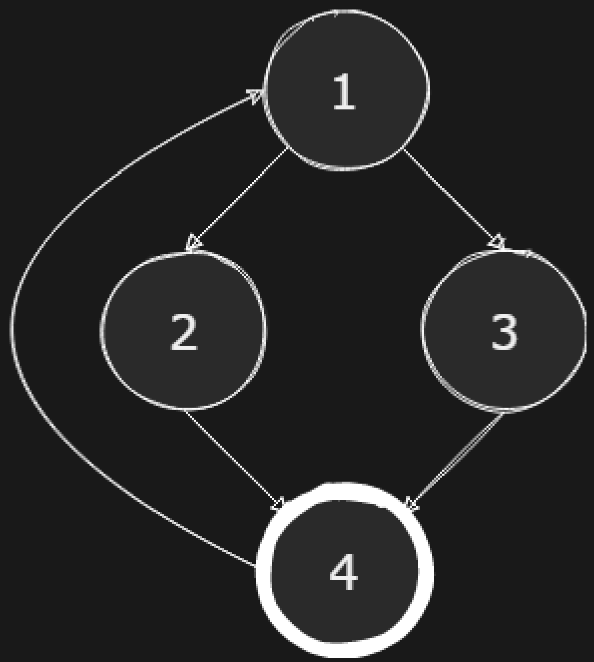

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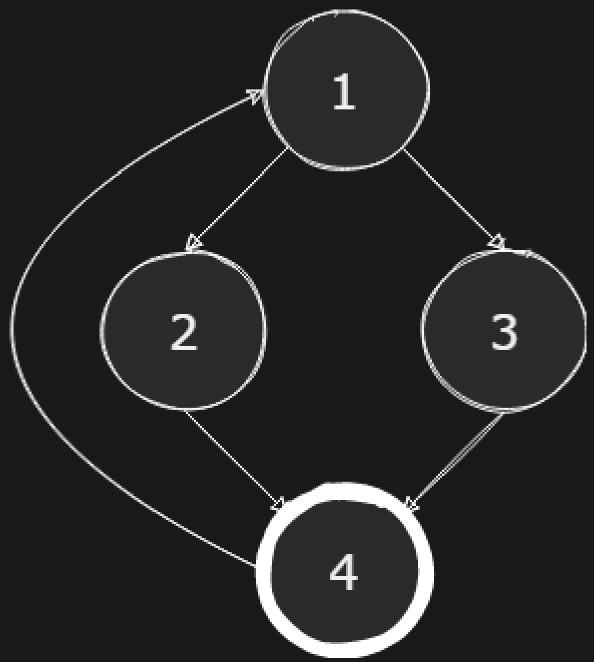

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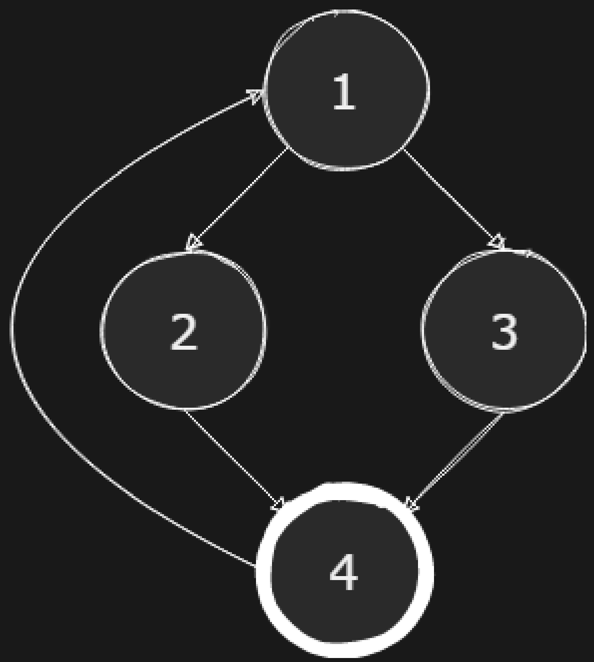

PRIME PATH COVERAGE

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- This actually subsumes node, edge, and edge-pair coverage.

ROUND TRIPS

A round trip is a prime path that starts and ends on the same node. We can define a few forms of coverage from these.

SIMPLE ROUND TRIP COVERAGE

TR contains at least one round-trip path for each reachable node in G that begins and ends a round-trip path.

COMPLETE ROUND TRIP COVERAGE

TR contains all round-trip paths for each reachable node in G

INFEASIBLE TEST REQUIREMENTS

Remember side trips and detours?

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- Some statements may simply be unreachable
- Some subpaths may rely on logical contradictions
- Worse still, it's undecidable whether all test requirements are feasible
- Allowing side trips (or even detours) may help this issue.

INFEASIBLE TEST REQUIREMENTS

Wherever possible, satisfy as many requirements directly. Failing that, allow side trips to satisfy test requirements that are otherwise infeasible.

UP NEXT...

That concludes structural coverage. Next week:

- Examples of Prime Paths!
- Data Flow Criteria
- Finite State Machines