

# Loops in Flow Graphs

Barteček Jakub, Bc.

Kanich Ondřej, Bc.

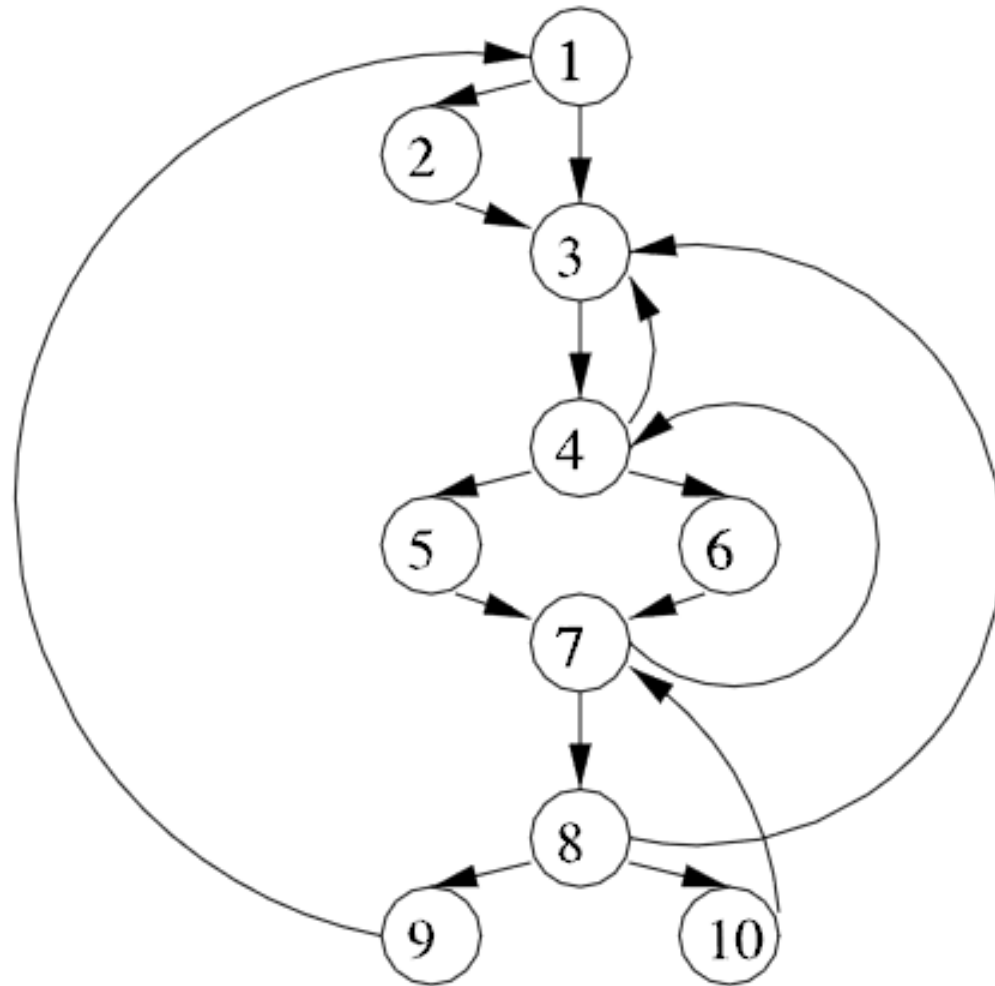
# Introduction

- ▶ Finding loops in FG
  - Loops are treated specially
  - Need more than 1 pass through program to analysis
  
- ▶ Presentation concentrates on general terms for finding loops in FG
  - Algorithms are in book in references

# Domination relation in FG

- ▶ Node  $D$  dominates node  $N$ , if every path from entry node of the flow graph to  $N$  goes through  $D$
- ▶ Every node dominates itself too

# Example



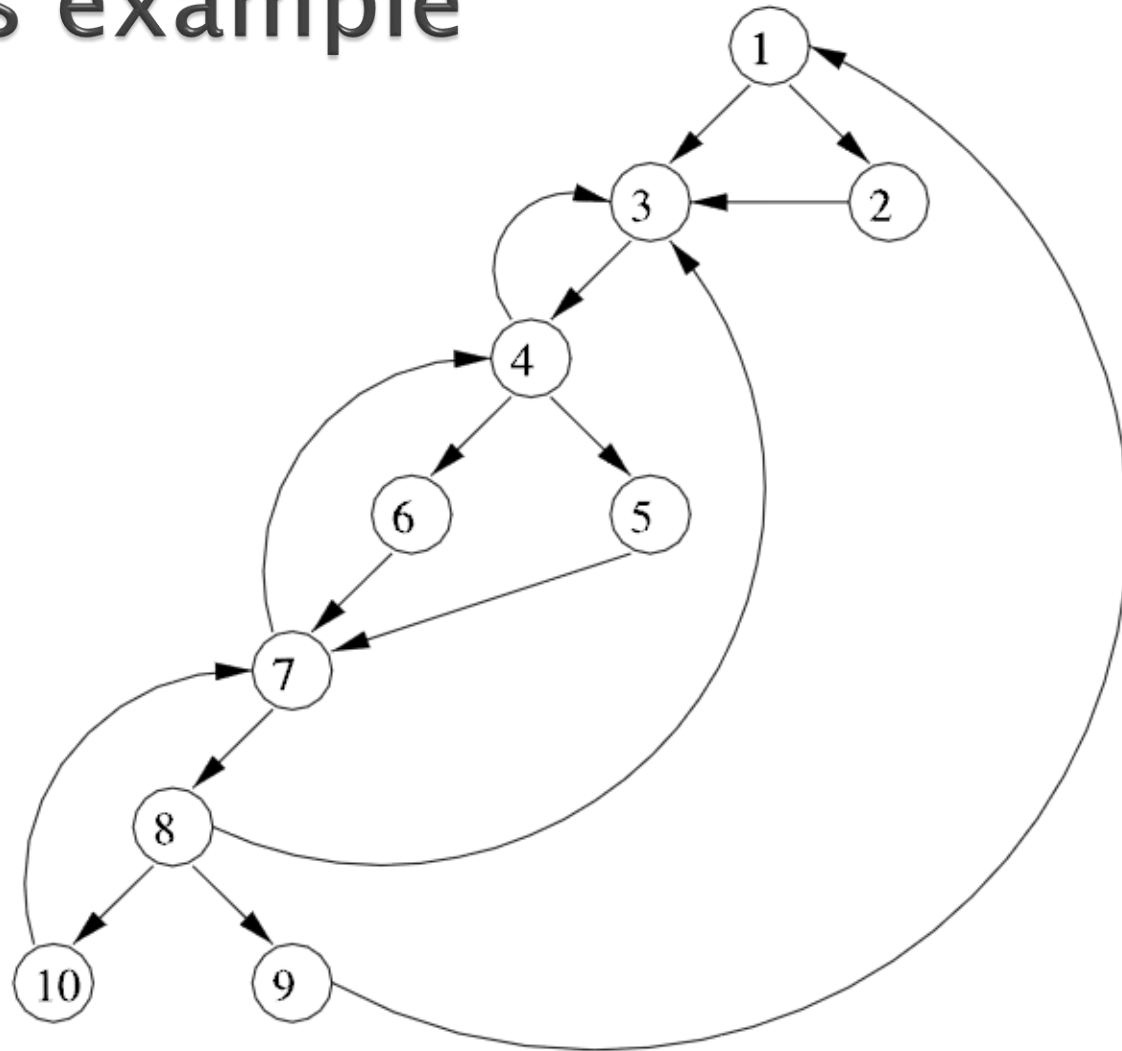
# Depth-first spanning tree (DFST)

- ▶ Construction of DFST for classifying edges in FG
- ▶ Using depth-first ordering for construction DFST
  - It is reverse of postorder traversal
  - Traverse each node only once
- ▶ Obtain order of nodes in FG

# Edges in a DFST

- ▶ Advancing edges
  - Edges from a node  $M$  to a proper descendant of  $M$
  - All edges in the DFST
- ▶ Retreating edges
  - Are not in DFST
  - Edges from a node  $M$  to an ancestor of  $M$  (possibly to  $M$  itself)
- ▶ Cross edges
  - Edges from  $M$  to  $N$  such that neither  $M$  nor  $N$  is ancestor of the other

# Depth-first presentation of previous example



# Back Edges

- ▶ Edge from node  $A$  to node  $B$  whose head  $B$  dominates its tail  $A$
- ▶ Every back edge is retreating edge, but not every retreating edge is back edge



# Reducibility

- ▶ FG is reducible if all retreating edges are back edges
- ▶ In practise FG are almost always reducible
- ▶ Exclusive use of structured flow-of-control statements produce programs whose FG are always reducible

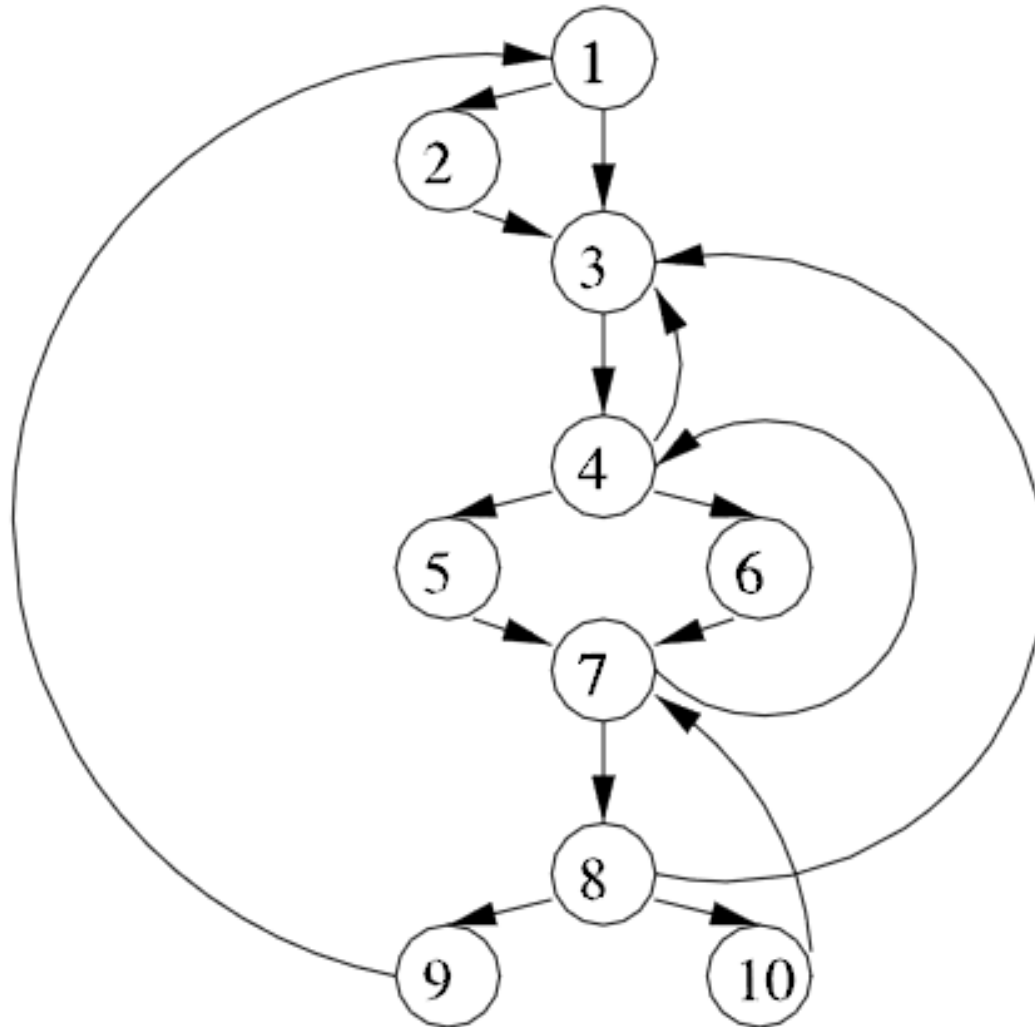
# Natural Loops

- ▶ Many ways to define loops
- ▶ Need to detect loops with single-entry node
- ▶ Definition
  - It must have single-entry node (header). This header dominates all nodes in the loop.
  - There must be a back edge that enters the loop header.

# Natural Loops

- ▶ Natural loop from back edge  $N \rightarrow D$  is  $D$  plus set of nodes that can reach  $N$  without going through  $D$
- ▶ In reducible FG we can define natural loop for each retreating edge
- ▶ Natural loop as only loop in programs

# Example



# Conclusion

- ▶ Core of loop detection is in domination relation, DFST and related classification of edges in FG
- ▶ Existence of algorithms for this process
- ▶ Automatic extraction of loops from FG

# References

- ▶ AHO, A. V., LAM, M. S., SETHI, R., ULLMAN, J. D.:  
*Compilers, Principles, Techniques and Tools*. Canada:  
Pearson Education, 2006, s. 74–90.  
ISBN 0–32148–681–1.

Thank you for your attention

