Proposal of Execution Paths Indication Method for Integration Testing by Using an Automatic Visualization Tool 'Avis'

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Agenda

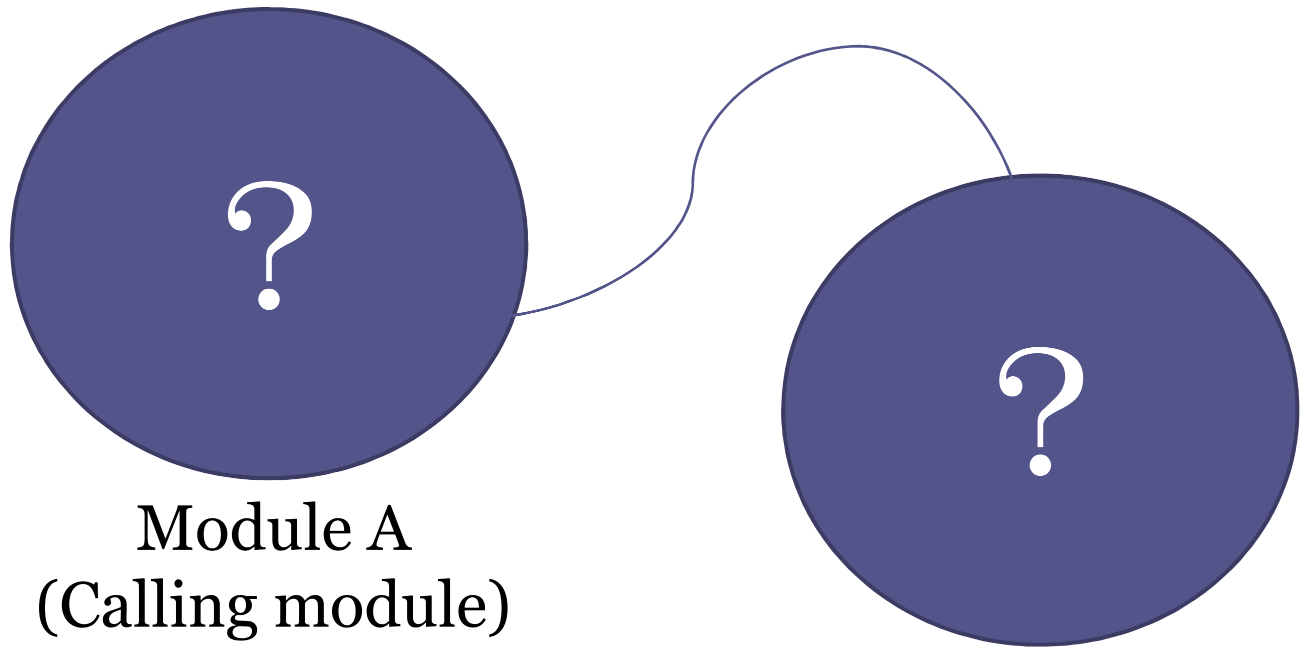
1. Background
2. Goal & Approach
3. Avis
4. Evaluation of Proposal method
5. Discussion
6. Conclusion & Future works

Background

- Integration Testing
  - A part of software testing process
  - Verification targets
    - Completeness of functionality
    - Data manipulation
    - Inter-module interfaces

Background

- Verification of inter-module interfaces by black-box testing.

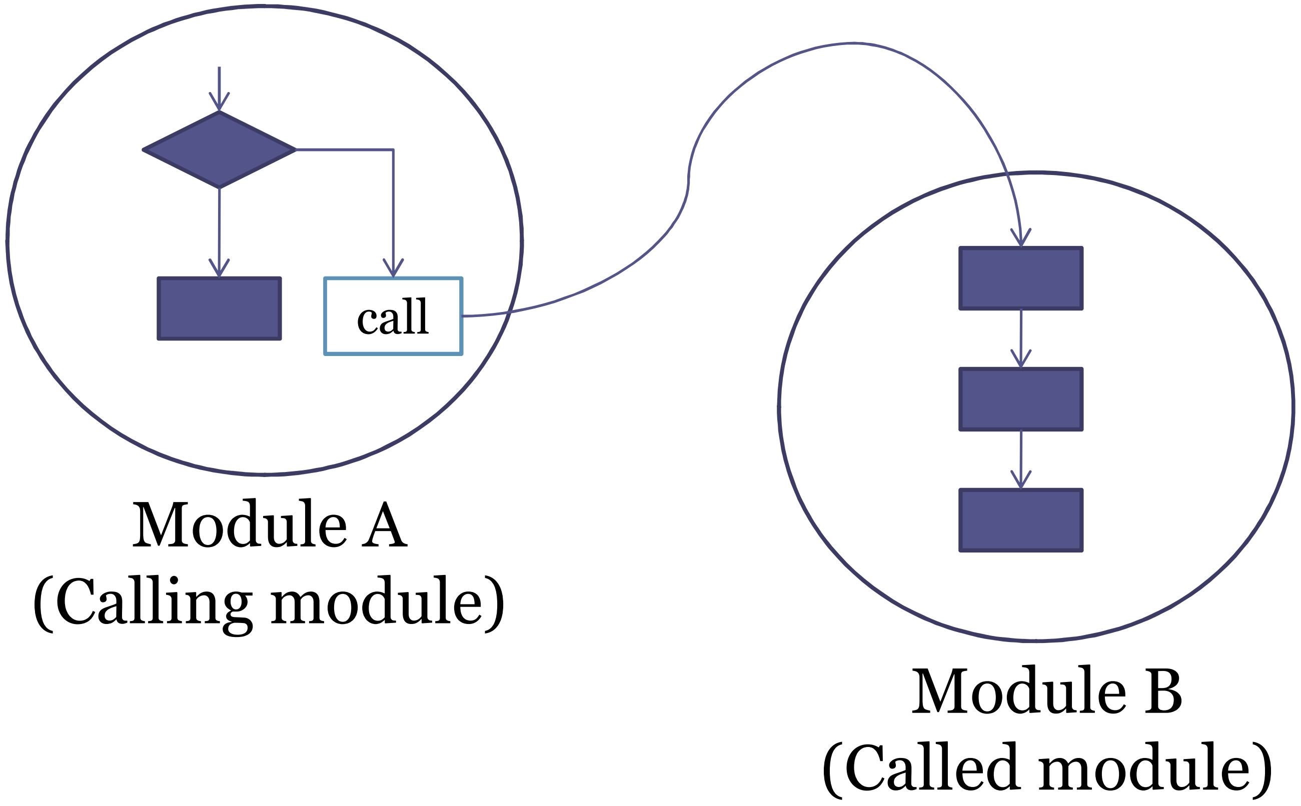


Module A
(Calling module)

Module B
(Called module)

Background

- Verification of inter-module interfaces by white-box testing.

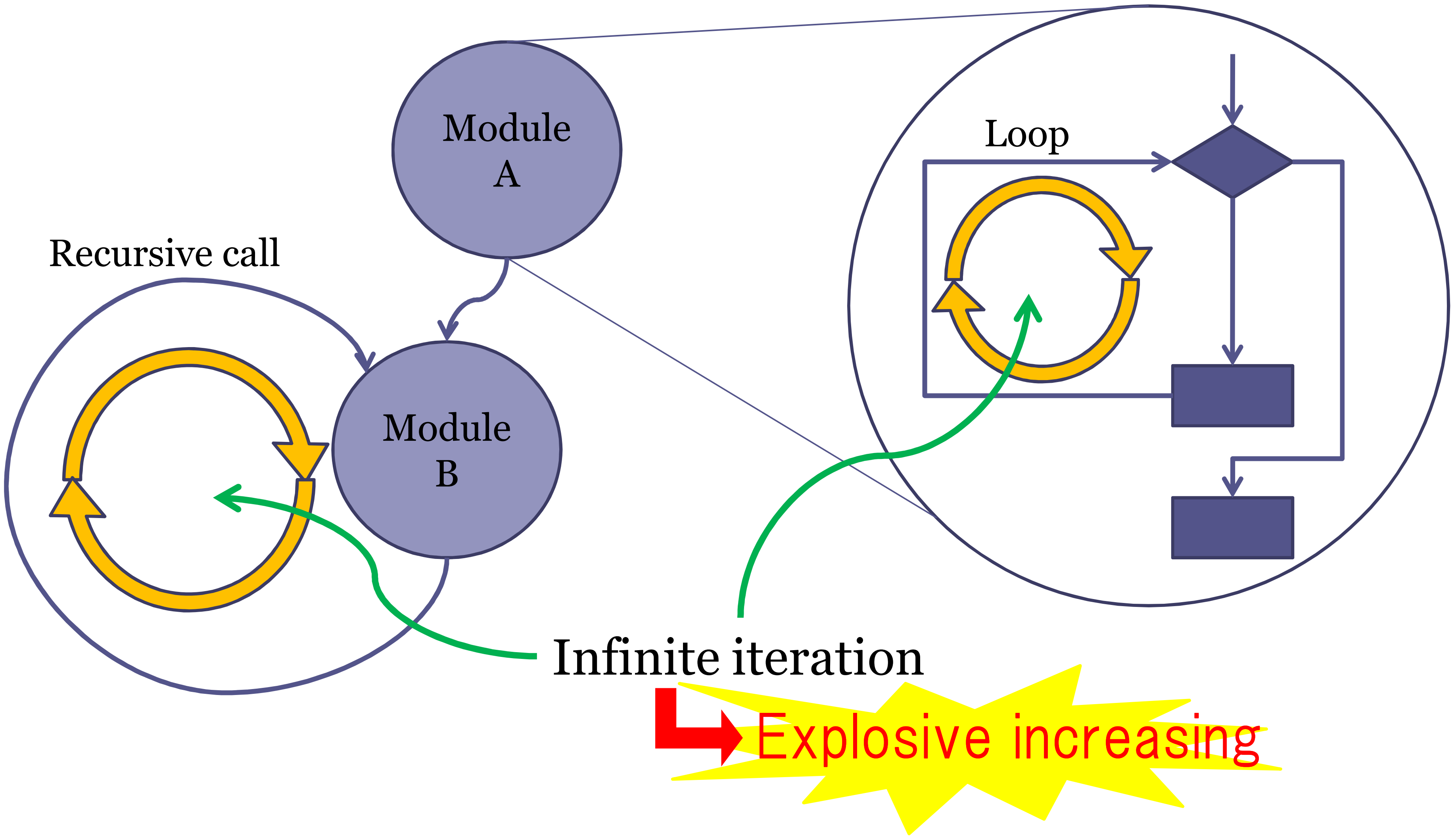


Background

- A problem of integration testing by white-box testing
  - Explosive increasing number of execution paths for covering all modules and call-pairs.

It is impossible to execute all paths.

Explosive increasing number of execution paths



Goal & Approach

- Goal

  Verification support of inter-module interfaces by white-box testing in integration testing

- Approach

  Indicate the minimum set of execution paths by using automatic visualization tool ‘Avis’.

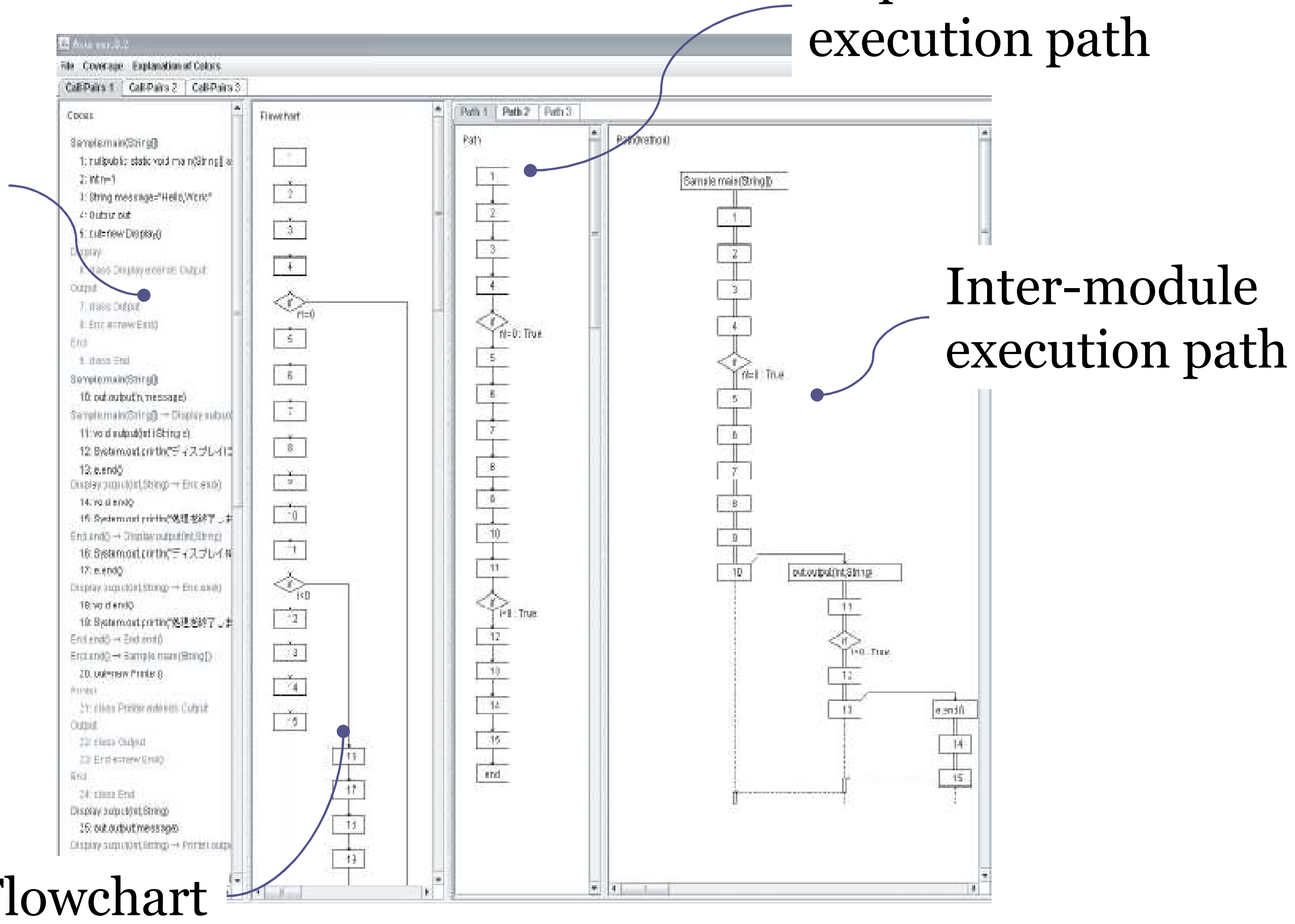
Avis

- Automatic Visualization Tool for Programs

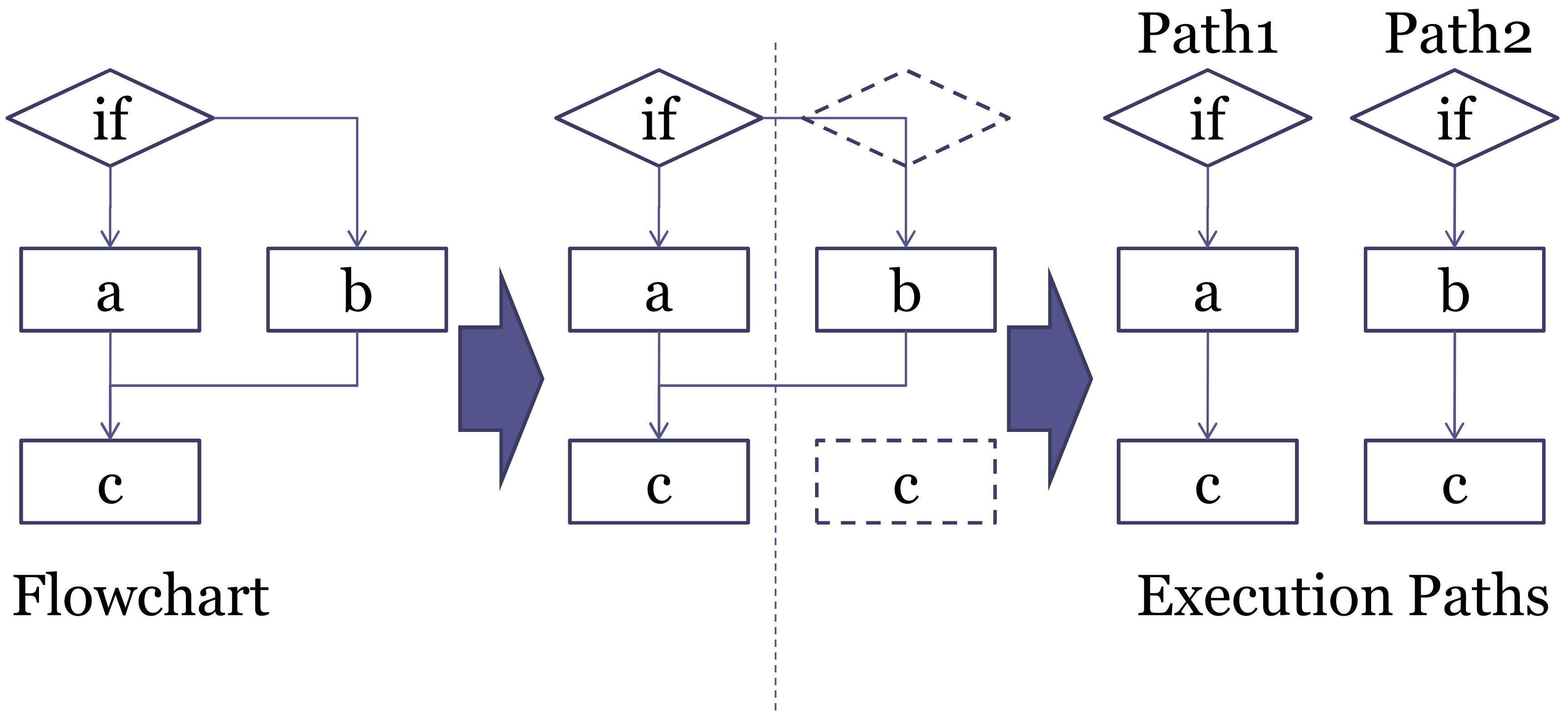
- Input
  - Source code of Java program

- Outputs
  - Flowchart
  - Sequential execution paths
  - Inter-module execution paths

View of Avis


Sequential execution path
Code
Inter-module execution path
Flowchart
File Coverage Explanation of Colors
Call-Pairs 1
Call-Pairs 2
Call-Pairs 3
Codes
Flowchart
Path 1
Path 2
Path 3
Path
Path(method)
Sample.main(String[])
out.output(int,String)
e.end()
end

Paths Generation

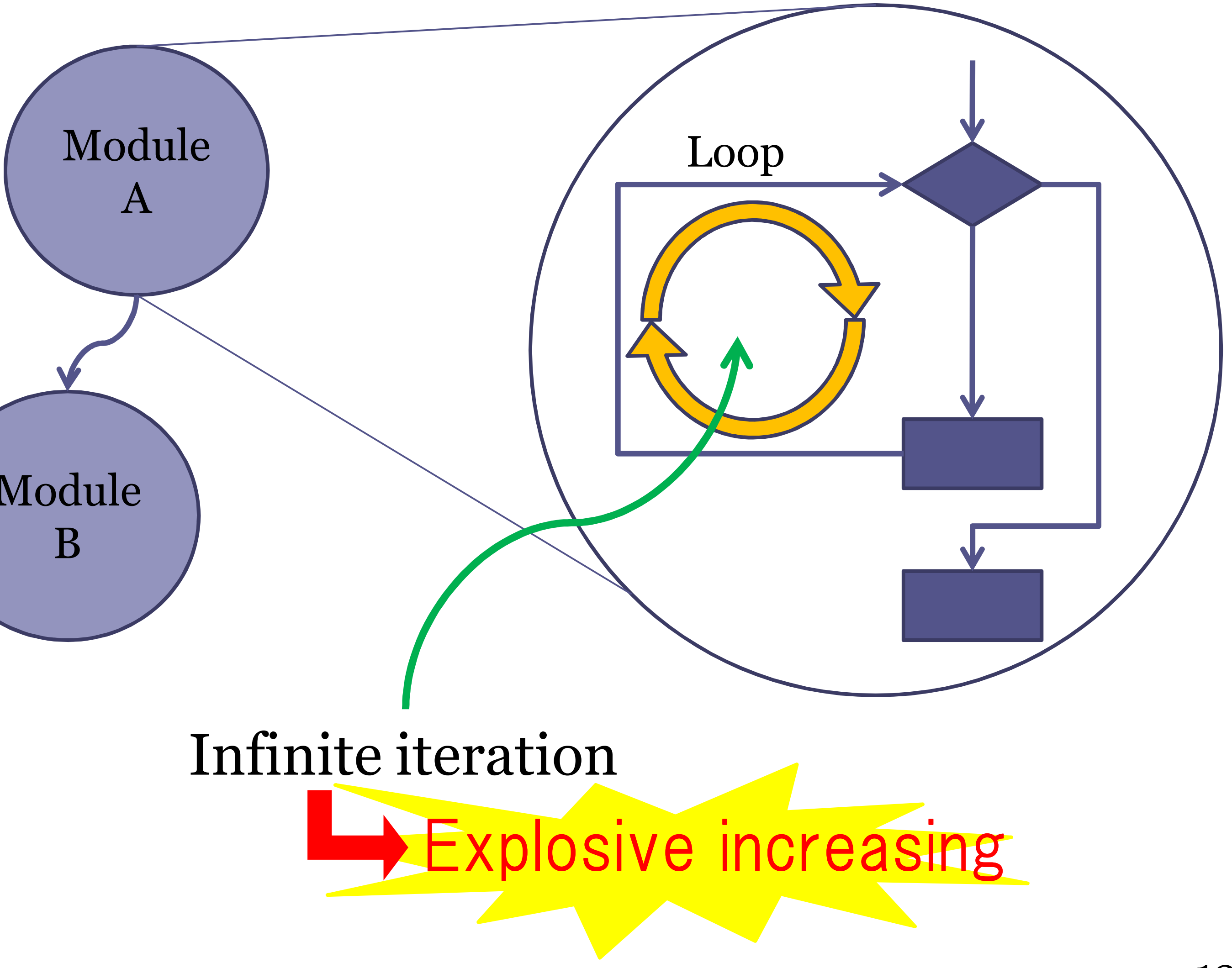


Separation

Solution of explosive increasing number of paths

- Criteria for generating execution paths
- Criteria for integration testing
- Algorithm for abstracting execution paths

Explosive increasing number of execution paths

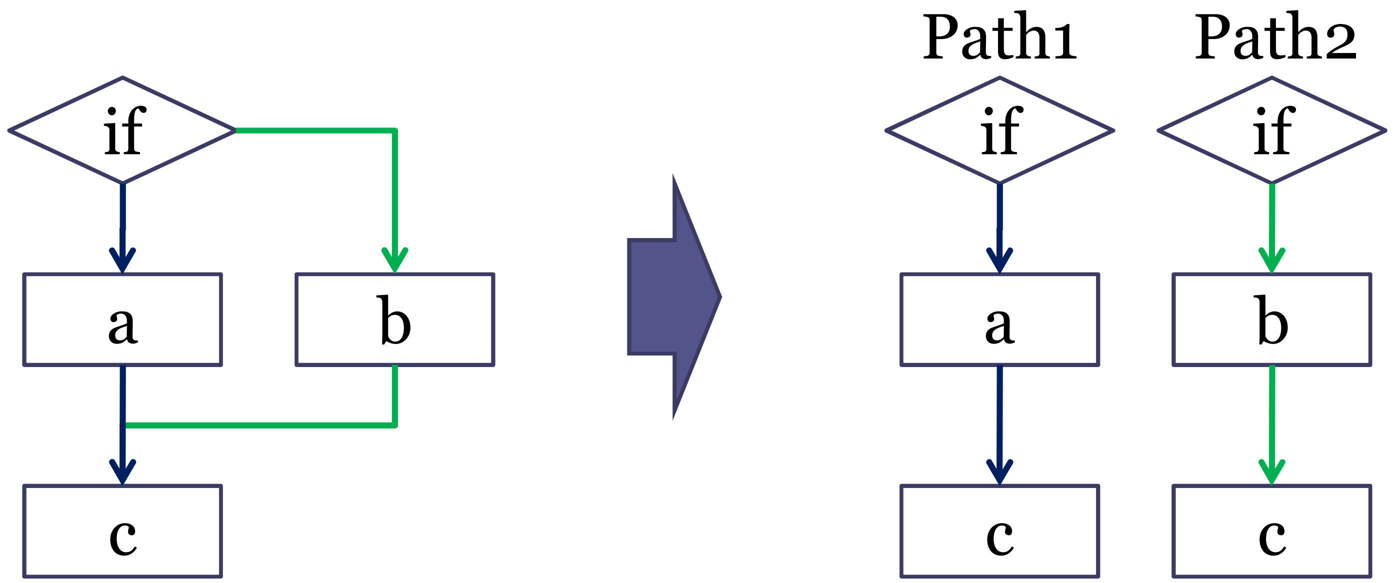


Criteria for generating execution paths

- Avis's criteria for reducing the number of paths based on branch coverage (C1)
  - Criterion for branch covering
  - Criterion for loop covering

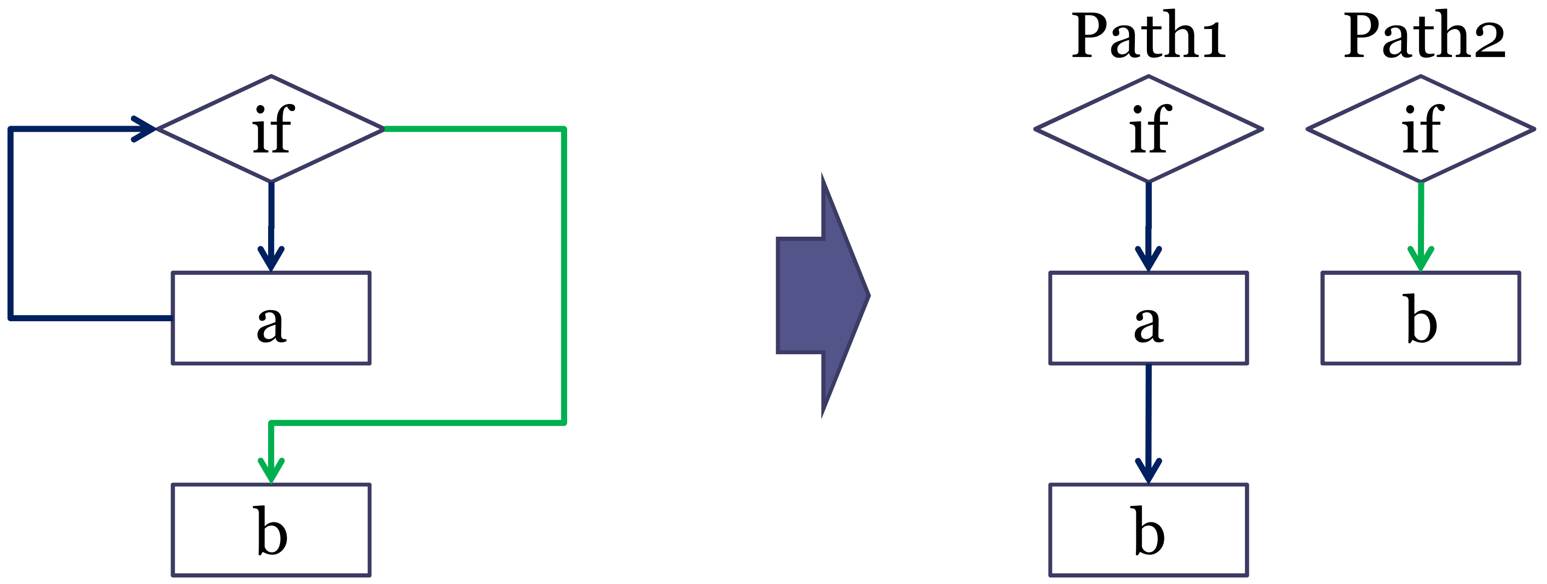
Criterion for branch covering

- All branches are executed at least once.



Criterion for loop covering

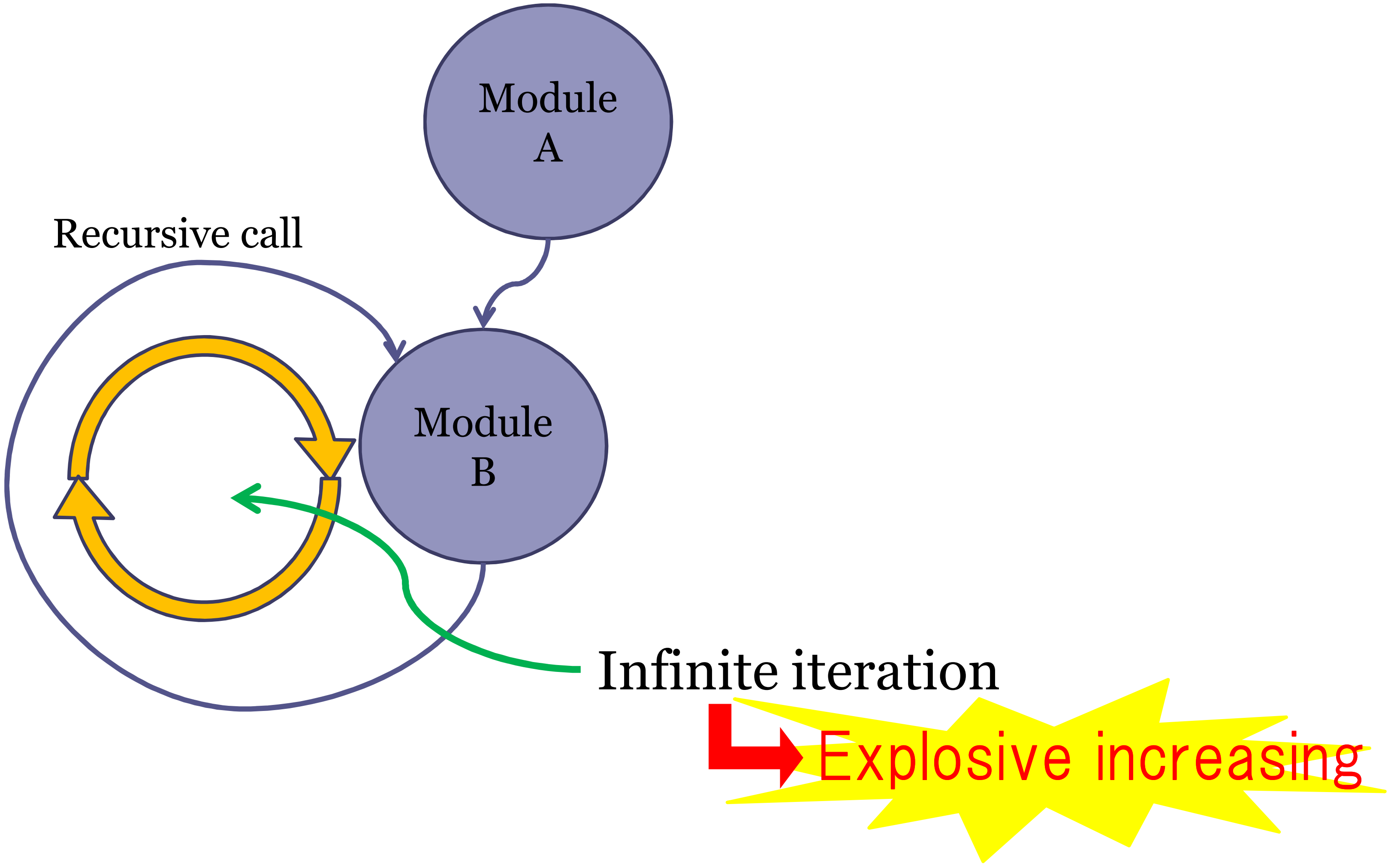
- All loops are iterated zero times (i.e. no iteration) and once.



Solution of explosive increasing number of paths

- Criteria for generating execution paths
- Criteria for integration testing
- Algorithm for abstracting execution paths

Explosive increasing number of execution paths

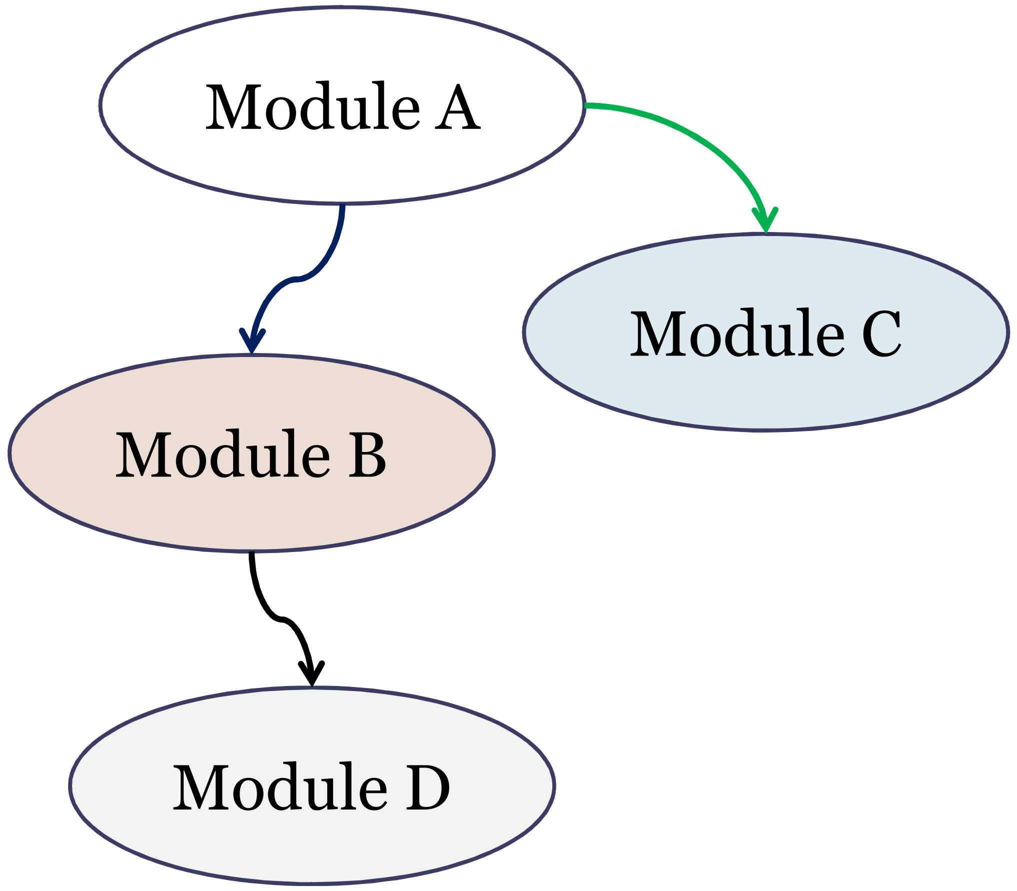


Criteria for integration testing

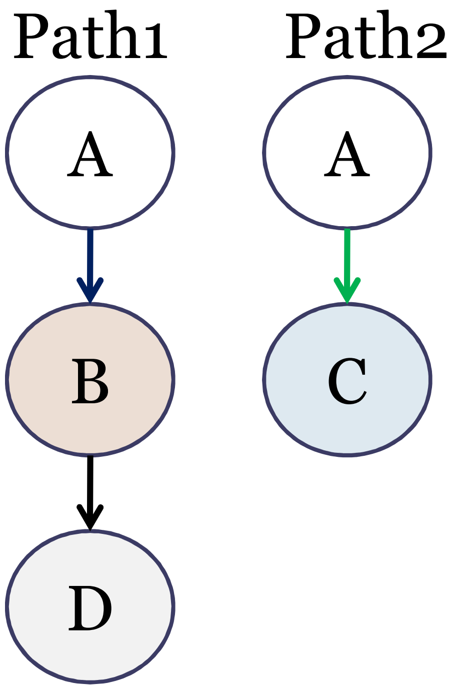
- Avis's new criteria for reducing the number of paths based on Module coverage(S0) and Call-pair coverage(S1) in integration testing.
  - Criterion for module covering
  - Criterion for recursive call covering

Criterion for module covering

- All modules are executed at least once.

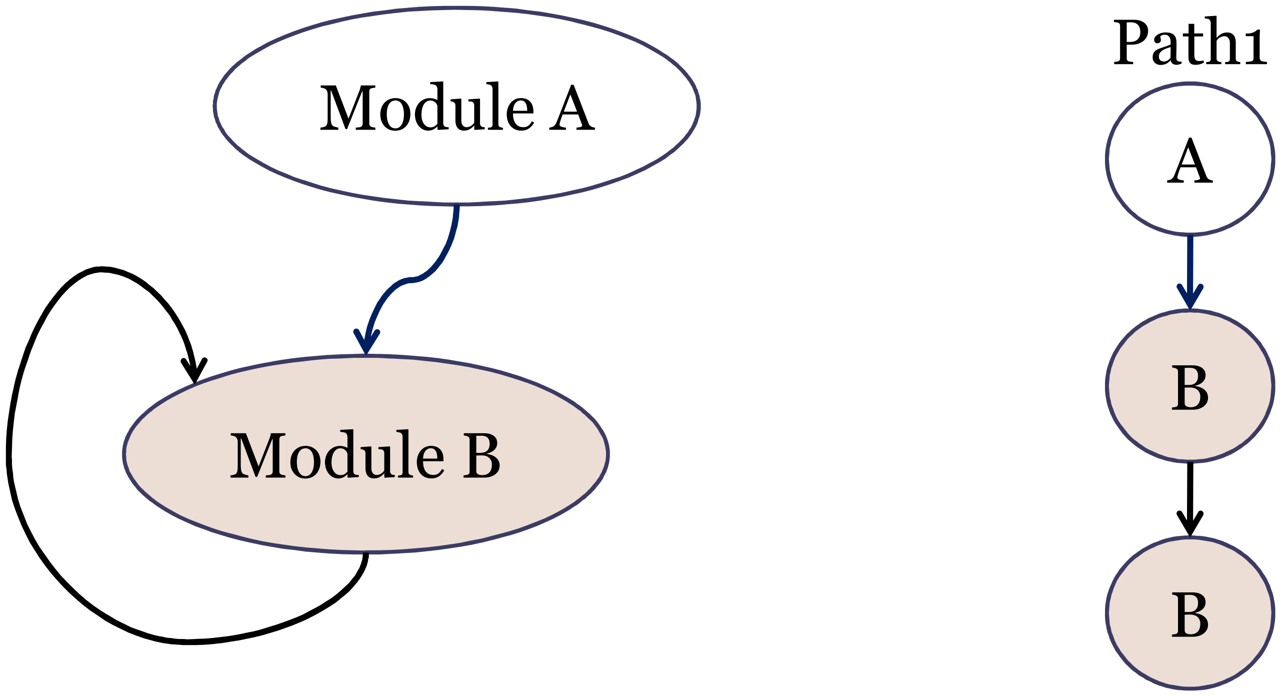


$$\begin{tikzcd}
A \arrow[d] & A \arrow[d] \\
B \arrow[d] & C \\
D &
\end{tikzcd}$$



Criterion for recursive call covering

- All recursive calls are iterated once.



Solution of explosive increasing number of paths

- Criteria for generating execution paths
- Criteria for integration testing
- Algorithm for abstracting execution paths

Useless of execution paths

- The execution paths are generated by Avis include useless paths for indicating

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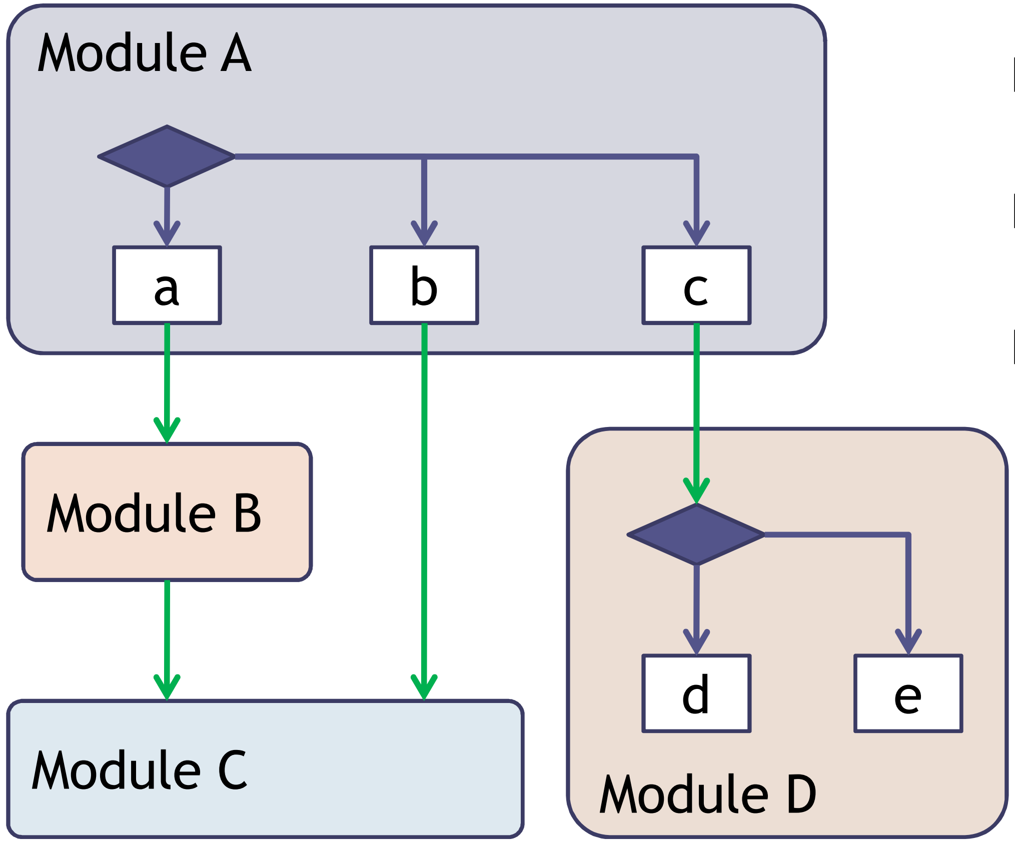
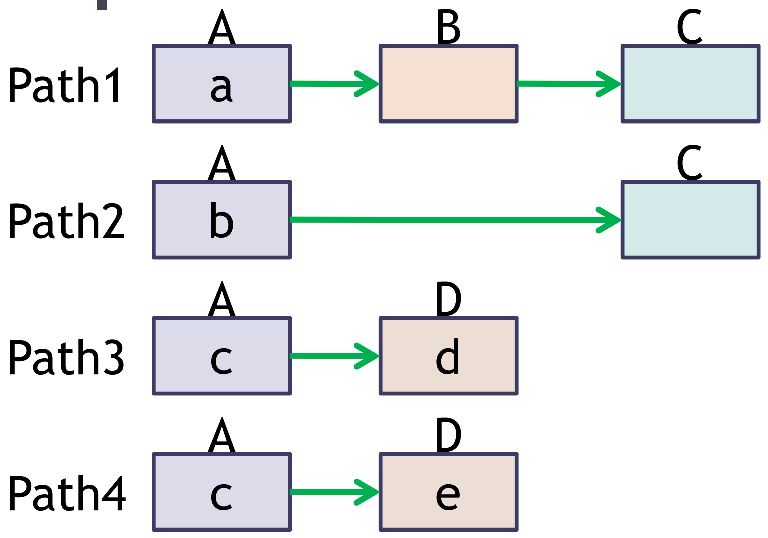
Abstraction of the useful execution paths

abstracting execution paths





Path1, Path2 and Path3
are abstracted paths
for covering all call-pairs.

Path1 and Path3 are
abstracted paths
for covering all modules.

Practicality of execution paths

- Infeasible paths may be generated in the following cases.
  - Paths disregard the dependence of branch conditions.
  - Paths include the code that it is impossible to execute (called ‘dead-code’).

Evaluation of proposal method

- Practicality of Avis
  - Runtime of Avis
- Abstraction of execution paths
  - Comparison between the number of modules (or call-pairs) and the number of paths generated by Avis
- Rate of executable paths
  - Number of executable paths among execution paths
- Usefulness of indicating infeasible paths
  - Number of dead-code included in infeasible paths

Practicality of Avis

- Runtime of Avis

Java Program	Lines of code	Runtime(sec)
Program A: Calendar	80	0.21
Program B: Simulation of bounding balls	155	0.36
Program C: Card game (Black jack)	722	1.22
Program D: Parser (A part of Avis)	8,034	9.73

Abstraction of execution paths

- Comparison between the number of modules and the number of execution path satisfying S0

Java Program	Number of modules	Number of execution paths satisfying S0	Reduction ratio(%)
Program A	7	3	57.1
Program B	23	14	39.1
Program C	76	38	50.0
Program D	573	352	38.6

Abstraction of execution paths

- Comparison between the number of call-pairs and the number of execution path satisfying S1

Java Program	Number of call-pairs	Number of execution paths satisfying S1	Reduction ratio(%)
Program A	17	3	82.4
Program B	66	16	75.8
Program C	259	45	82.6
Program D	2,277	372	83.7

Rate of executable paths

- Number of executable paths among execution paths satisfying So

Java Program	Num. of paths	Num. of executable paths	Num. of covering modules
Program A	3	3 (100.0%)	7 (100.0%)
Program B	14	13 (92.0%)	22 (95.7%)
Program C	38	27 (71.1%)	61 (80.3%)
Program D	352	217 (61.6%)	409 (71.4%)

Rate of executable paths

- Number of executable paths among execution paths satisfying S1

Java Program	Num. of paths	Num. of executable paths	Num. of covering call-pairs
Program A	3	3 (100.0%)	7 (100.0%)
Program B	16	14 (87.5%)	63 (95.5%)
Program C	45	29 (64.4%)	217 (83.8%)
Program D	372	223 (59.9%)	1,558 (68.4%)

Usefulness of indicating infeasible paths

- Number of dead-code included in infeasible paths

Java Program	Num. of infeasible paths(S0)	Num. of dead-codes	Num. of infeasible paths(S1)	Num. of dead-codes
Program A	0	-	0	-
Program B	1	0	2	0
Program C	11	0	16	0
Program D	135	7	149	9

Discussion

- Result of evaluation
  - Reducing the number of execution paths by proposed criteria.
  - Minimum set of execution paths can cover all modules and call-pairs.
  - Infeasible paths include dead-code.

Conclusion

- Goal

  Verification support of inter-module interfaces by white-box testing in integration testing

- Proposal

  Indicate the minimum set of execution paths by using automatic visualization tool 'Avis'.

- Out Comes
  - Minimum set of execution paths can cover both all modules and call-pairs.
  - The set of execution paths contain dead-code can be specified.

Future works

- Measures for infeasible paths
- Applications of Avis to software testing education
- Applications of Avis to other programming languages for integration testing

Thank you for your attention!!