Huynh Tuong Nguyen Nguyen Ngoc Le



Chapter 11 Trees - DFS

Discrete Structures for Computing



Huynh Tuong Nguyen, Nguyen Ngoc Le Faculty of Computer Science and Engineering University of Technology - VNUHCM htnguyen@hcmut.edu.vn;ngngle@gmail.com

TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS



Start!\ CNCo TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS

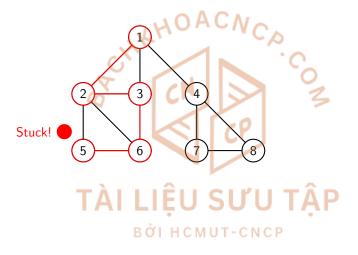


TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS

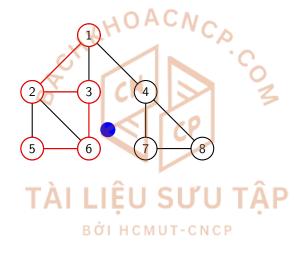




BACHKHOACNCP.COM

Trees - DFS





BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS

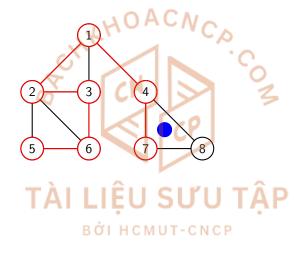


TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS

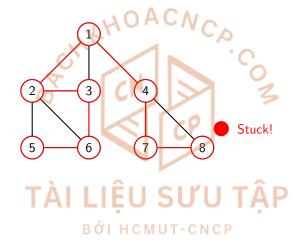




BACHKHOACNCP.COM

Trees - DFS





BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS



TÀI LIÊU SƯU TẬP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS

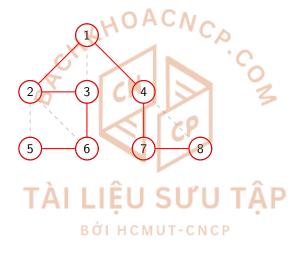


End! TÀI LIÊU SƯU TÂP **B**ổI HCMUT-CNCP

BACHKHOACNCP.COM

Trees - DFS

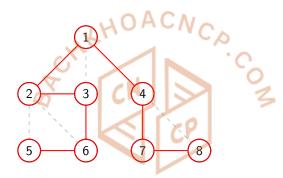




BACHKHOACNCP.COM

Trees - DFS





#### Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le



### **Property**

- Go deeper as you can
- Backtrack (quay lui) to possible branch when you are stuck.
- $\bullet \ O(e) \ {\rm or} \ O(n^2)$

BACHKHOACNCP.COM

# **Depth-First Search**

Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le



MHOACNCA

# Algorithm

procedure DFS (G)

 $T := \mathsf{tree} \ \mathsf{consisting} \ \mathsf{only} \ \mathsf{vertex} \ v_1 \ \mathit{visit}(v_1)$ 

procedure visit(v): vertex of G) /\* recursive \*/
for each vertex w adjacent to v and not in Tadd w and edge  $\{v,w\}$  to T visit(w)

BỞI HCMUT-CNCP

BACHKHOACNCP.COM

#### A pseudocode of DFS

# XX X

#### void DFS(G)

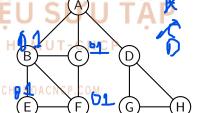
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v]=null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	W	•	•
В	-	W	•	•
С	-	W_	•	• _
D	-	W	•	•
Е	-	W		•
F	-	W	•	. 2
G	-	W	•	RM I
Ш		14/		_

time = 0



- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
- $2.\mathsf{DFSVisit}(G, u)$ 5.color[v]=**B**lack
- 6.time=time+1
- o.time=time+1
- 7.f[v]=time



Trees - DFS



Huynh Tuong Nguyen Nguyen Ngoc Le

# BK TP.HCM

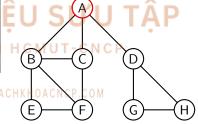
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	W	•	•
В	-	W	•	•
С	-	W_	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	BD I
Н	-	W	•	•

time = 0

- 1.color[v]=**G**ray
- 2.time = time + 1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



# BK TP.HCM

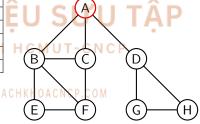
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

	vertex	father	color	d	f
ſ	А	-	WG	•	•
ſ	В	-	W	•	•
Ī	С	-	W_	•	•_
Ī	D	-	W	•	•
ſ	E	-	W		•
Ī	F	-	W	•	. 2
Ī	G	-	W	•	В'n
ľ	Н	-	W	•	•

time = 0

- 1.color[v]=Gray
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v] = time



# BK TP.HCM

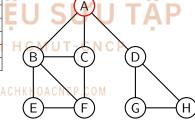
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] = \mathbf{W}\mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	•	•
В	-	W	•	•
С	-	W_	•	• _
D	-	W	•	•
E	-	W	•	•
F	-	W	•	. %
G	-	W	•	ВŊ
Н	-	W	•	•

time = 1

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



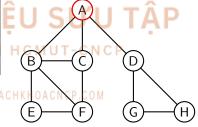
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	-	W	•	•
С	-	W_	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	В'n
Н	-	W	•	•

time = 1

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
      - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v] = time



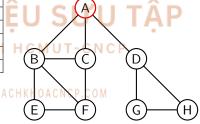
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	W	•	•
С	-	W_	•	•
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	В'n
Н	-	W	•	•

time = 1

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v2.DFSVisit(G, u)
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v]=time



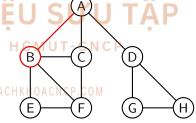
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= White}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	W	•	•
С	-	W_	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	Β'n
Н	-	W	•	•

time = 1

- 1.color[v]=**G**ray
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - **2.DFSVisit**(G, u)
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v] = time



# BK TP.HCM

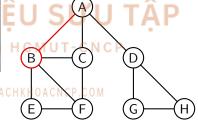
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	•	•
С	-	W_	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	Βħ
Н	-	W	•	•

time = 1

- 1.color[v]=Gray
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



# BK TP.HCM

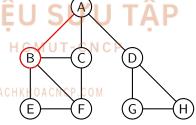
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	•	•
С	-	W_	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. %
G	-	W	•	RN
Н	-	W	•	•

time = 2

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v] = time



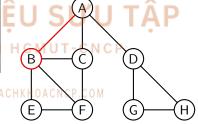
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WG	2	•
С	-	W_	•	•
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	ВŊ
Н	-	W	•	•

time = 2

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



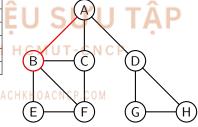
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

	vertex	father	color	d	f
	Α	-	WG	1	•
	В	Α	WG	2	•
	С	В	W_	•	• _
	D	-	W	•	•
	E	-	W	•	•
	F	-	W	•	. %
	G	-	W	•	RN
ı	Н	-	W	•	•

time = 2

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v2.DFSVisit(G, u)
- $5.\operatorname{color}[v] = \mathbf{Black}$
- 6.time=time+1
- 7.f[v] = time



# BK TP.HCM

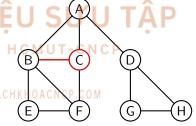
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	W_	•	• _
D	-	W	•	•
E	-	W	•	•
F	-	W	•	. 2
G	-	W	•	Βħ
Н	-	W	•	•

time = 2

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
- 2.**DFSVisit**(G, u)5.color[v]=**B**lack
- 6.time=time+1
- 7.f[v] = time



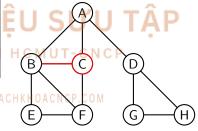
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. %
G	-	W	•	ВŊ
Н	-	W	•	•

time = 2

- 1.color[v]=Gray
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
- 2.DFSVisit(G, u)5.color[v]=Black
- 6.time=time+1
- 7.f[v] = time



# BK TP.HCM

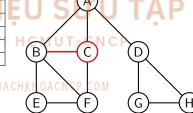
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
C	В	WG	•	• _
D	-	W	•	•
E	-	W		•
F	-	W	•	. 2
G	-	W	•	ВŊ
Н	-	W	•	•

time = 3

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



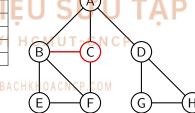
#### void DFS(G)

- 1.loop (more vertex v in G)
  - 1.color[v]= **W**hite 2.father[v]=null
- 2 time=0
- 3.loop (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

	vertex	father	color	d	f
	Α	-	WG	1	•
	В	Α	WG	2	•
	С	В	WG	3	• _
	D	-	W	•	•
	E	-	W	•	•
	F	-	W	•	. %
	G	-	W	•	RN
ı	Н	-	W	•	•

time = 3

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father [u]=v
      - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



# BK TP.HCM

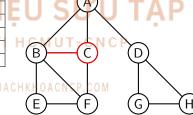
#### void DFS(G)

- 1.loop (more vertex v in G)
  - 1.color[v]= **W**hite 2.father[v]=null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	-	W		•
F	С	W	•	. %
G	-	W	•	ВŊ
Н	-	W	•	•

time = 3

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v2.DFSVisit(G, u)
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v]=time



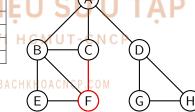
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	-	W		•
F	С	W	•	. %
G	-	W	•	RN
Н	-	W	•	•

time = 3

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - **2.DFSVisit**(G, u)
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



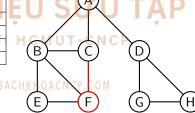
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	-	W		•
F	С	WG	•	. 2
G	-	W	•	ВŊ
Н	-	W	•	•

time = 3

- 1.color[v]=Gray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7 fl.1 +:---
- 7.f[v] = time



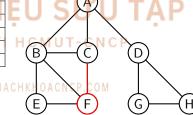
#### void DFS(G)

- 1.loop (more vertex v in G)
  - 1. $color[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	-	W	•	•
F	С	WG	•	. %
G	-	W	•	ВŊ
Н	-	W	•	•

time = 4

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



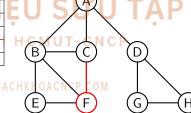
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	-	W		•
F	С	WG	4	. 2
G	-	W	•	ВŊ
Н	-	W	•	•

time = 4

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



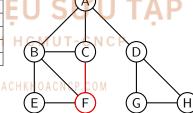
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	. • _
D	-	W	•	•
E	F	W		•
F	С	WG	4	. 2
G	-	W	•	В'n
Н	-	W	•	•

time = 4

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v2.DFSVisit(G, u)
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v]=time



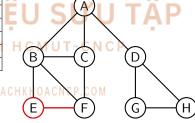
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

	vertex	father	color	d	f
	Α	-	WG	1	•
	В	Α	WG	2	•
	С	В	WG	3	• _
	D	-	W	•	•
	E	F	W		•
	F	С	WG	4	. 2
	G	-	W	•	ВŊ
ı	Н	-	W	•	•

time = 4

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
- 2.**DFSVisit**(G, u)5.color[v]=**B**lack
- 6.time=time+1
- o.time=time+1
- 7.f[v] = time



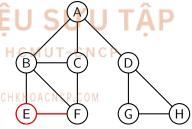
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	F	WG		•
F	С	WG	4	. 2
G	-	W	•	Β'n
Н	-	W	•	•

time = 4

- 1.color[v]=Gray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time



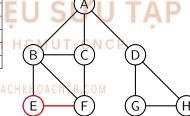
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
E	F	WG		•
F	С	WG	4	. %
G	-	W	•	ВŊ
Н	-	W	•	•

time = 5

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



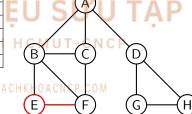
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] = \mathbf{W}\mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	3	• _
D	-	W	•	•
Е	F	WG	5	•
F	С	WG	4	. 2
G	-	W	•	ВŊ
Н	-	W	•	•

time = 5

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v]=time



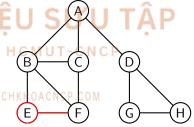
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
C	В	WG	_3	•_
D	-	W	•	•
Е	F	WGB	5	•
F	С	WG	4	
G	-	W	• [	5 <b>U</b> I
Н	-	W	•	•

time = 5

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v]=time



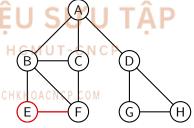
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	3	•_
D	-	W	•	•
E	F	WGB	5	•
F	С	WG	4	٠.
G	-	W	• 1	5 <b>U</b> I
Н	-	W	•	•

time = 6

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+
- 7.f[v] = time



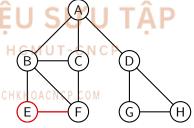
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	_3	•_
D	-	W	•	•
E	F	WGB	5	6
F	С	WG	4	٠.٠.
G	-	W	• 1	5 <b>U</b> I
Н	-	W	•	•

time = 6

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v]=time



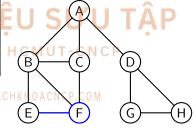
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

d	
1	•
2	•
_3	•_
•	•
5	6
4	
• [	ו ען פ
•	•
	1 2 3 • 5

time = 6

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v]=time



### BK

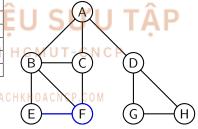
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	_3	•_
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	٠.
G	-	W	• 1	5 <b>U</b> I
Н	-	W	•	•

time = 6

- $1.\operatorname{color}[v] = \operatorname{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v] = Black6.time=time+1
- 7.f[v]=time



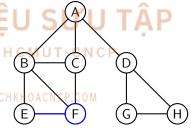
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	_3	•_
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	٠.٠.
G	-	W	• 1	5 <b>U</b> I
Н	-	W	•	•

time = 7

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time



void DFS(G)

2.time=0

BK

- $1.\operatorname{color}[v] = \operatorname{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v]=time

- void DFSVisit (G, v)

  - - - $2.\mathsf{DFSVisit}(G,u)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WG	_3	•_
D	-	W	•	•
Е	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 <b>U</b> I
Н	-	W	•	•

1.loop (more vertex v in G)

3.loop (more vertex v in G)

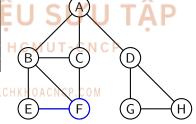
1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 

 $1.\mathsf{DFSVisit}(G, v)$ 

 $1.\operatorname{color}[v] = \mathbf{W}$  hite

2.father[v] = null

time =



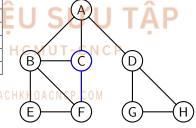
#### void DFS(G)

- 1.loop (more vertex v in G)
  - 1.color[v]= **W**hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WG	2	•
С	В	WG	_3	•_
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 <b>U</b> I
Н	-	W	•	•

time = 7

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



## BK

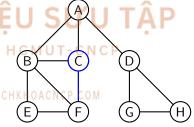
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WG	2	•
С	В	WGB	_3	•_
D	-	W	•	•
Е	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 🕡
Н	-	W	•	•

time =

- $1.\operatorname{color}[v] = \operatorname{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v] = Black6.time=time+1
- 7.f[v]=time



#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WG	2	•
C	В	WGB	_3	•_
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 🕡 I
Н	-	W	•	•

time = 8

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time+
- U SAU TAP

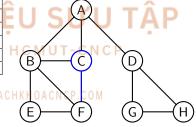
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WG	2	•
С	В	WGB	_3	8
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 <b>U</b> I
Н	-	W	•	•

time = 8

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v]=time



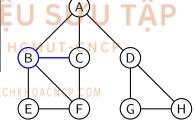
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

	vertex	father	color	d	f
	Α	-	WG	1	•
	В	Α	WG	2	•
ĺ	С	В	WGB	_3	8
	D	-	W	•	•
	Е	F	WGB	5	6
ĺ	F	С	WGB	4	7.
Ì	G	-	W	• 1	5 <b>U</b> I
	Н	-	W	•	•

time = 8

- 1.color[v]= $\mathbf{G}$ ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



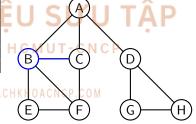
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	•
С	В	WGB	_3	8
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 <b>U</b> I
Н	-	W	•	•

time = 8

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- b.time=time+
- 7.f[v] = time



#### void DFS(G)

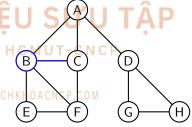
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	•
С	В	WGB	_3	8
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 🕡 I
Н	-	W	•	•

9

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time



#### void DFS(G)

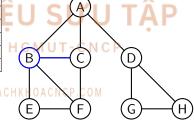
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

	vertex	father	color	d	f
	Α	-	WG	1	•
	В	Α	WGB	2	9
	C	В	WGB	3	8
	D	-	W	•	•
	Е	F	WGB	5	6
ĺ	F	С	WGB	4	7.
	G	-	W	• [	5 🕡 I
	Н	-	W	•	•

9

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v]=time



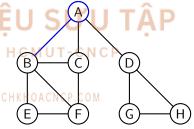
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
C	В	WGB	_3	8
D	-	W	•	•
E	F	WGB	5	6
F	С	WGB	4	. 7.
G	-	W	• [	5 🕡 I
Н	-	W	•	•

time =

- 1.color[v]= $\mathbf{G}$ ray
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v]=time



#### void DFS(G)

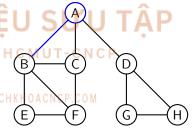
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	_3	8
D	А	W	•	•
E	F	WGB	5	6
F	С	WGB	4	. Z.
G	-	W	• 1	5 <b>U</b> I
Н	-	W	•	•

9

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v2.DFSVisit(G, u)
- 5.color[v]=Black
- 6.time = time + 1
- 7.f[v] = time



#### void DFS(G)

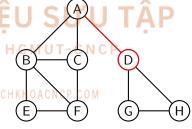
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] = \mathbf{W}\mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
C	В	WGB	_3	8
D	Α	W	•	•
E	F	WGB	5	6
F	С	WGB	4	. 7.
G	-	W	• [	5 🕡 I
Н	-	W	•	•

9

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - **2.DFSVisit**(G, u)
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



### BK

#### void DFS(G)

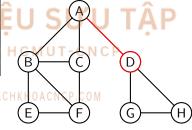
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] = \mathbf{W}\mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
C	В	WGB	_3	8
D	А	WG	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 <b>U</b> I
Н	-	W	•	•

time =

9

- 1.color[v]=Gray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



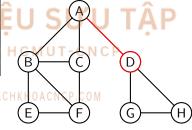
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= White}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	_3	8
D	А	WG	•	•
E	F	WGB	5	6
F	С	WGB	4	7.
G	-	W	• [	5 <b>(</b> ) 1
Н	-	W	•	•

time = 10

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time



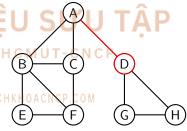
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= W} \mathsf{hite}$
  - 2.father[v]=null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	-	W	• B	Q1
Н	-	W	•	•

time = 10

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v] = time



#### void DFS(G)

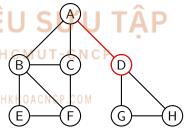
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= W} \mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	W	• B	Q1
Н	-	W	•	•

10

time =

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v2.DFSVisit(G, u)
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v] = time



#### void DFS(G)

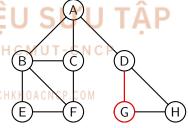
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= White}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	W	• 15	Q1
Н	-	W	•	•

10

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - **2.DFSVisit**(G, u)
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



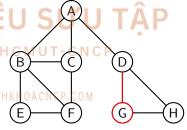
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🌶
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	٤7.
G	D	WG	• B	Q1
Н	-	W	•	•

time = 10

- 1.color[v]=Gray
- 2.time= time+1
- 3.d[v]= time 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
  - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v] = time





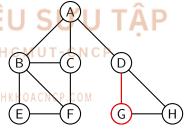
#### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🌶
D	Α	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	• B	Q1
Н	-	W	•	•

time = 11

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+.
- 7.f[v] = time



Huynh Tuong Nguyen Nguyen Ngoc Le

### BK TP.HCM

#### void DFS(G)

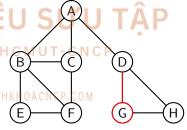
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	C	WGB	4_	27.
G	D	WG	11 <sup>15</sup>	Q1
Н	-	W	•	•

11

time =

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v]=time



#### void DFS(G)

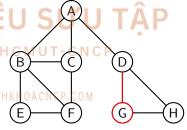
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= W}\mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🌶
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	11 <sup>15</sup>	Q.
Н	G	W	•	•

11

time =

- 1.color[v]= $\mathbf{G}$ ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v2.DFSVisit(G, u)
- 5.color[v] = Black
- 6.time=time+1
- 7.f[v]=time



### BK TP.HCM

### void DFS(G)

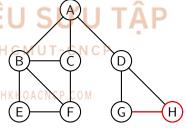
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🌶
D	Α	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	٤7.
G	D	WG	11 <sup>15</sup>	Q1
Н	G	W	•	•

11

time =

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - **2.DFSVisit**(G, u)
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v] = time



### J

### void DFS(G)

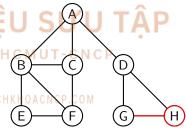
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] = \mathbf{W}\mathsf{hite}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	11 <sup>15</sup>	Q1
Н	G	WG	•	•

11

time =

- 1.color[v]=Gray
- 2.time= time+1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v]=time



## ВК

### void DFS(G)

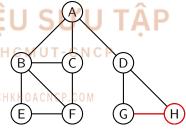
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	11 <sup>15</sup>	Q1
Н	G	WG	•	•

12

time =

- 1.color[v]= $\mathbf{G}$ ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v]=time



## ВК

### void DFS(G)

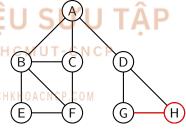
- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= White}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
Е	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	11 <sup>15</sup>	Q1
Н	G	WG	12	•

12

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v]=time



### BK TP.HCM

### void DFS(G)

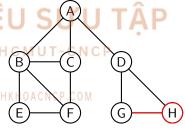
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$  hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🎍
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	11 <sup>15</sup>	Q1
Н	G	WGB	12	•

12

time =

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time = time + 1
- 3.d[v] = time
- 4. $loop(more \ u \ adjacent \ to \ v)$ 
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v]=time



Huynh Tuong Nguyen Nguyen Ngoc Le

### ВК

### void DFS(G)

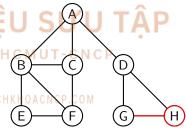
- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\operatorname{\mathsf{loop}}$  (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WGB	2	9
С	В	WGB	3	8 🎍
D	Α	WG	10	•
Е	F	WGB	5	6
F	С	WGB	4	ي7.
G	D	WG	11 <sup>15</sup>	ų,
Н	G	WGB	12	•

13

time =

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time



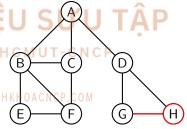
## ВК

### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= White}$
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 _
D	Α	WG	10	•
E	F	WGB	5	6
F	С	WGB	4	ي7.
G	D	WG	11 <sup>15</sup>	u, i
Н	G	WGB	12	13
time	e =	13		

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+
- 7.f[v]=time

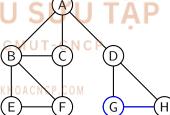


### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🥒
D	Α	WG	10	•
Е	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WG	11 <sup>15</sup>	U,I
Н	G	WGB	12	13
time =		13		

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time



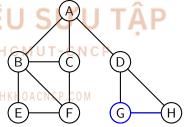
## ВК

### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\mathsf{color}[v] \mathbf{= White}$
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if (color[v] == White)
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8 🥒
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WGB	11 <sup>15</sup>	U,I
Н	G	WGB	12	13
time =		13		

- $1.\operatorname{color}[v] = \mathbf{G}\operatorname{ray}$
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- o.time=time+1
- 7.f[v] = time



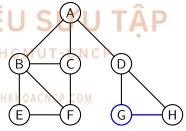
### BK TP.HCM

### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WGB	2	9
С	В	WGB	3	8 🥒
D	Α	WG	10	•
Е	F	WGB	5	6
F	С	WGB	4_	ي7.
G	D	WGB	11 <sup>15</sup>	U, I
Н	G	WGB	12	13
time =		14		

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u]==**W**hite)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time+1



Huynh Tuong Nguyen Nguyen Ngoc Le

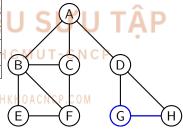
### BK

### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	А	WGB	2	9
С	В	WGB	3	8_
D	Α	WG	10	•
Е	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	<b>U</b> 14
Н	G	WGB	12	13
time =		14		

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time

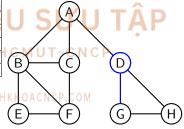


### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8_
D	А	WG	10	•
E	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	14
Н	G	WGB	12	13
time =		14		

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v] = time



### BK TP.HCM

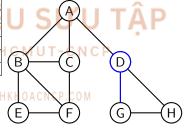
### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G )
  - 1.if  $(color[v] == \mathbf{W}hite)$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8_
D	Α	WGB	10	•
Е	F	WGB	5	6
F	С	WGB	4	٠,7
G	D	WGB	11 <sup>15</sup>	<b>U</b> 14
Н	G	WGB	12	13
		1.4		

time = 14

- 1.color[v]=**G**ray
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 6.time=time+1
- 7.f[v] = time

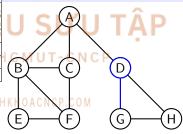


### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8_
D	Α	WGB	10	•
Е	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	<b>U</b> 14
Н	G	WGB	12	13
time =		15		

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v] = time

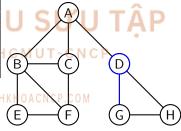


### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
C	В	WGB	3	8 _
D	Α	WGB	10	15
E	F	WGB	5	6
F	С	WGB	4_	.7
G	D	WGB	11 <sup>15</sup>	14
Н	G	WGB	12	13
time =		15		

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time



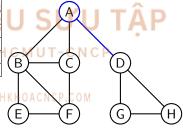
### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WG	1	•
В	Α	WGB	2	9
С	В	WGB	3	8_
D	Α	WGB	10	15
Е	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	14
Н	G	WGB	12	13
time =		15		

time =

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v] = time



# ВК

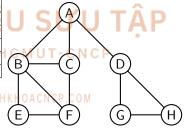
### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3. $\mathsf{loop}$  (more vertex v in G )
  - 1.if  $(\operatorname{color}[v] == \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G,v)$

vertex	father	color	d	f
А	-	WGB	1	•
В	Α	WGB	2	9
С	В	WGB	3	8_
D	Α	WGB	10	15
E	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	14
Н	G	WGB	12	13

time = 15

- 1.color[v]=**G**ray
- 2.time= time+1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father[u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black
- 6.time=time+1
- 7.f[v] = time

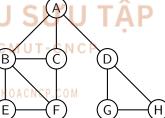


### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WGB	1	•
В	Α	WGB	2	9
С	В	WGB	3	8_
D	Α	WGB	10	15
E	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	14
Н	G	WGB	12	13
time =		16	ĵ	

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time

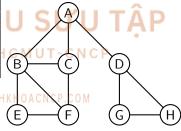


### void DFS(G)

- 1.loop (more vertex v in G)
  - $1.\operatorname{color}[v] = \mathbf{W}$ hite
  - 2.father[v] = null
- 2.time=0
- 3.loop (more vertex v in G)
  - 1.if  $(\operatorname{color}[v] = \mathbf{W} \operatorname{hite})$ 
    - $1.\mathsf{DFSVisit}(G, v)$

vertex	father	color	d	f
Α	-	WGB	1	16
В	Α	WGB	2	9
С	В	WGB	3	8
D	Α	WGB	10	15
E	F	WGB	5	6
F	С	WGB	4_	٠,7
G	D	WGB	11 <sup>15</sup>	<b>U</b> 14
Н	G	WGB	12	13
time =		16	ĵ	

- $1.\operatorname{color}[v] = \mathbf{Gray}$
- 2.time = time + 1
- 3.d[v] = time
- 4.loop(more u adjacent to v)
  - 1.if(color[u] == White)
    - 1. father [u]=v
    - $2.\mathsf{DFSVisit}(G,u)$
- 5.color[v]=Black 6.time=time+1
- 7.f[v]=time

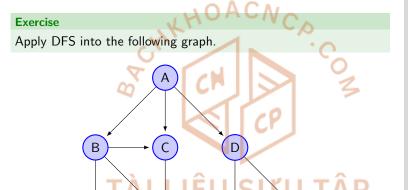




Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le





Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le



### KHOACNCD

### How to apply & modify DFS algorithm to ...

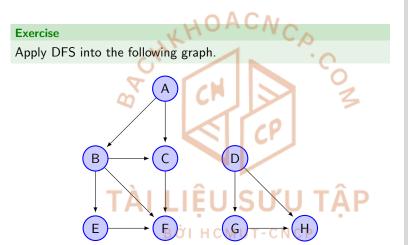
- a determine whether there exists a cycle in digraph,
- **b** determine whether a graph is bipartite,
- determine topological order,
- d calculate number of connected components,
- identify articulation points,
- f determine a longest path in a given digraph...

BŐI HCMUT-CNCP

Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le

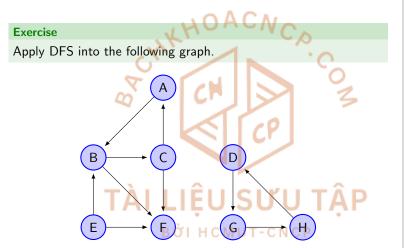




Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le

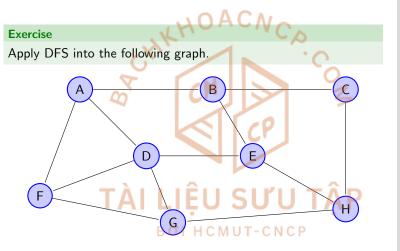




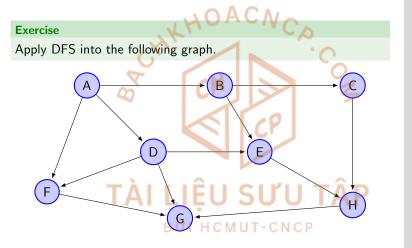
Trees - DFS

Huynh Tuong Nguyen,
Nguyen Ngoc Le





Huynh Tuong Nguyen Nguyen Ngoc Le



Trees - DFS

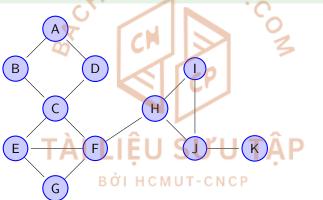


Huynh Tuong Nguyen Nguyen Ngoc Le



#### **Exercise**

Apply DFS into the following graph.

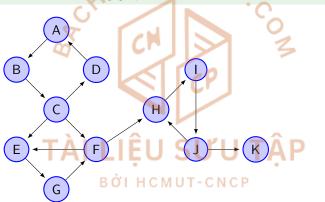


Huynh Tuong Nguyen Nguyen Ngoc Le



#### **Exercise**

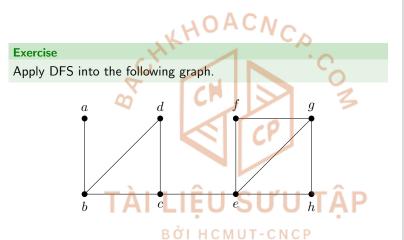
Apply DFS into the following graph.



Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le





Trees - DFS

Huynh Tuong Nguyen Nguyen Ngoc Le



