Tarjan's SCC Algorithm

Fundamental Algorithms

Rodica Potolea, Camelia Lemnaru and Ciprian Oprișa

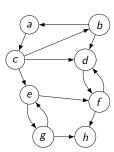
Technical University of Cluj-Napoca Computer Science Department



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TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
  5
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
              STRONG-CONNECT(G, u)
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     u.index = u.lowLink = index
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  3 Push(S, u)
     u. onStack = TRUE
     for each v \in G.Adi[u]
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         if v index ==-1
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              u.lowLink = min(u.lowLink, v.lowLink)
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         elseif v.onStack
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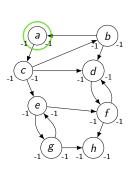
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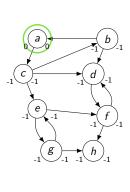
а

call stack S

index: 0

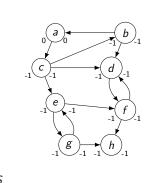


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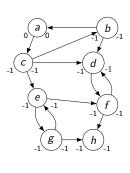
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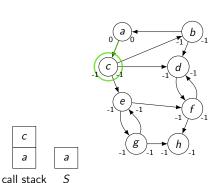
index: 1

nrComponents: 0

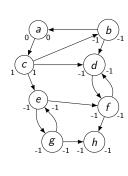
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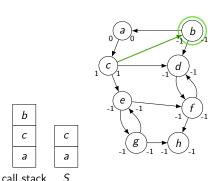
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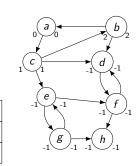
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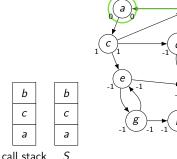


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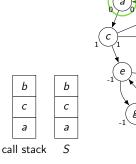
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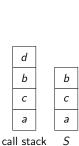
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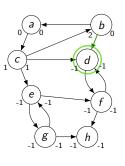


Tarjan's SCC Algorithm

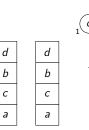


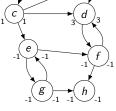
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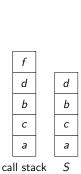
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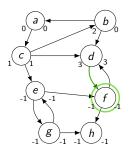




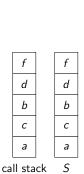


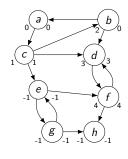
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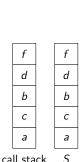
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              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

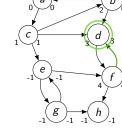






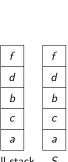
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adj[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



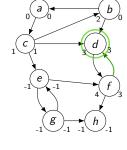




```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v.onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u, lowLink == u, index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

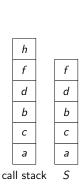


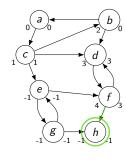






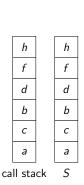
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

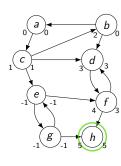






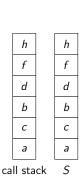
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

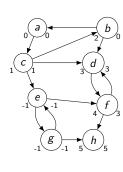






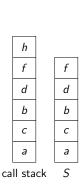
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
          until v == u
```

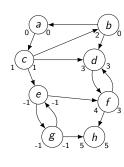






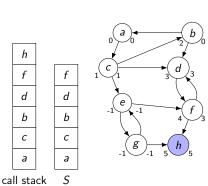
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





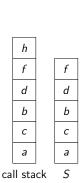


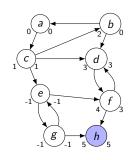
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





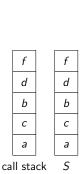
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

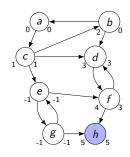






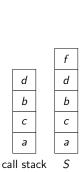
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
          until v == u
```







```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
          until v == u
```

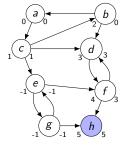


d

h

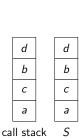
C

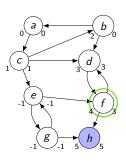
а



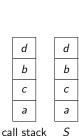
index · 6

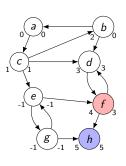
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





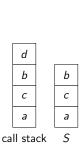
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

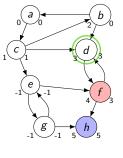




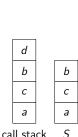


```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





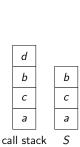
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

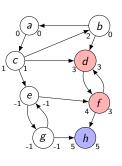




```
T
```

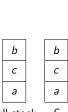
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```







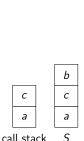
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
          until v == u
```

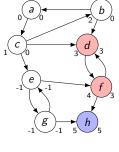




```
V
```

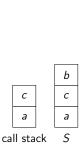
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





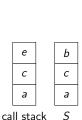


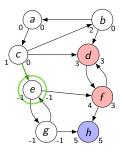
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



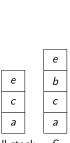


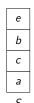
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





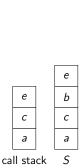
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u. onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
                                                       call stack
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

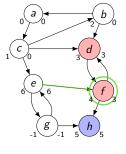






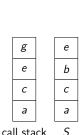
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adj[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

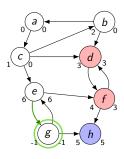






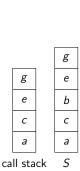
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```







```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     PUSH(S, u)
     u. onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

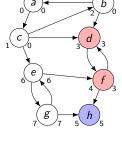


g

e

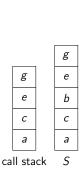
C

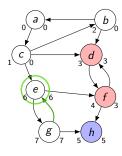
а





```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adj[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





nrComponents: 2

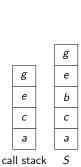
g

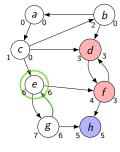
e

C

```
V
```

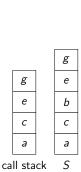
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v.onStack
              u.lowLink = min(u.lowLink, v.index)
 10
 11
     if u, lowLink == u, index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

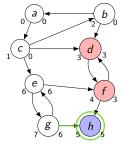




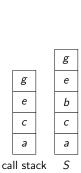


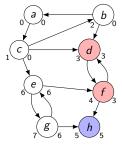
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adj[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
```



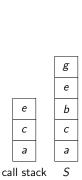


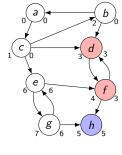
nrComponents: 2

17

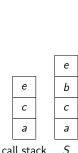


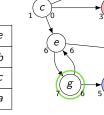
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
          until v == u
```





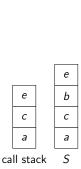
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

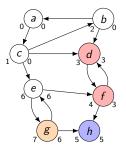




```
W
```

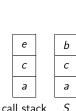
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```







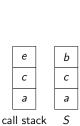
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

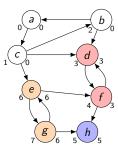




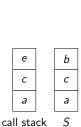


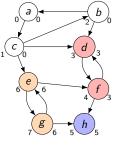
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



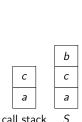


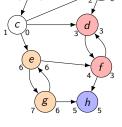
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
```

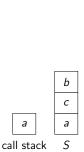


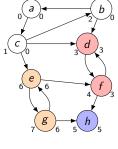


17



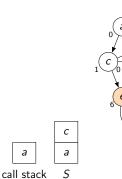
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
          u.index = u.lowLink = -1
          u.onStack = FALSE
          u.comp = 0
     for each vertex u \in G.V
  9
          if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
          if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
          elseif v. onStack
 10
              \underline{u}.lowLink = min(u.lowLink, v.index)
     if u.lowLink == u.index
 11
 12
          nrComponents = nrComponents + 1
 13
          repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
          until v == u
```



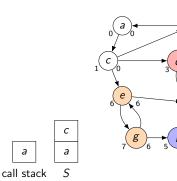


nrComponents: 4

```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u index = u lowl ink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

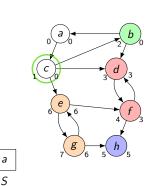


```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



nrComponents: 4

```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```

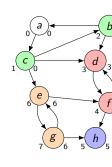


а

call stack

```
III
```

```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



а

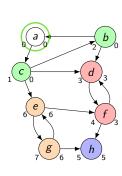
call stack

index: 8

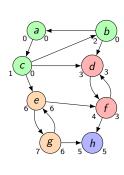
nrComponents: 4



```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
                                                            а
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
                                                       call stack
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



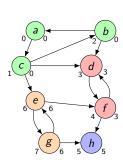
```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```



а

call stack

```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
              STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
                                                            а
              STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
                                                       call stack
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
 12
         nrComponents = nrComponents + 1
 13
         repeat
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```





```
TARJAN(G)
     global index = 0
     global S = \text{EMPTY-STACK}
     global nrComponents = 0
     for each vertex u \in G.V
         u.index = u.lowLink = -1
         u.onStack = FALSE
         u.comp = 0
     for each vertex u \in G.V
  9
         if u.index == -1
 10
             STRONG-CONNECT(G, u)
STRONG-CONNECT(G, u)
     u.index = u.lowLink = index
     index = index + 1
     Push(S, u)
     u.onStack = TRUE
     for each v \in G.Adi[u]
  6
         if v index ==-1
             STRONG-CONNECT(G, v)
  8
              u.lowLink = min(u.lowLink, v.lowLink)
                                                       call stack
  9
         elseif v. onStack
 10
              u.lowLink = min(u.lowLink, v.index)
 11
     if u lowl ink ==u index
                                                                         index · 8
 12
         nrComponents = nrComponents + 1
 13
         repeat
                                                               nrComponents: 4
              v = Pop(S)
 14
 15
              v.onStack = FALSE
 16
              v.comp = nrComponents
 17
         until v == u
```