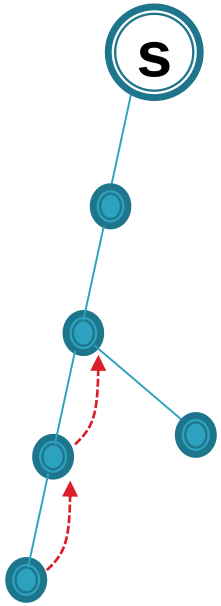
Parcurgerea în adâncime

Parcurgerea în adâncime



Parcurgerea în adâncime

Se vizitează

- **Inițial**: vârful de start s - devine vârf curent

Parcurgerea în adâncime

Se vizitează

- **Inițial**: vârful de start s - devine vârf curent
- **La un pas**:
  - se trece la primul vecin nevizitat al vârfului curent, **dacă există**

Parcurgerea în adâncime

Se vizitează

- **Inițial**: vârful de start s – devine vârf curent
- **La un pas**:
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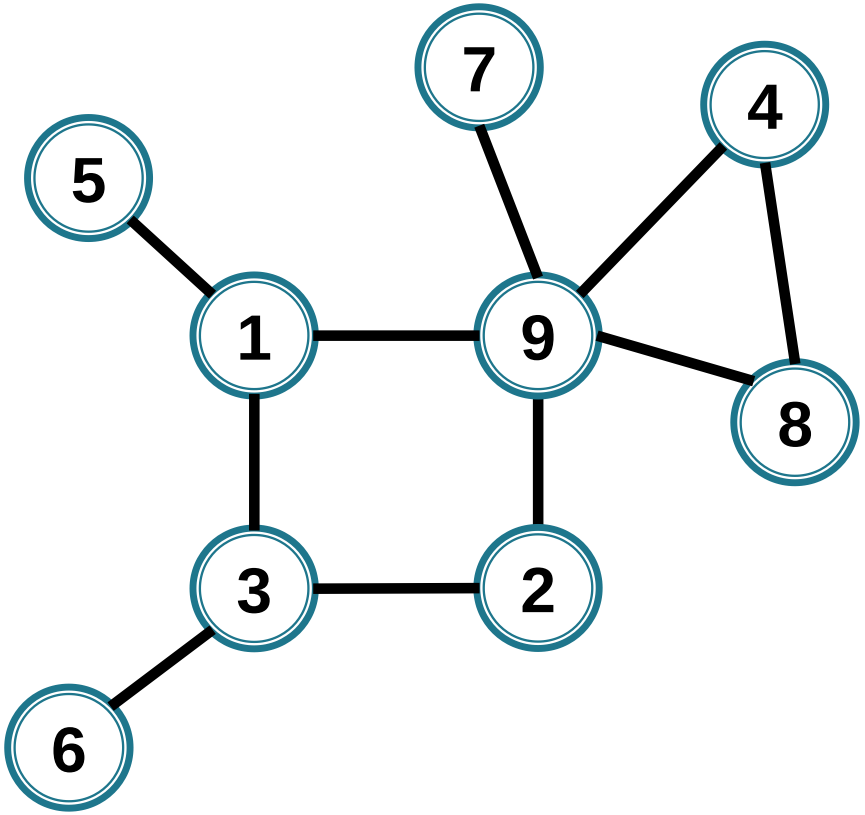
  - altfel
    - **se merge înapoi pe drumul de la s la vârful curent, până se ajunge la un vârf cu vecini nevizitați**
    -

Parcurgerea în adâncime

Se vizitează

- **Inițial**: vârful de start s – devine vârf curent
- **La un pas**:
  - se trece la primul vecin nevizitat al vârfului curent, **dacă există**
  - altfel
    - **se merge înapoi pe drumul de la s la vârful curent, până se ajunge la un vârf cu vecini nevizitați**
    - **se trece la primul dintre aceștia și se reia procesul**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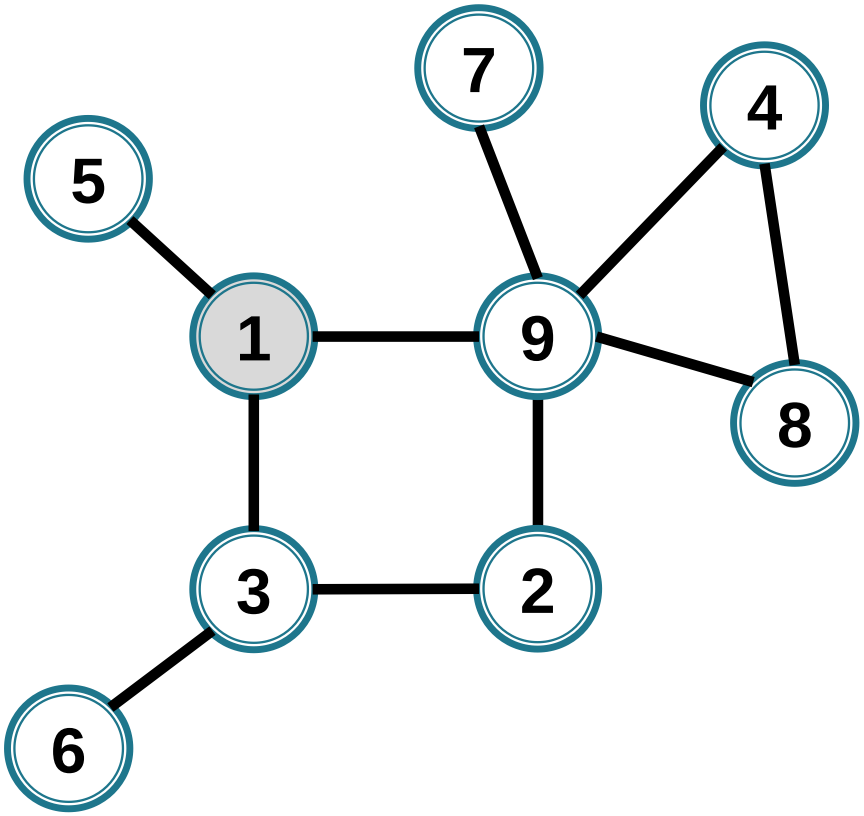
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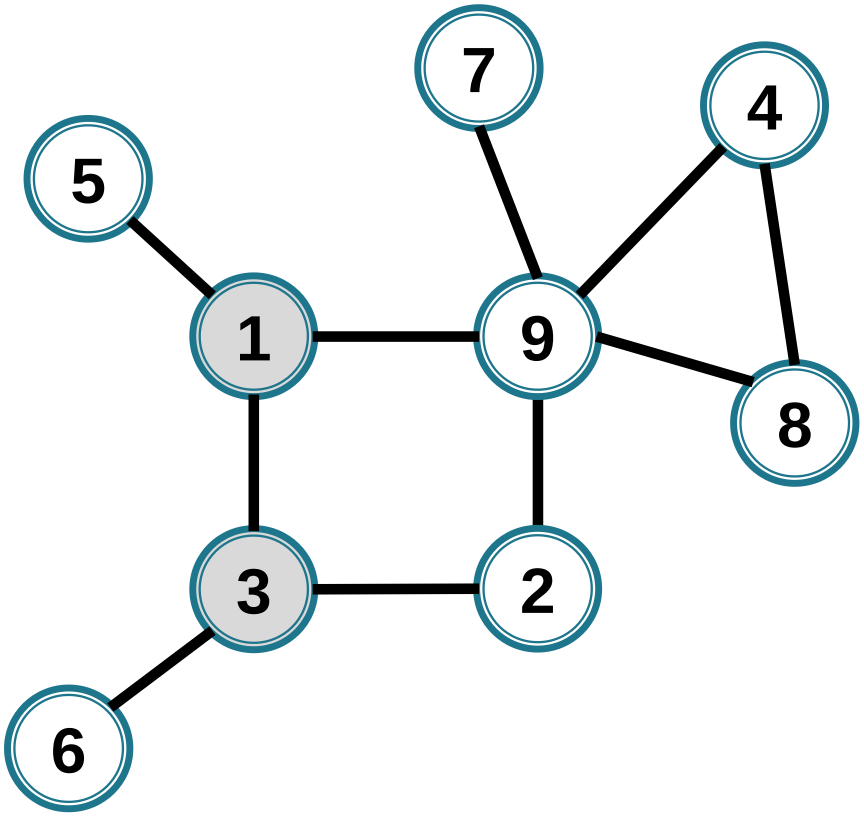
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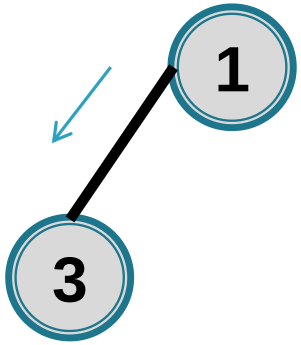
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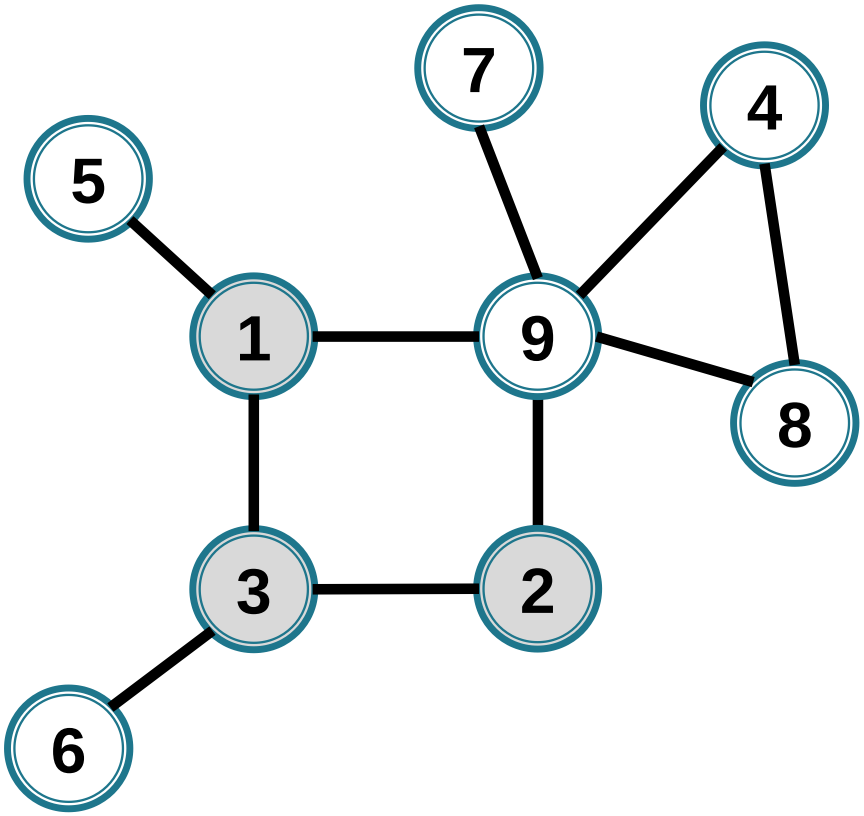
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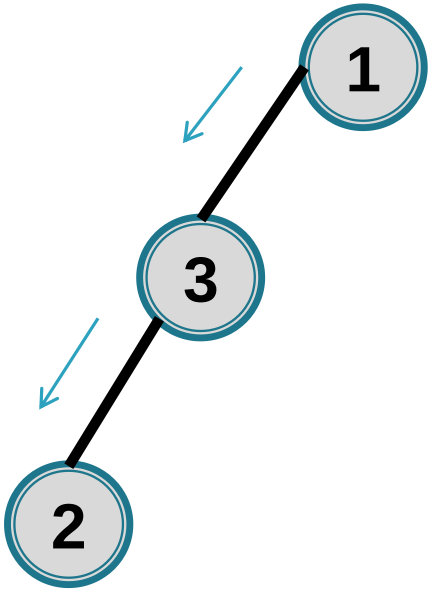
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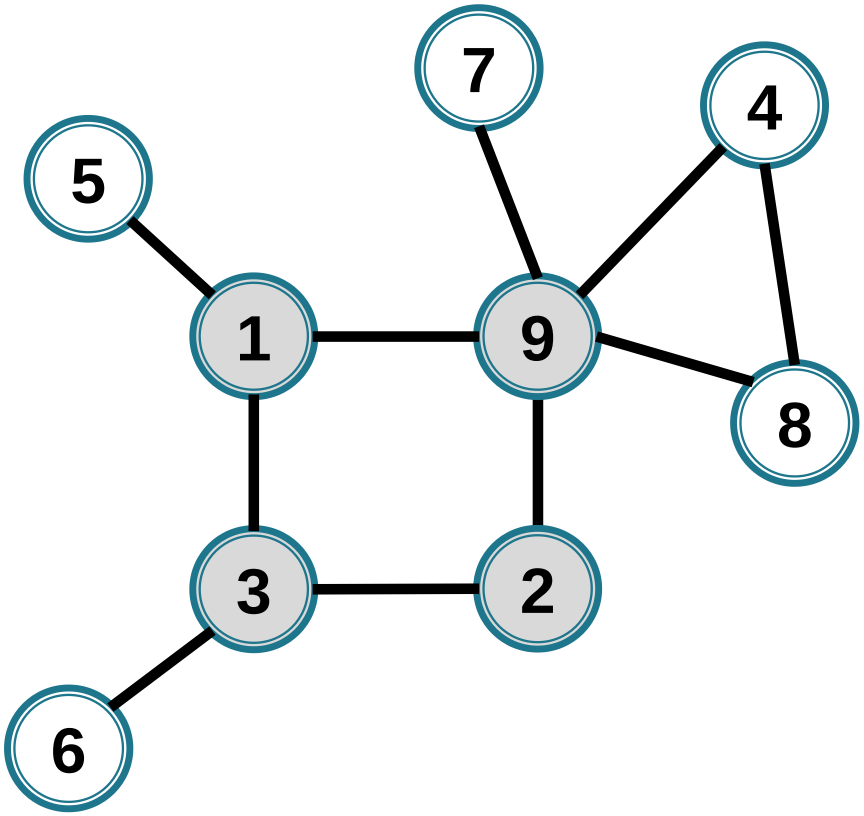
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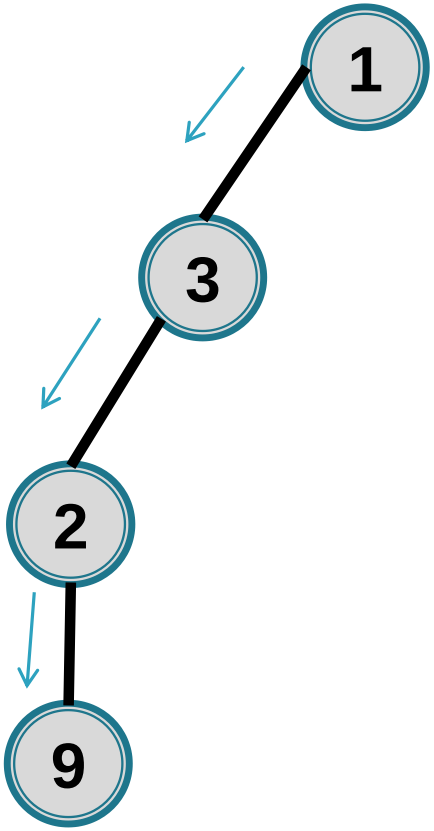
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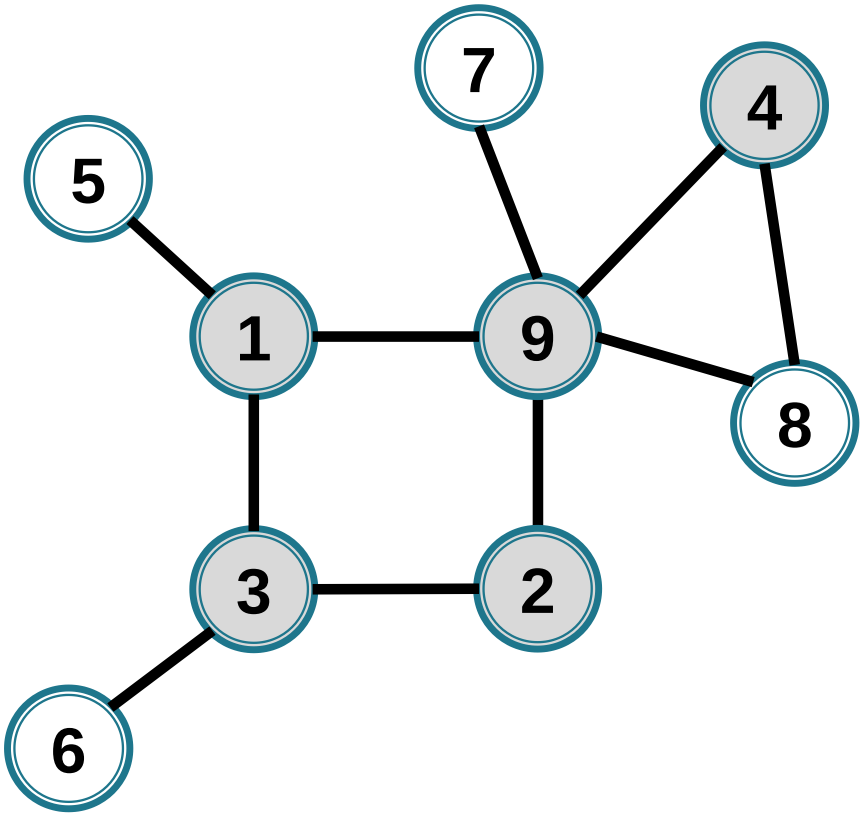
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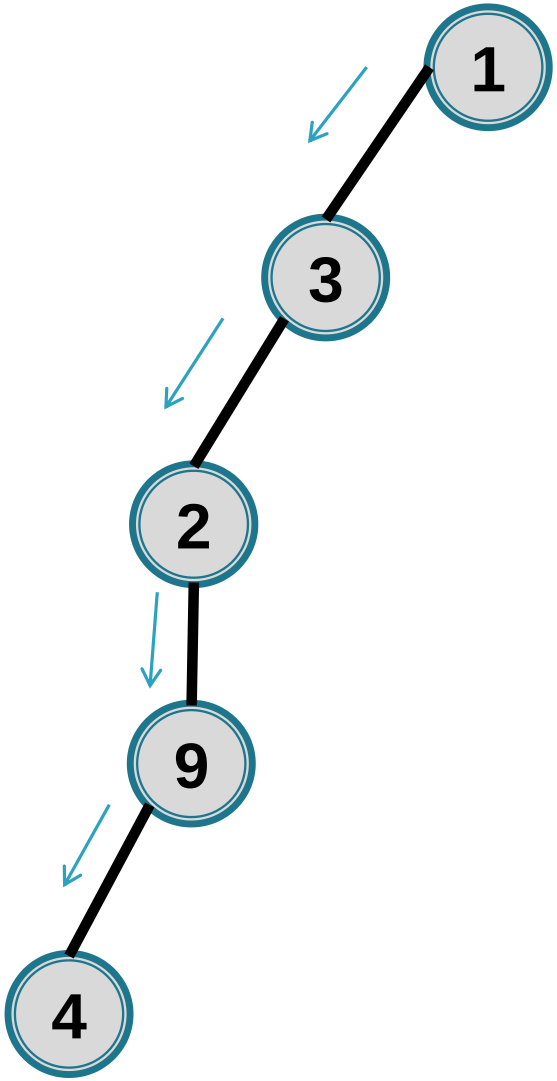
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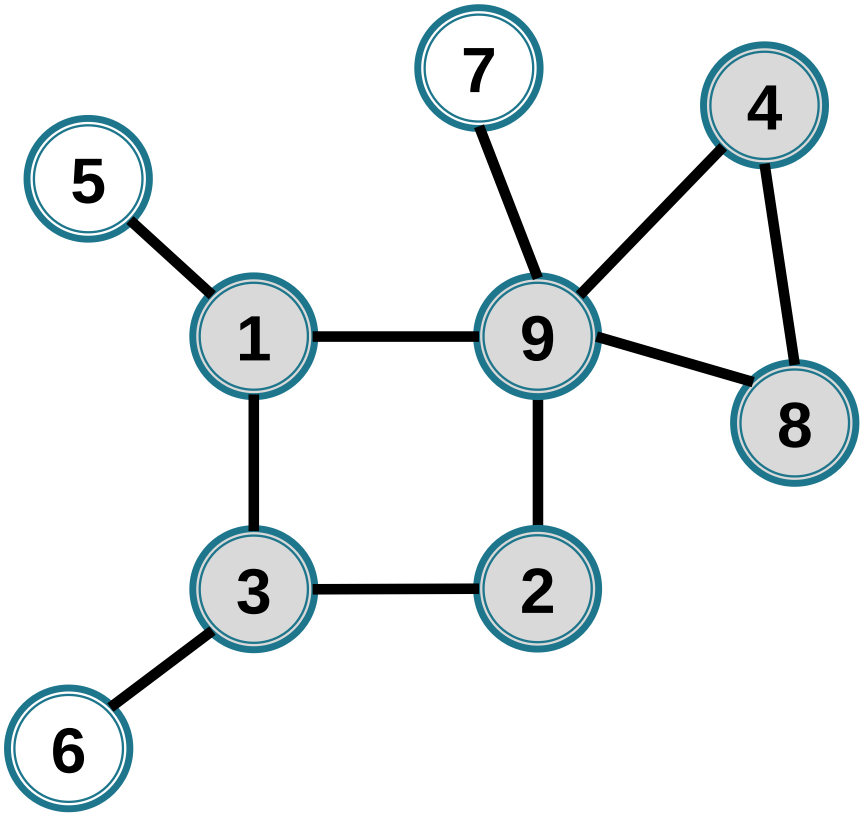
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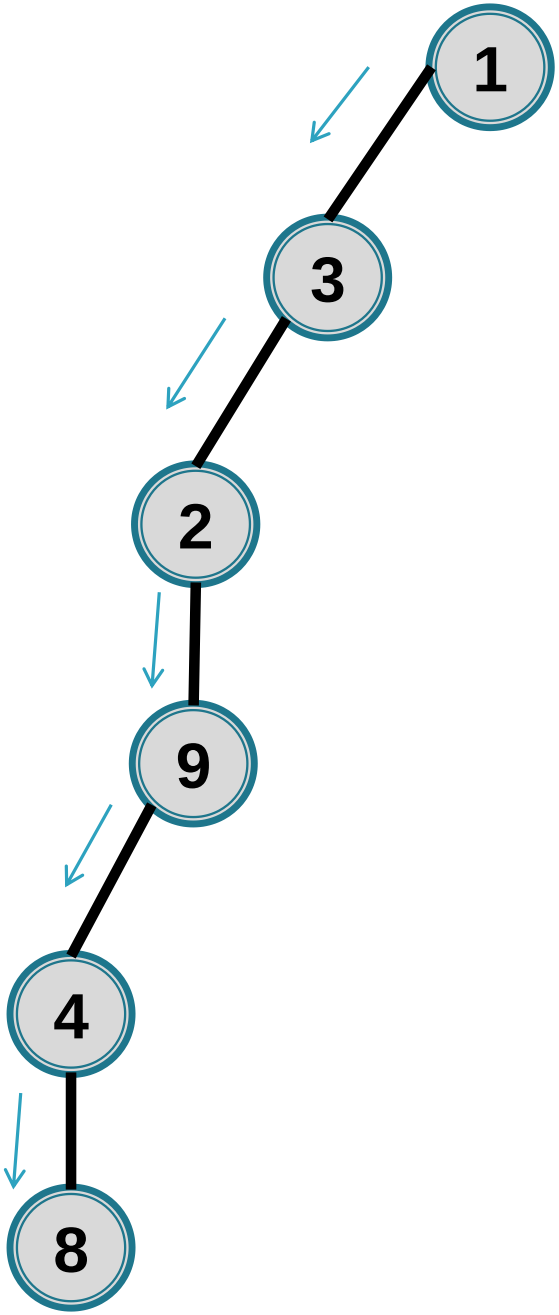
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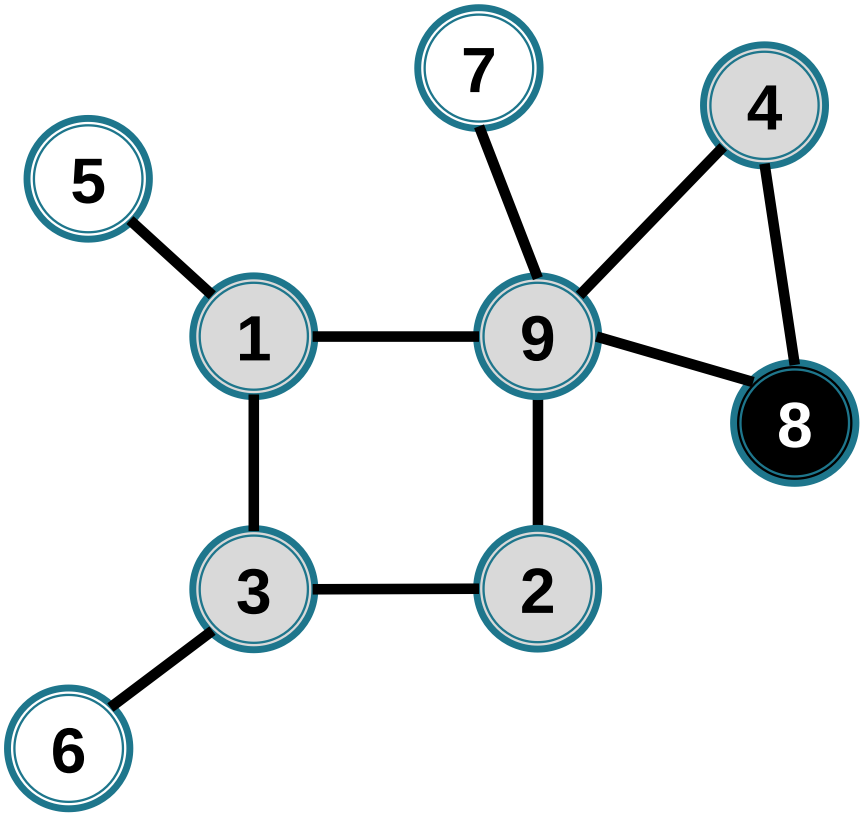
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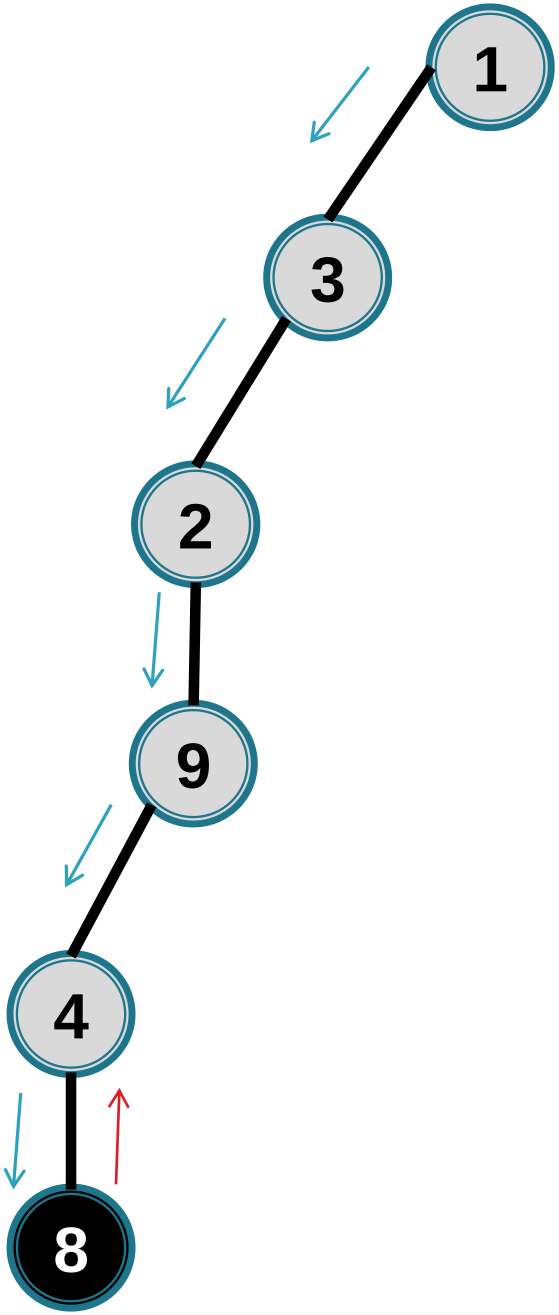
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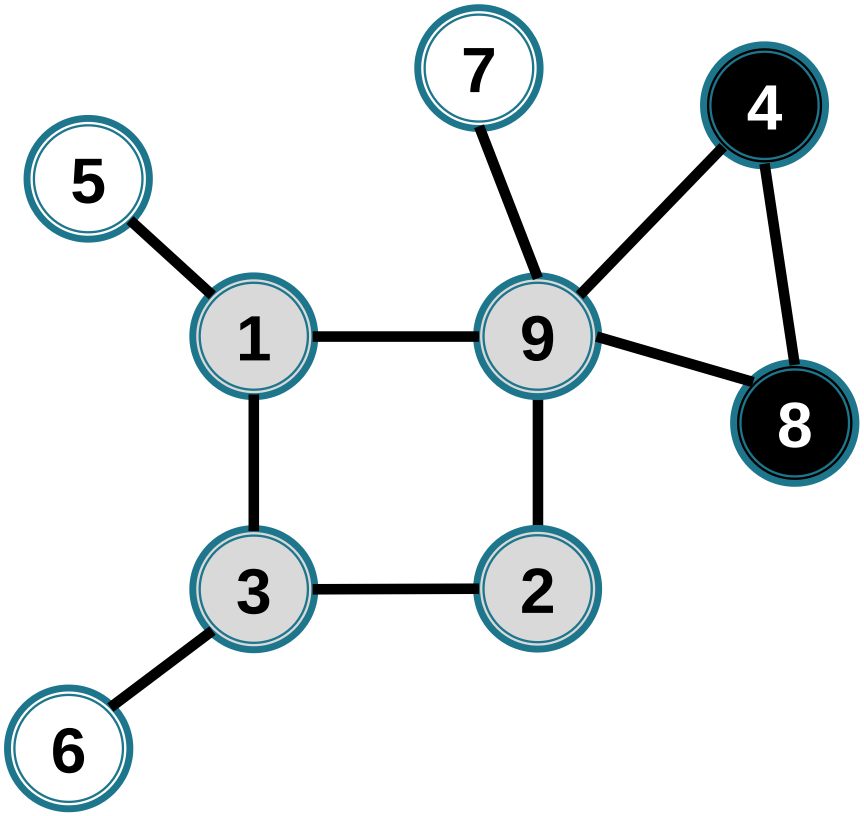
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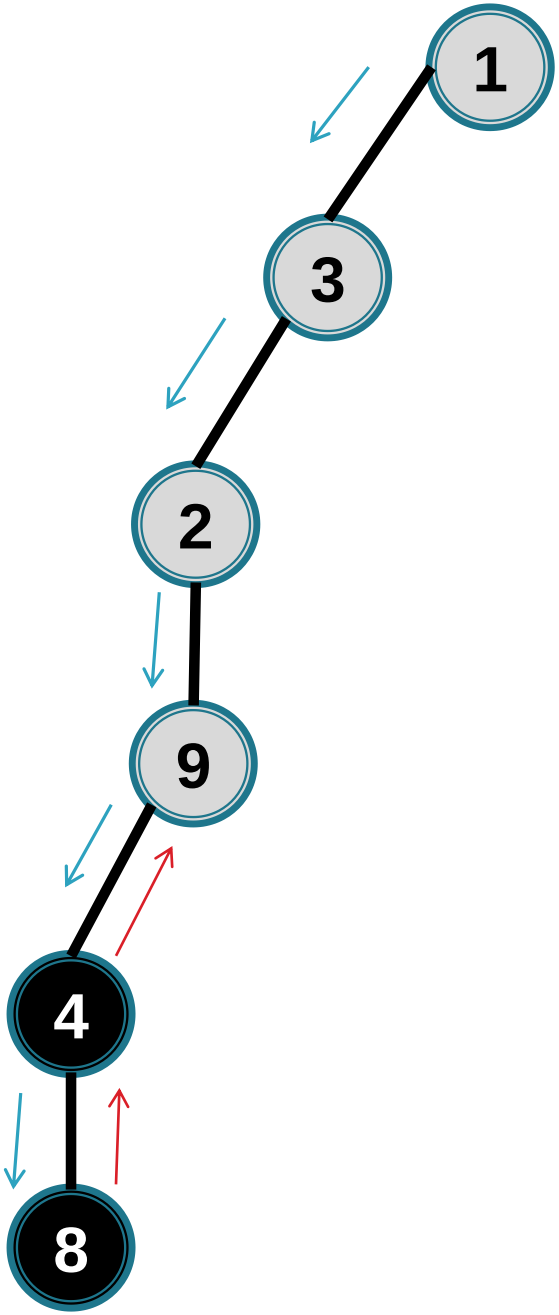
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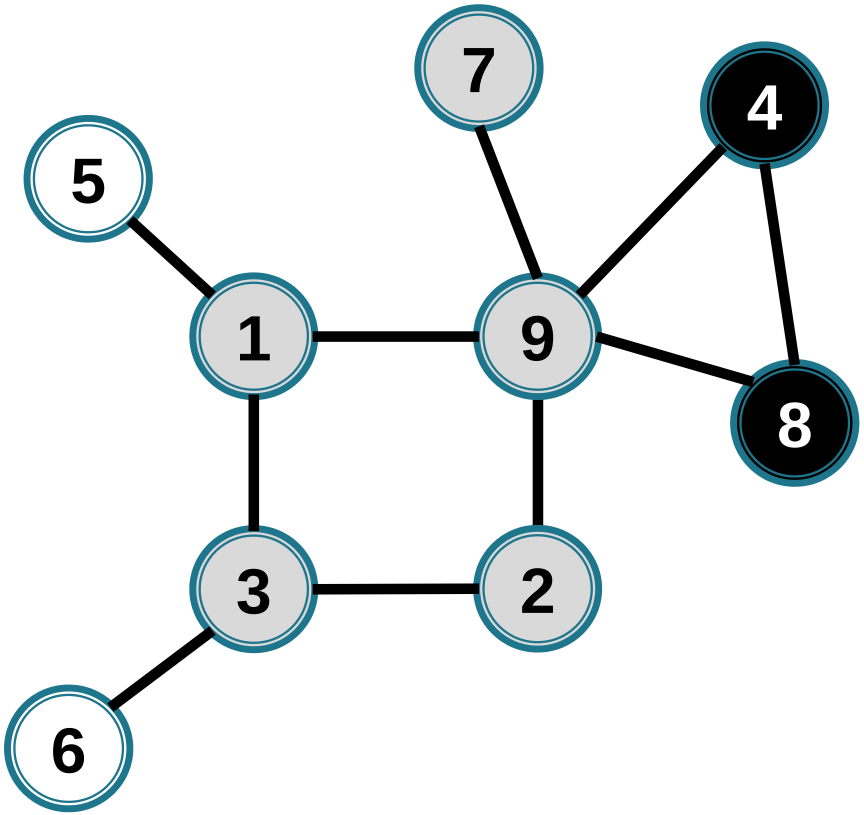
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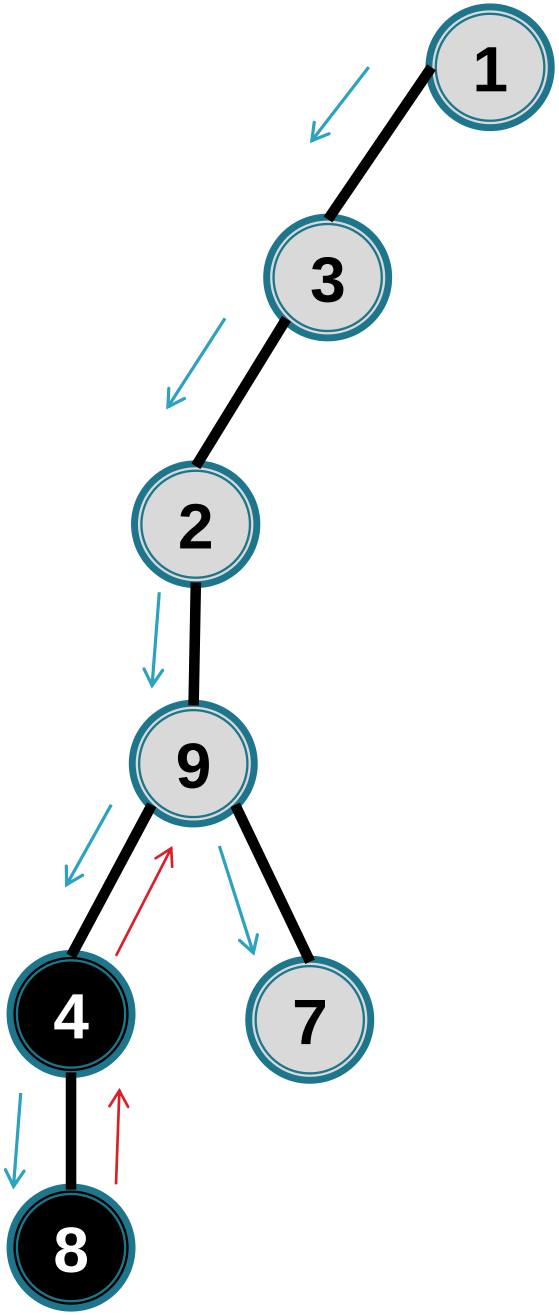
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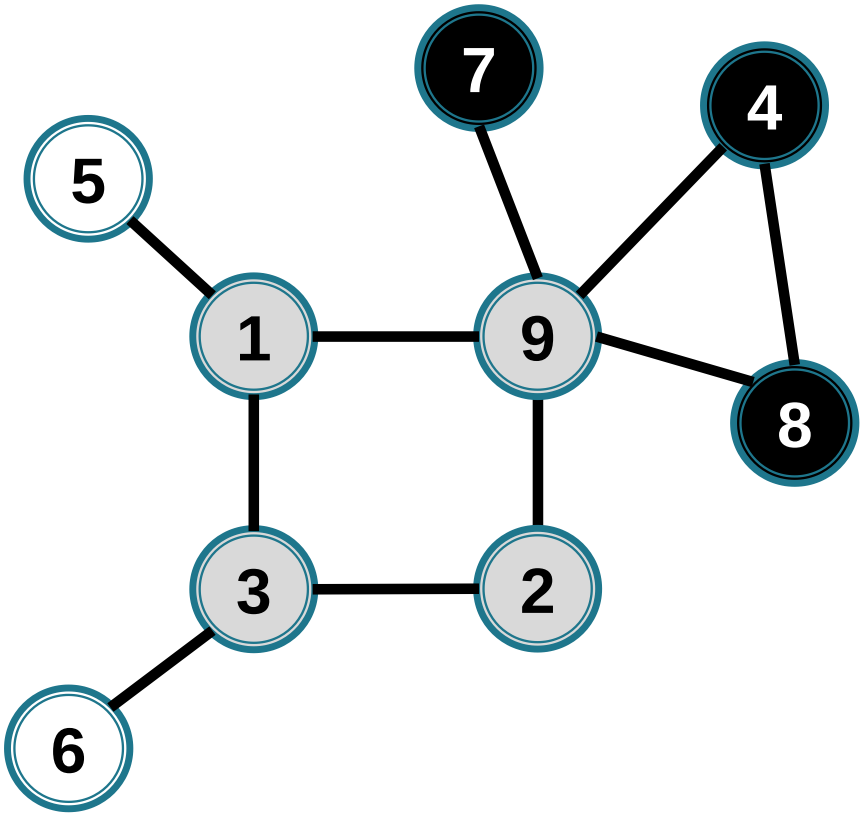
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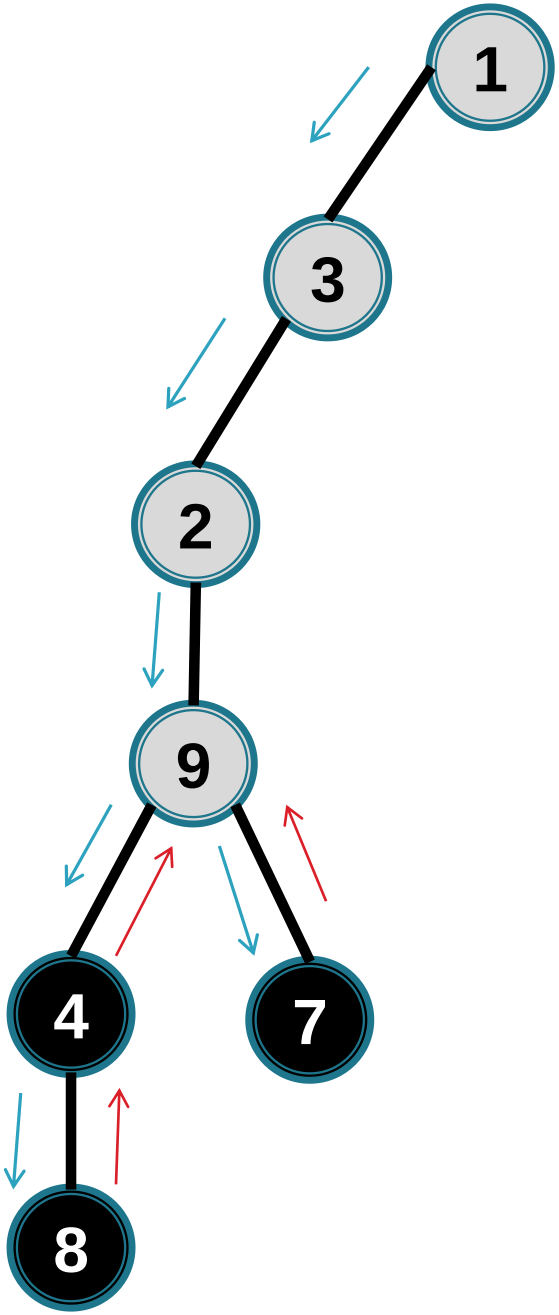
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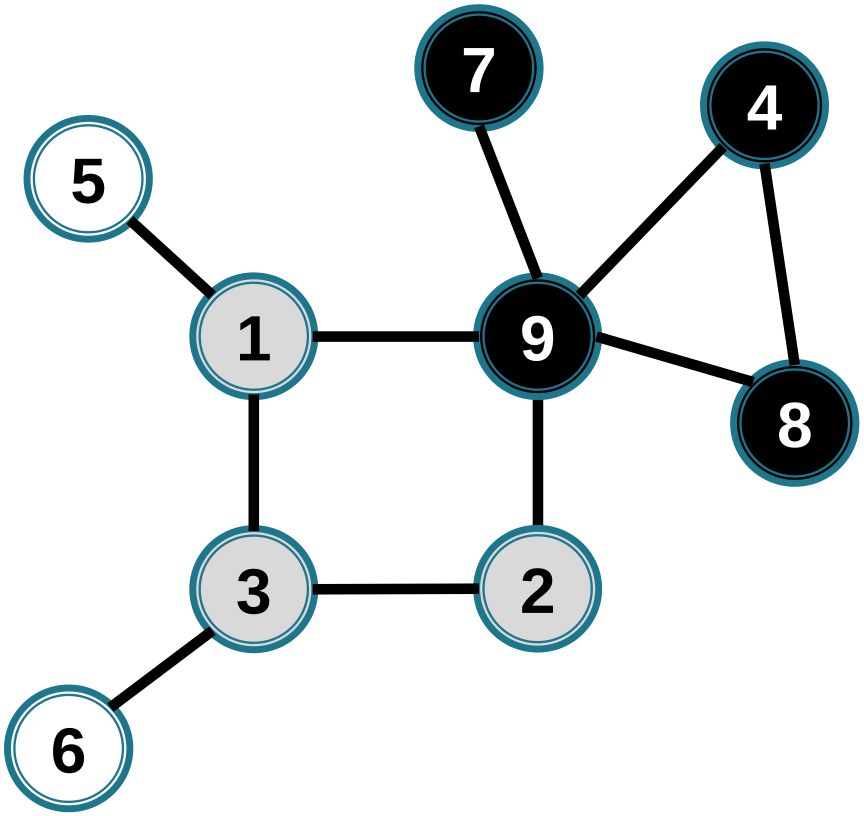
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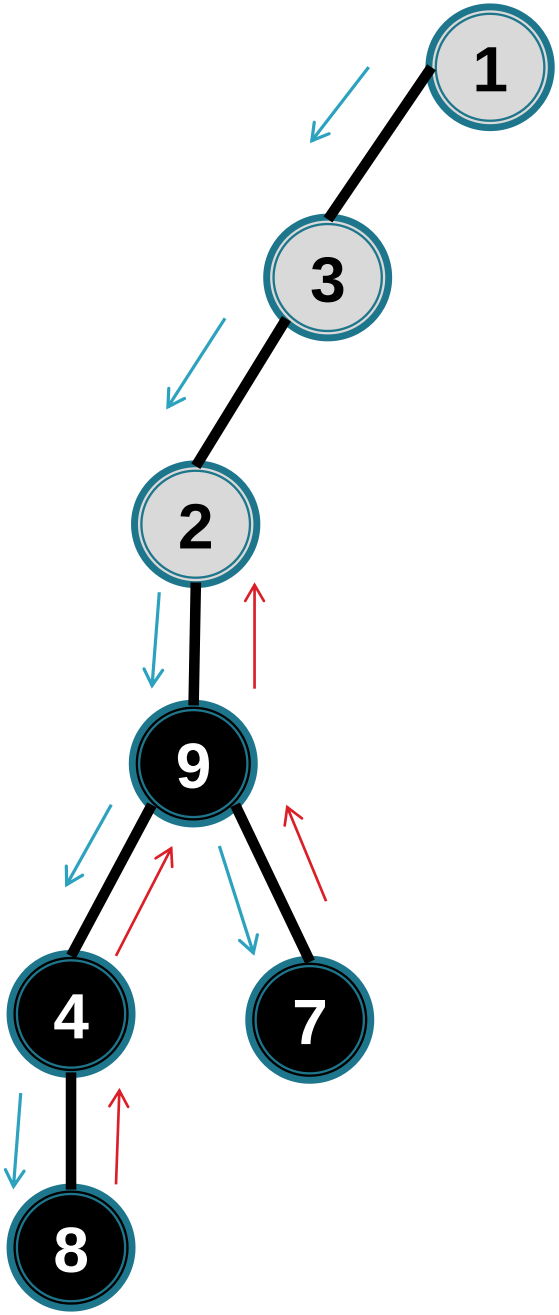
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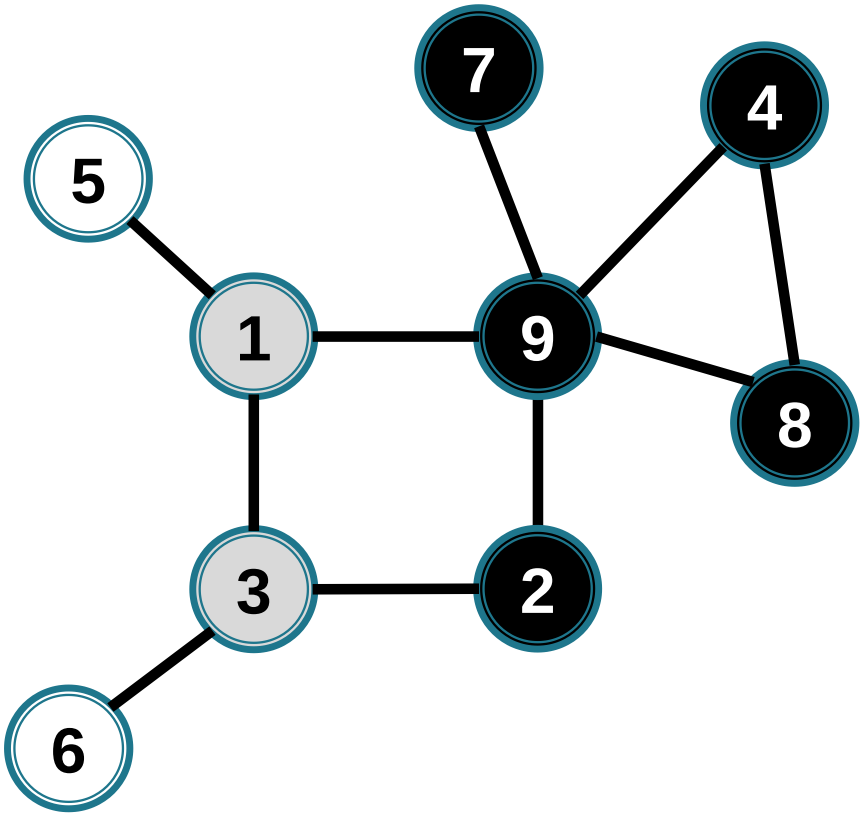
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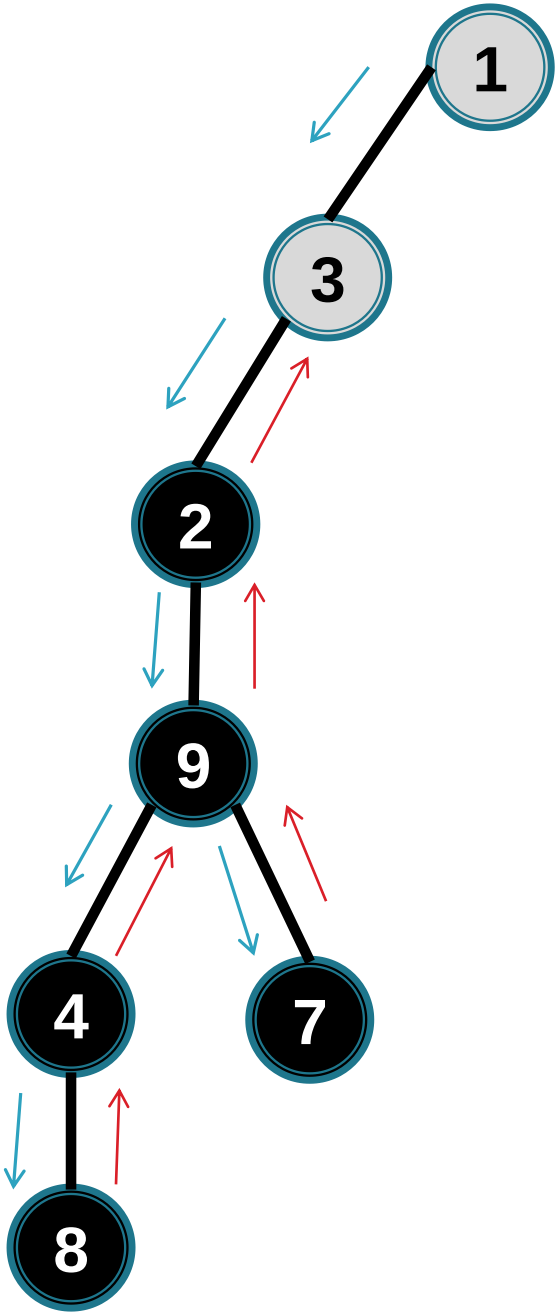
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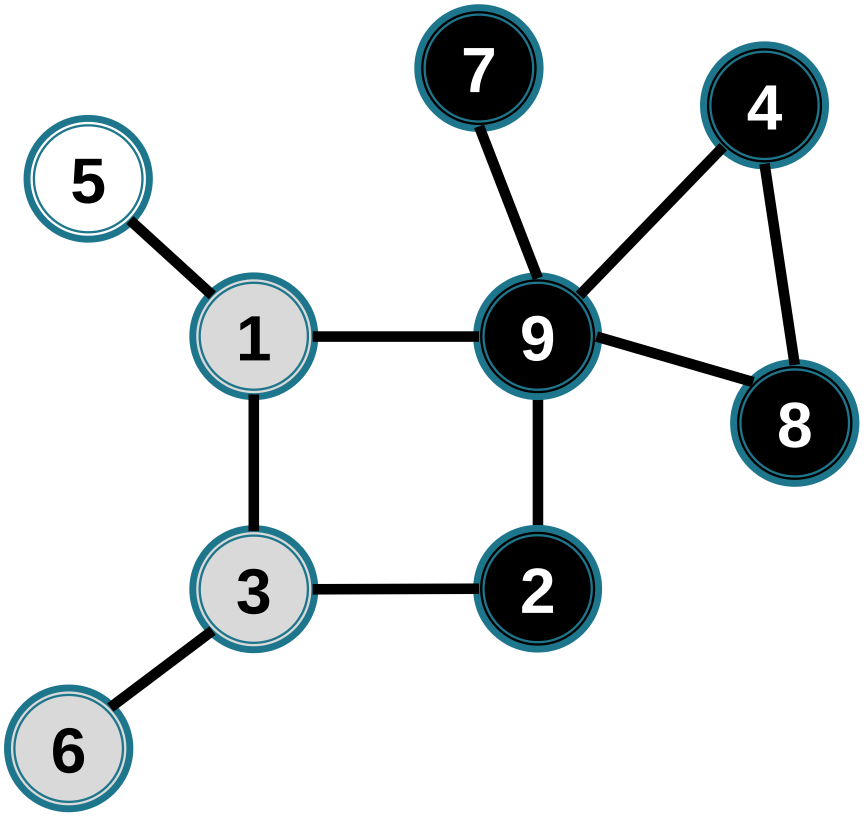
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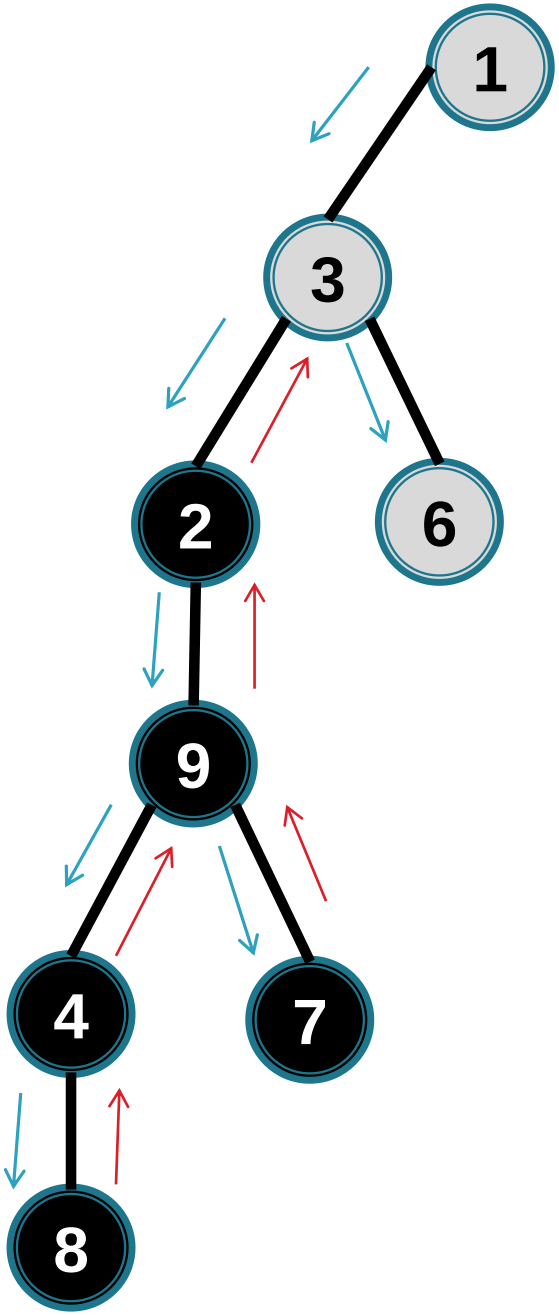
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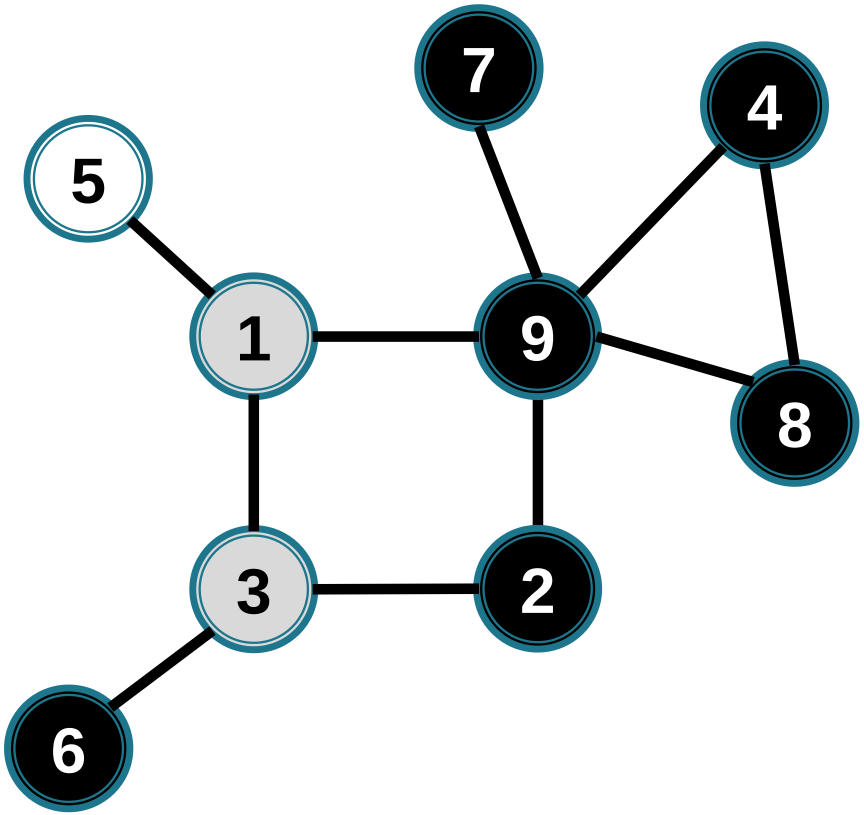
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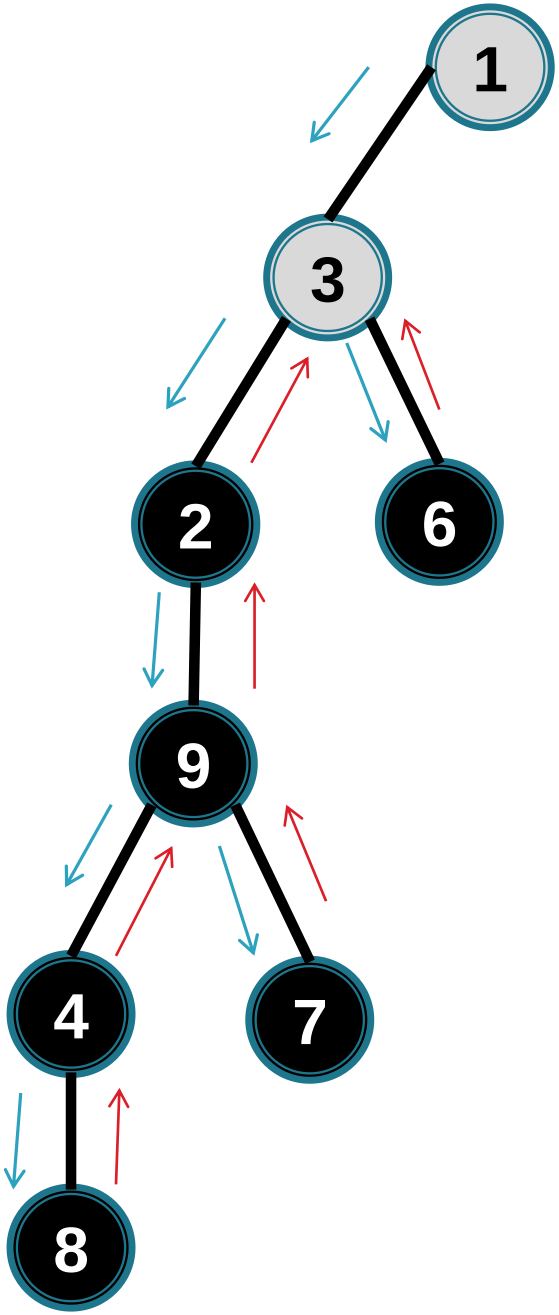
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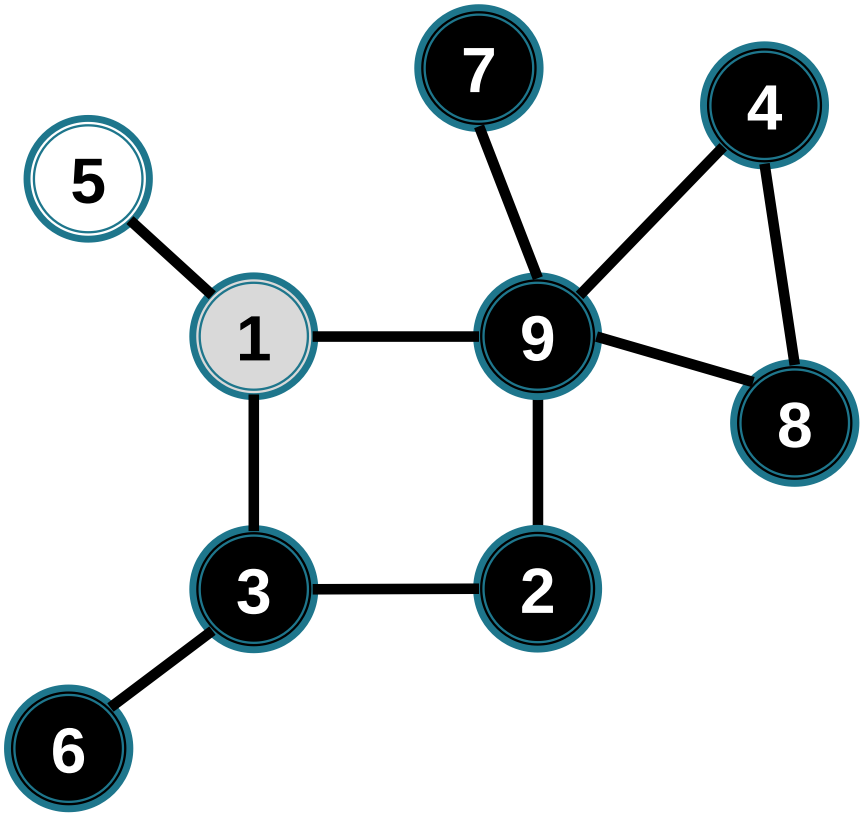
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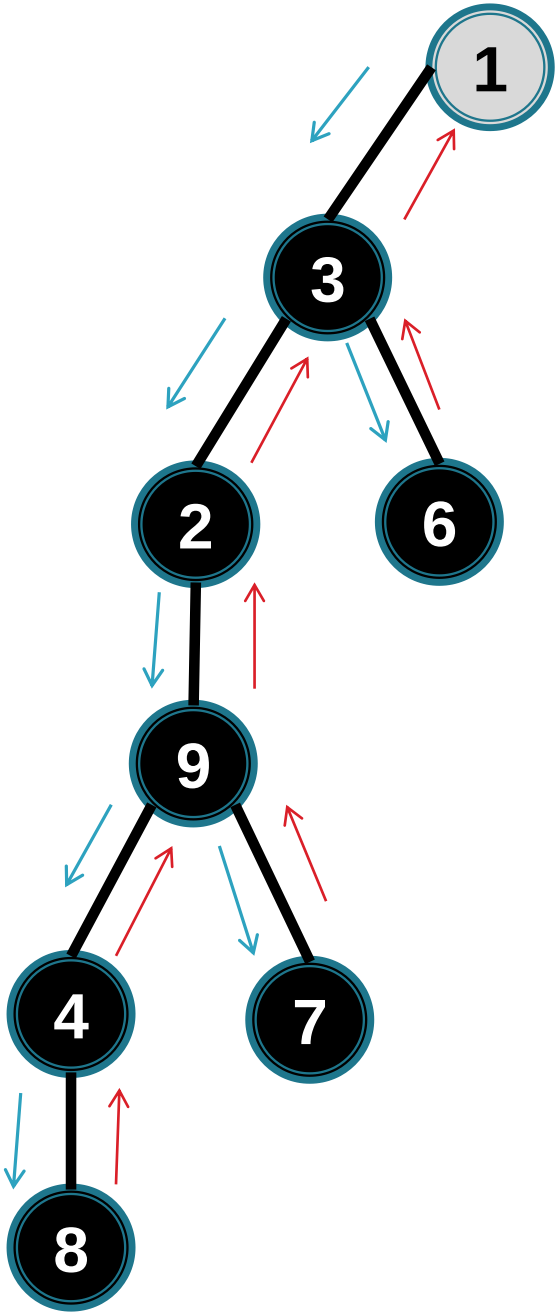
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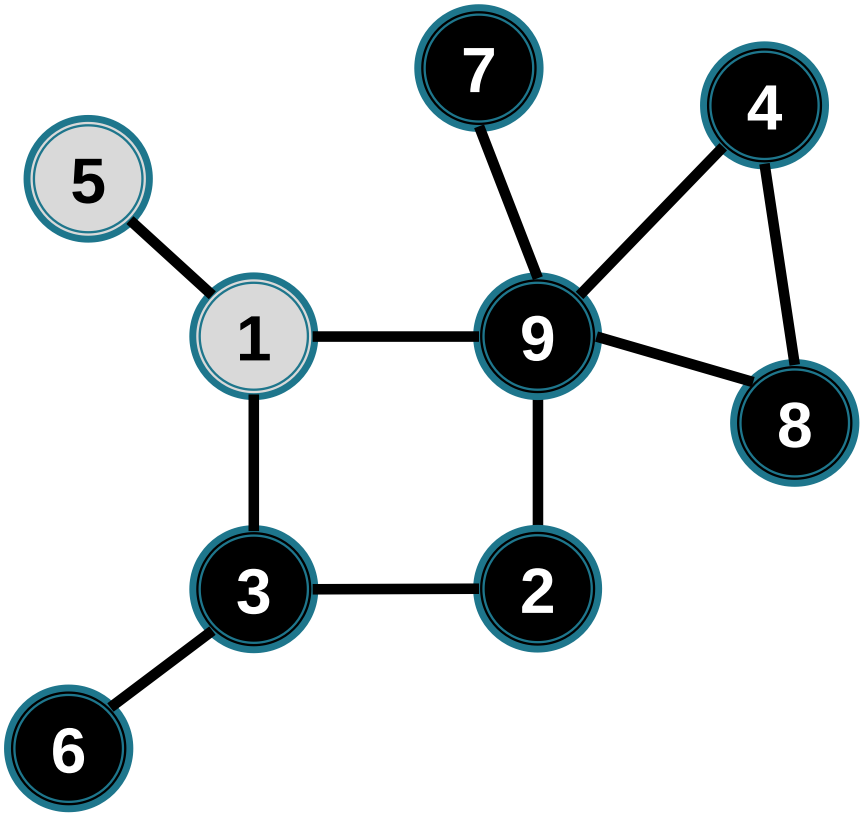
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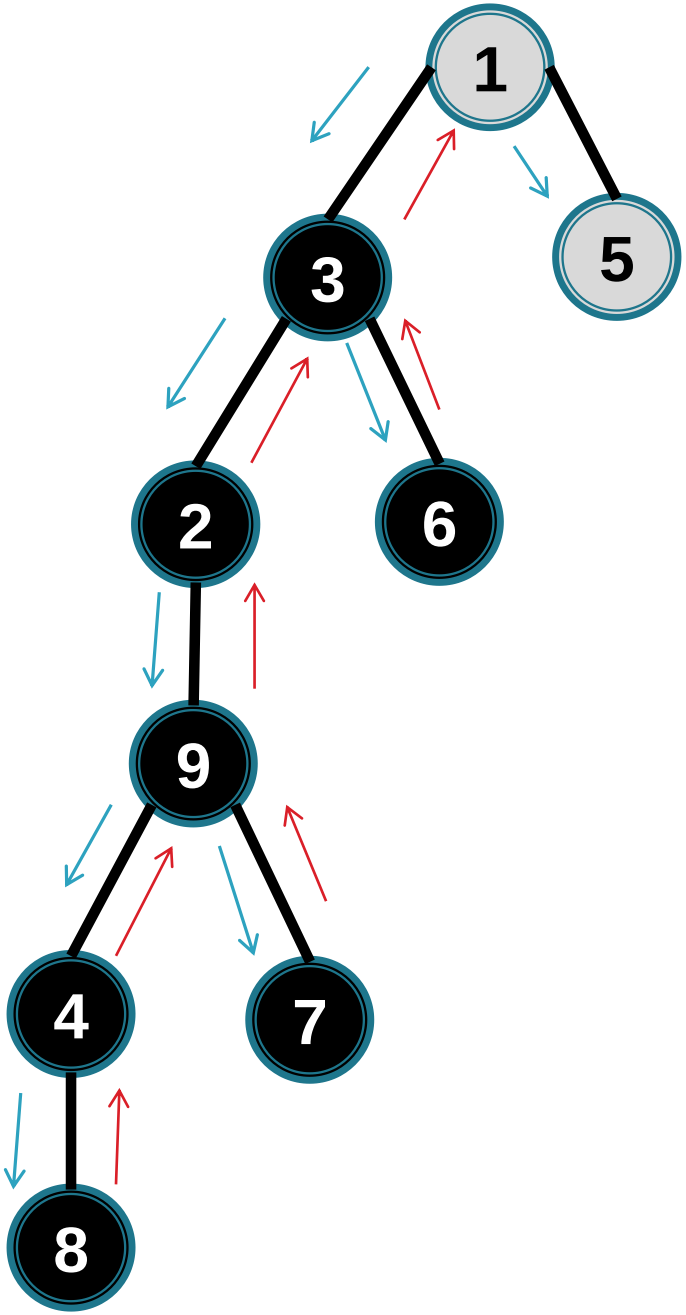
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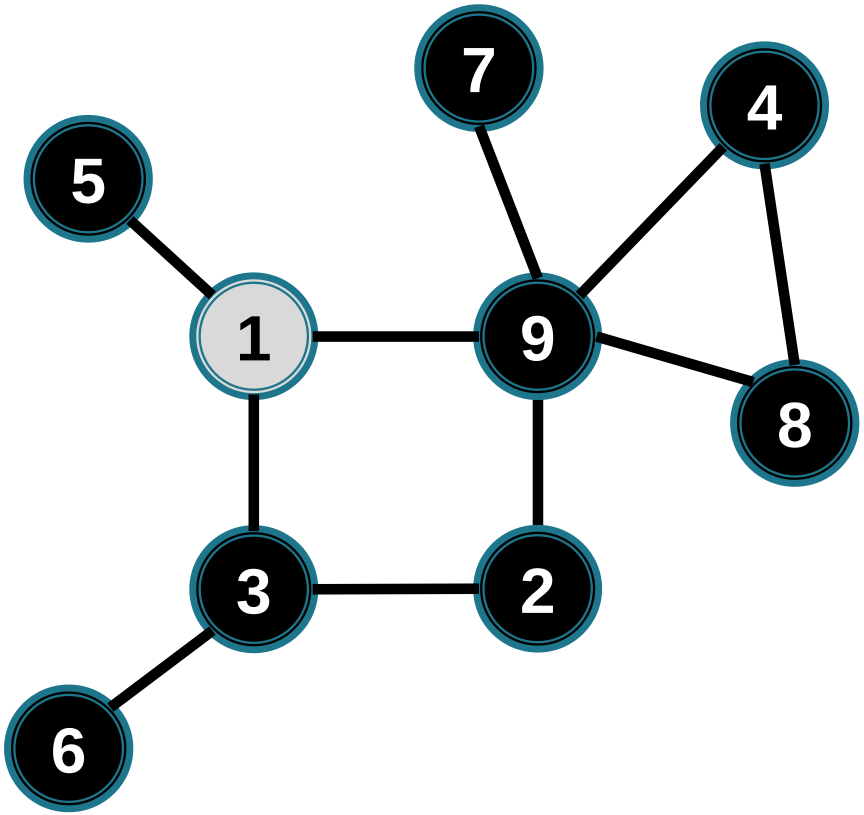
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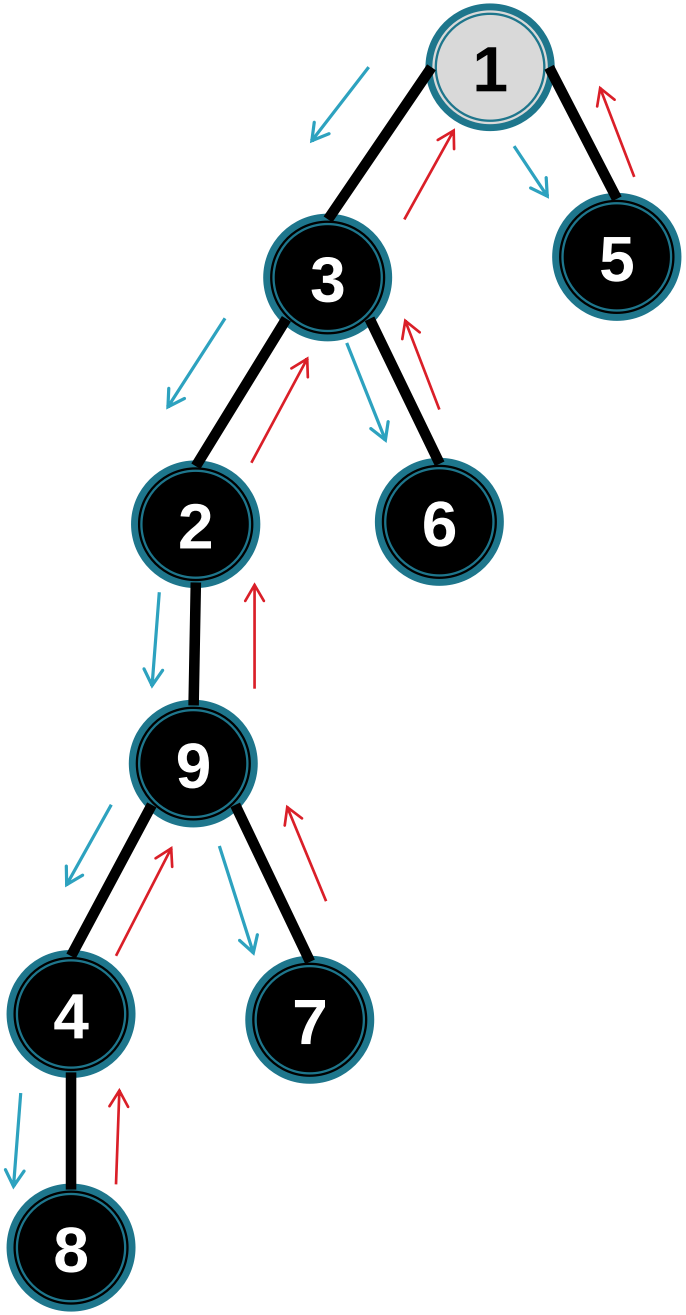
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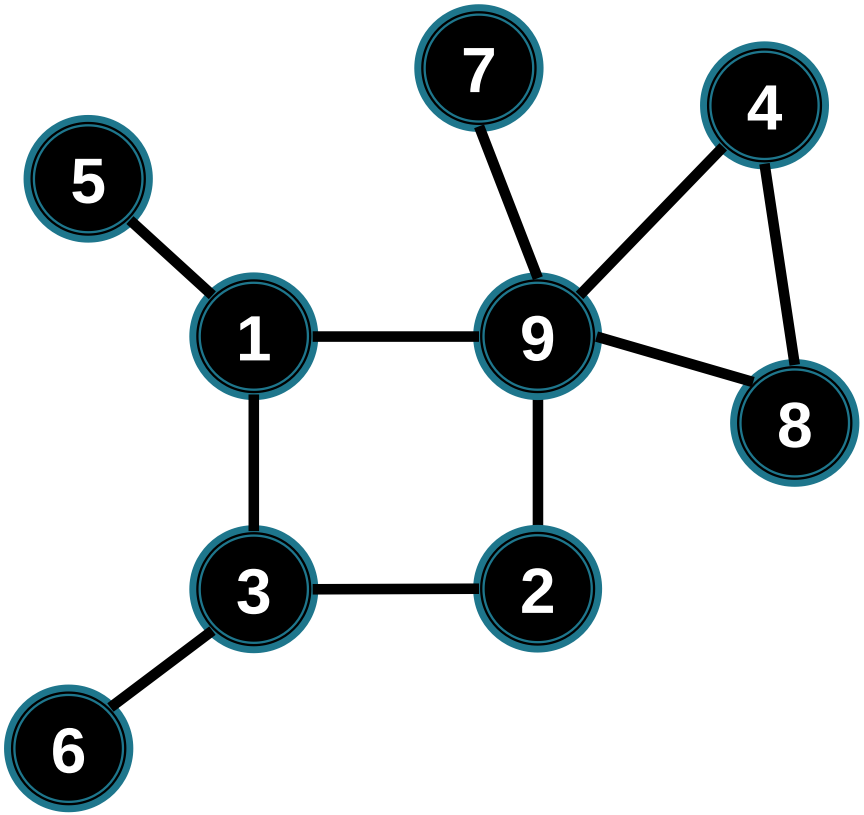
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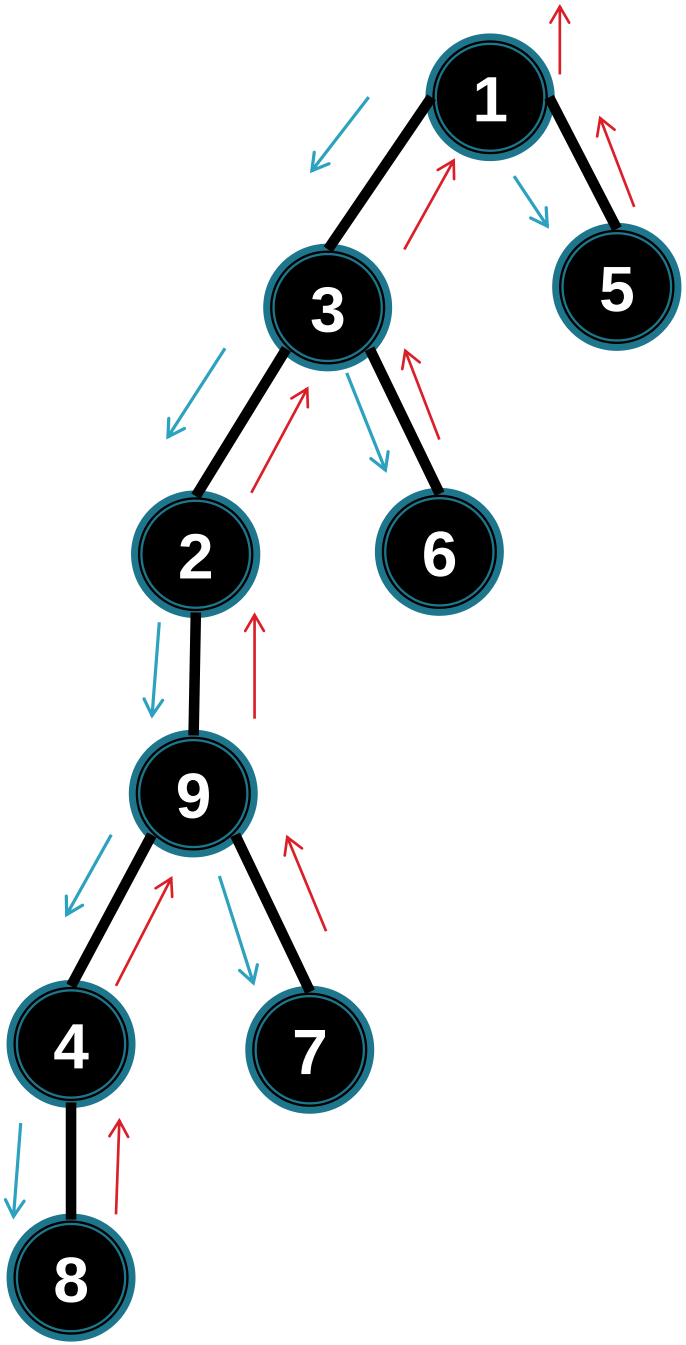
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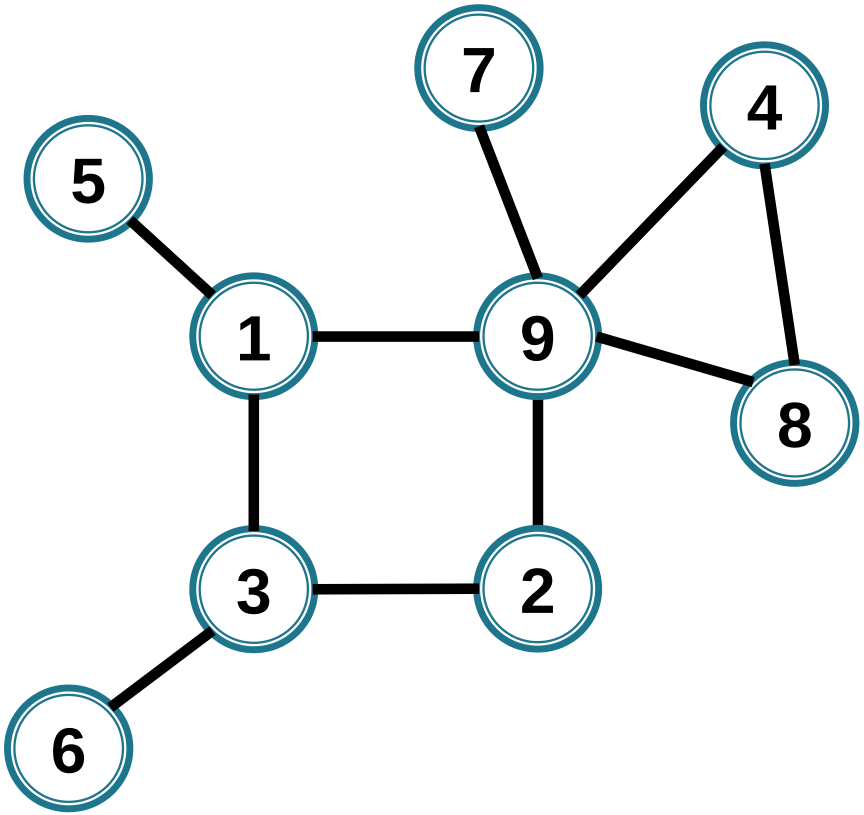
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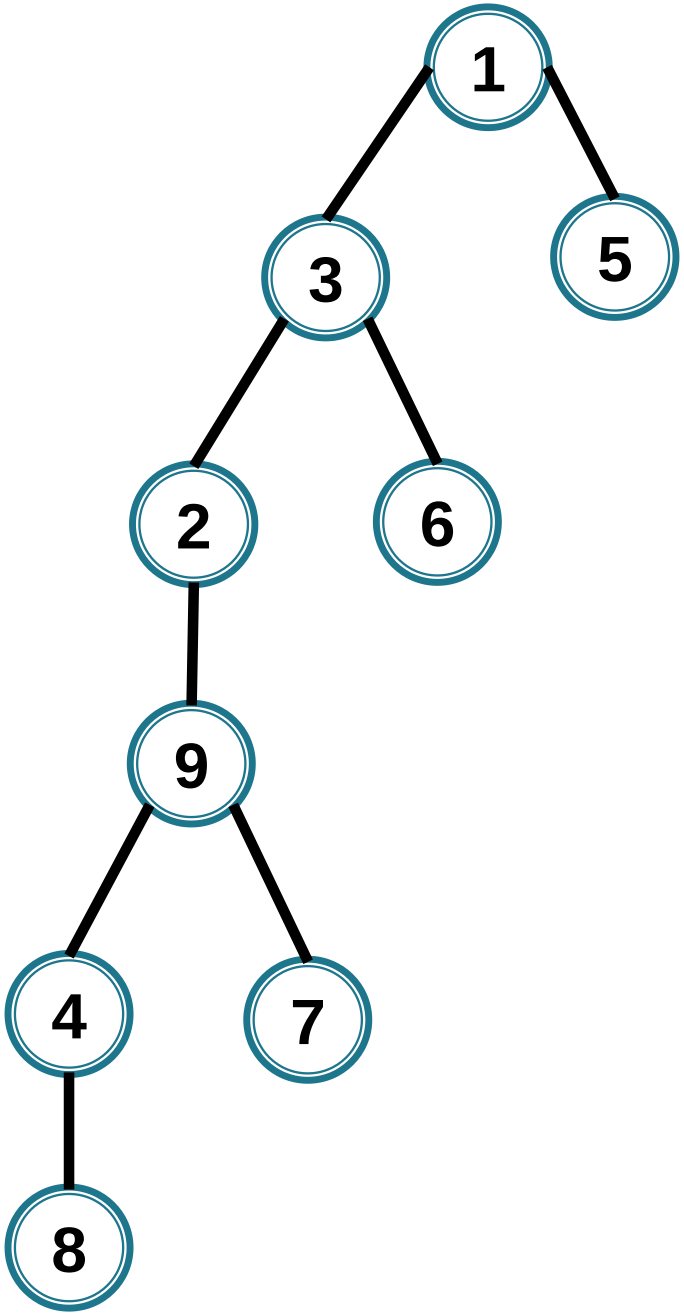
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```
DFS(x)
     //incepe explorarea varfului x
     viz[x] = 1
     pentru fiecare  xy ∈ E //y vecin al lui x
        daca viz[y]==0 atunci
              tata[y] = x
              d[y] = d[x]+1 //nivel, nu distanta
              DFS(y)
      //s-a finalizat explorarea varfului x
```

x alb

x gri

x negru

Apel:

```
DFS(s)
```

Proprietăți

Proprietăți DF

Starea unui vârf:

- **nevizitat** – culoarea albă
- **în explorare** – culoare gri
- **finalizat** – culoare neagră

Proprietăți DF

Dacă menținem pe parcursul algoritmului o variabilă de timp care se modifică atunci când se schimbă starea unui vârf (îl descoperim sau îl finalizăm), putem asocia fiecărui vârf două valori:

- desc[v] – momentul la care vârful a fost descoperit
  (a devenit **gri**)
- fin[v] – momentul la care vârful a fost finalizat
  (a devenit **negru**)

Proprietăți DF

Dacă dorim determinarea unor elemente de structură în graf precum circuite, componente tare conexe etc poate fi util să memorăm în parcurgerea DFS culoarea fiecărui vârf și/sau momentul în care a fost descoperit sau finalizat.

Dacă memorăm culoarea fiecărui vârf, nu mai este necesar și vectorul vizitat, deoarece

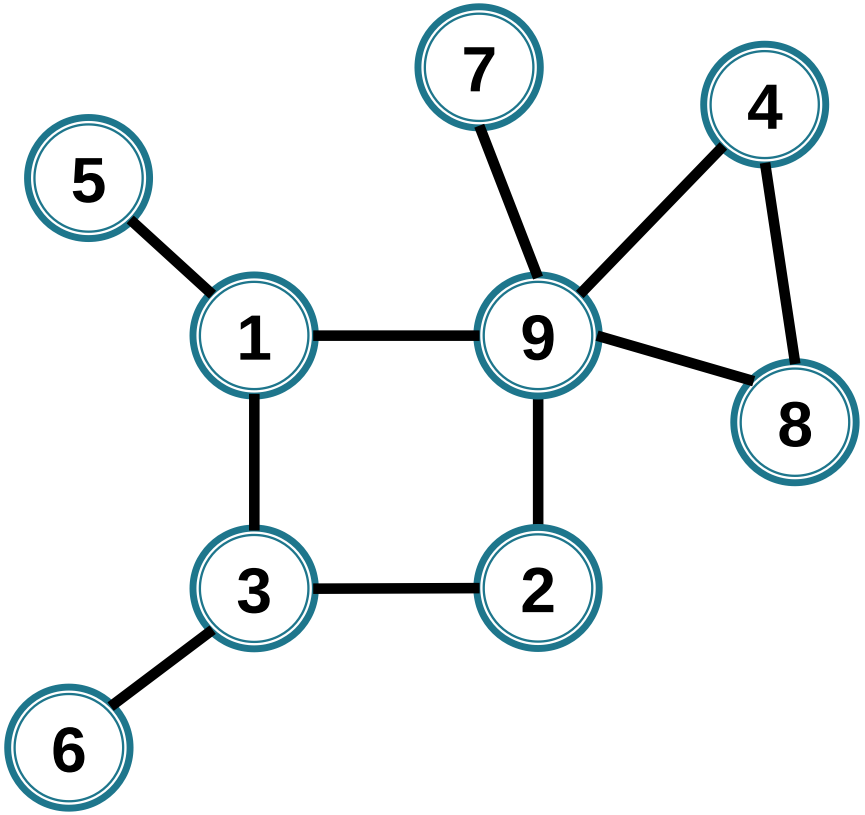
$$viz[x] = 0 \Leftrightarrow culoare[x] = alb$$

Un pseudocod complet în acest caz este următorul:

```
DFS(x)
      culoare[x] = gri
      timp = timp + 1
      desc[x]= timp;//incepe explorarea varfului x
      pentru fiecare  xy ∈ E //y vecin al lui x
        daca culoare[y]==alb atunci
              tata[y] = x
              d[y] = d[x]+1 //nivel, nu distanta
              DFS(y)
      culoare[x] = negru
      timp = timp + 1
      fin[x] = timp //s-a finalizat explorarea varfului x
```

Apel:

```
pentru fiecare x in V executa
      culoare[x] = alb
timp = 0
pentru fiecare x in V executa
       daca culoare[x] == alb atunci
           DFS(x)
```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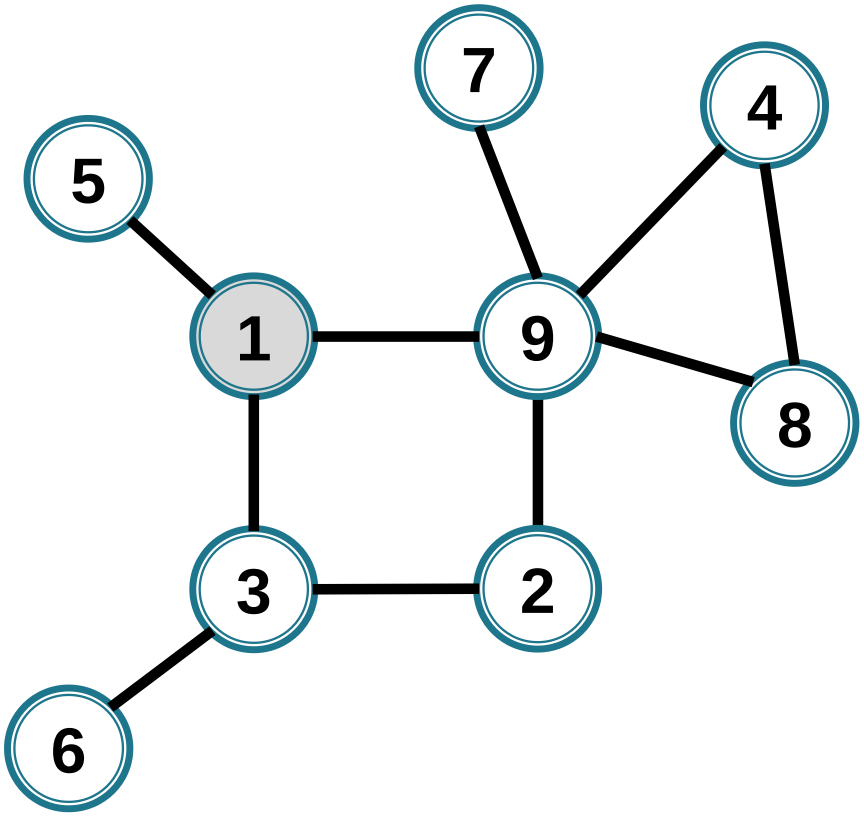

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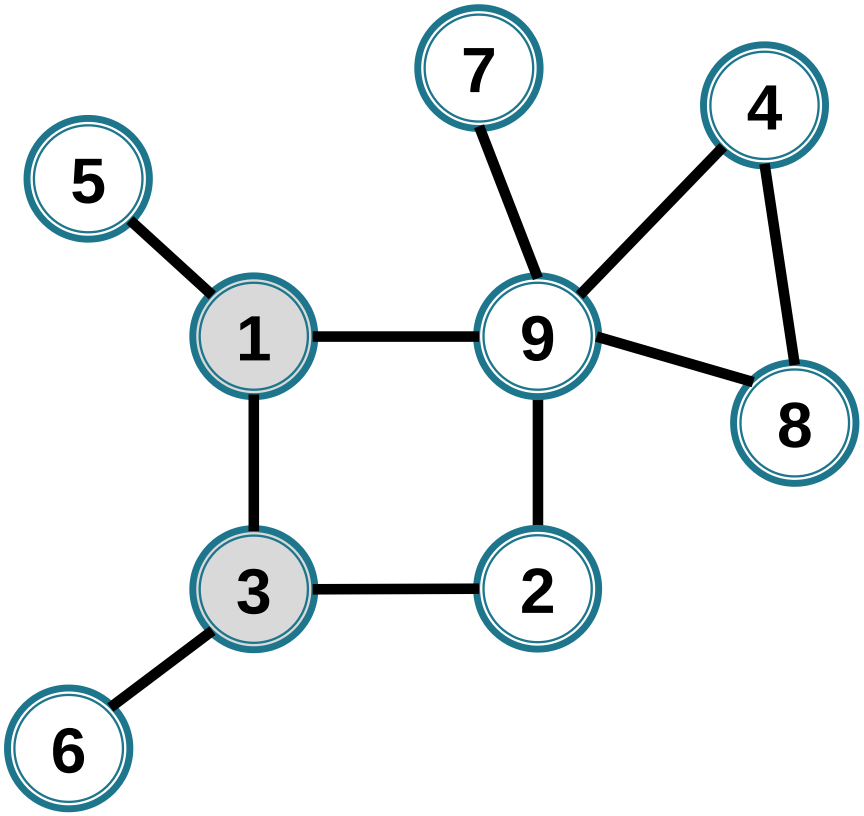
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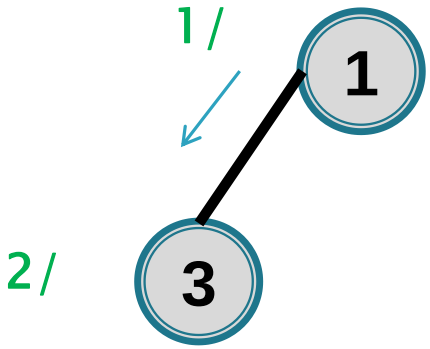
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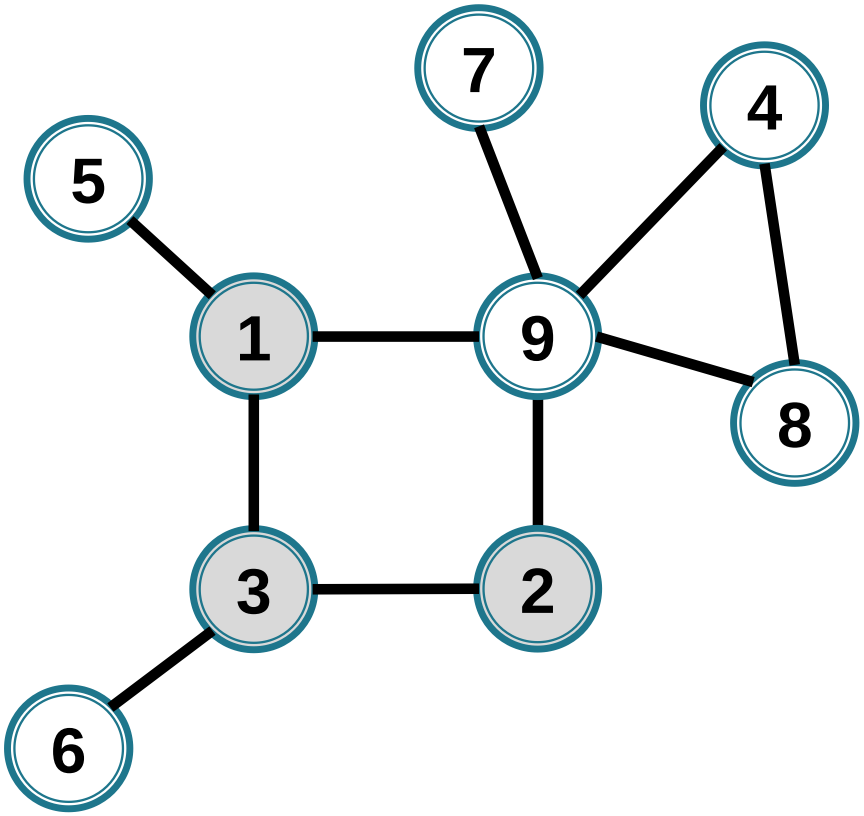
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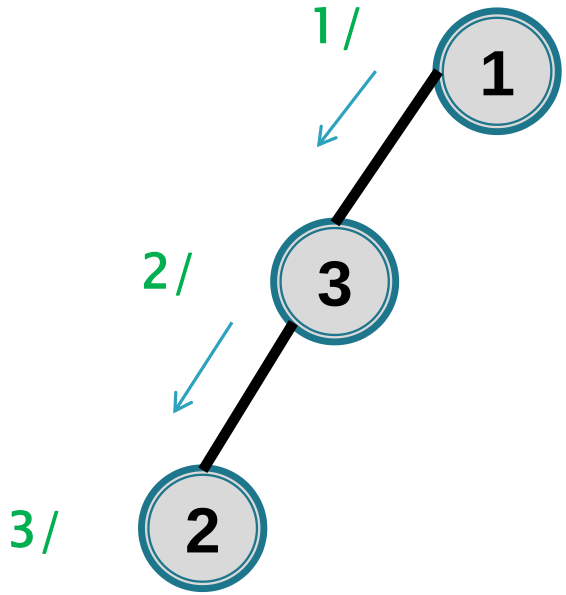
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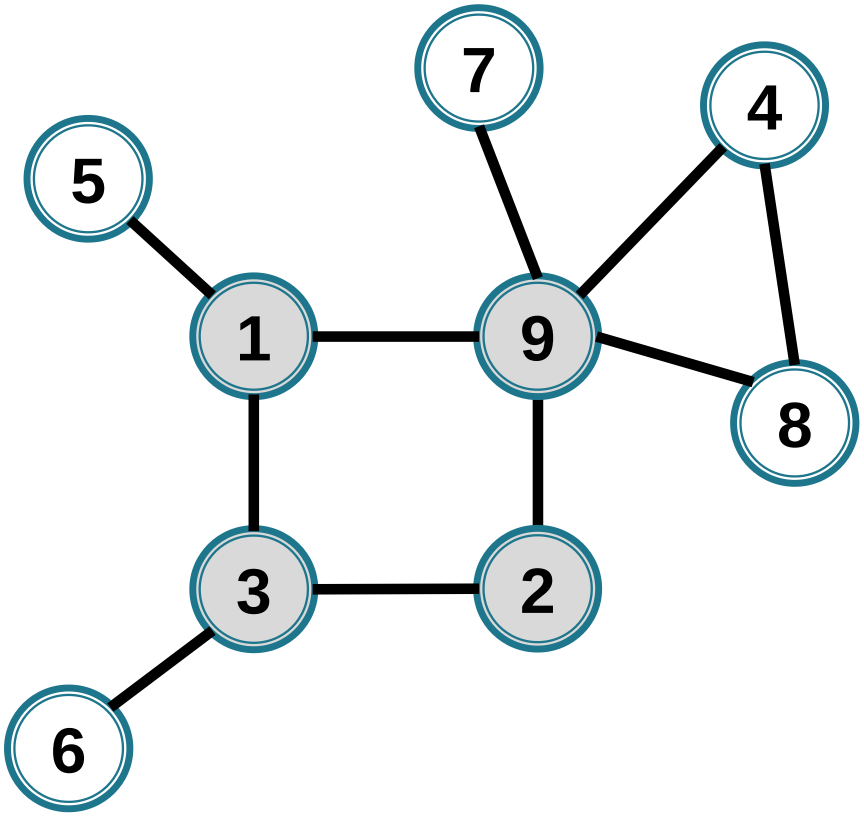
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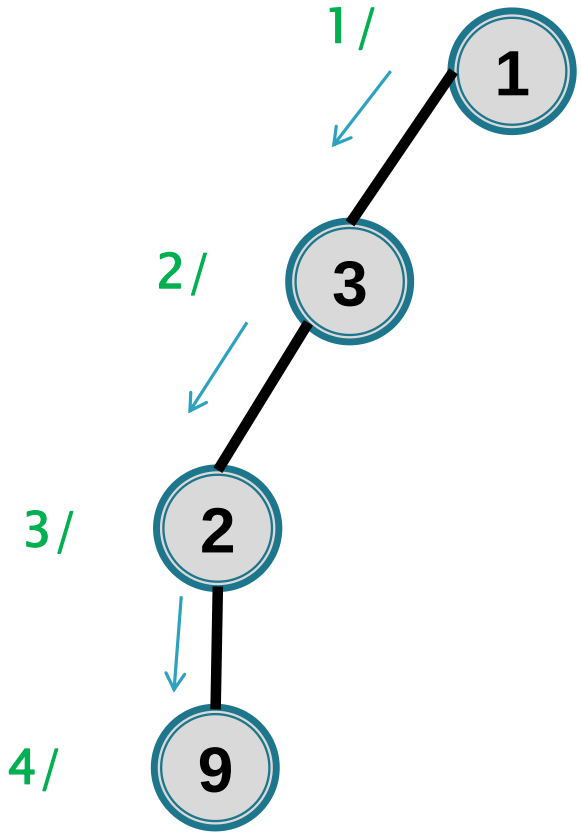
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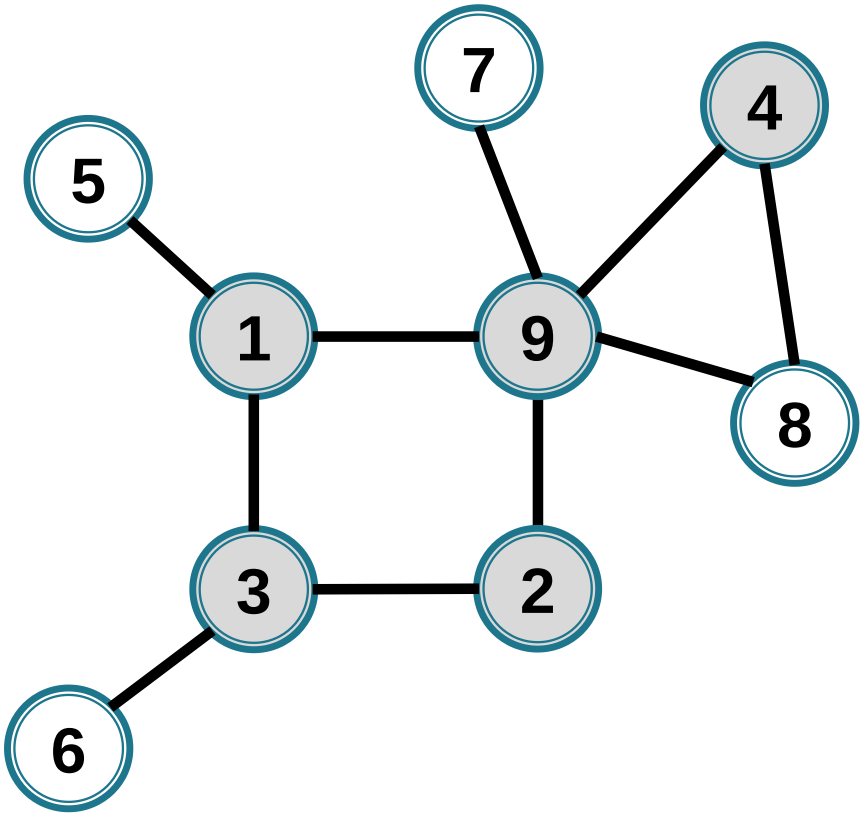
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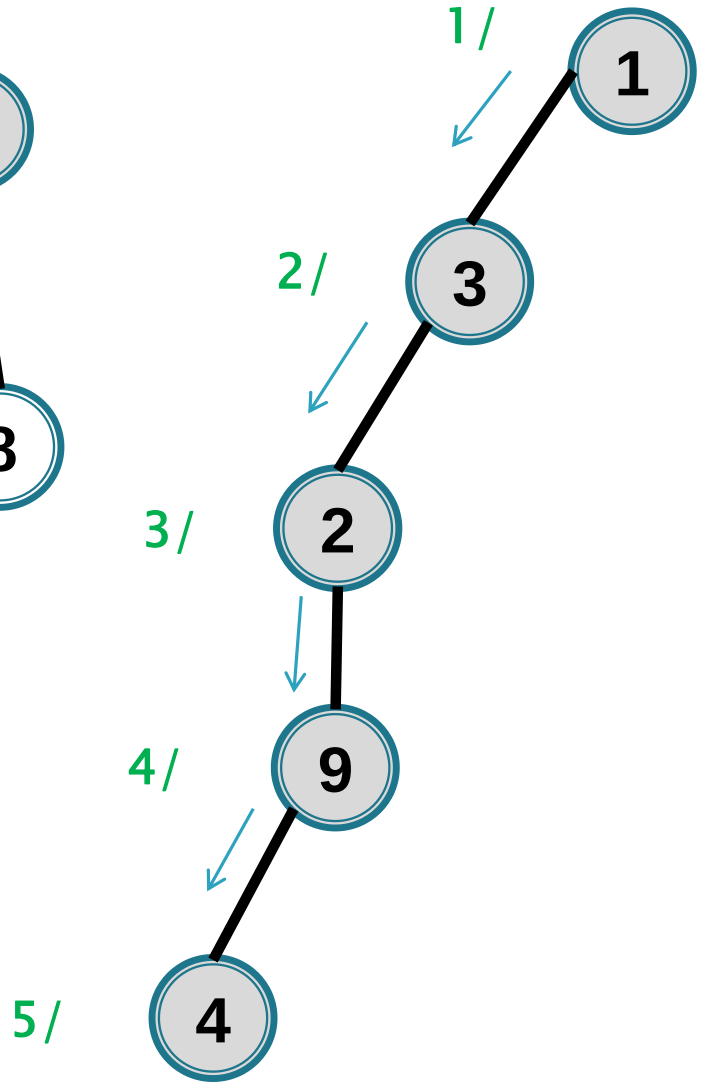
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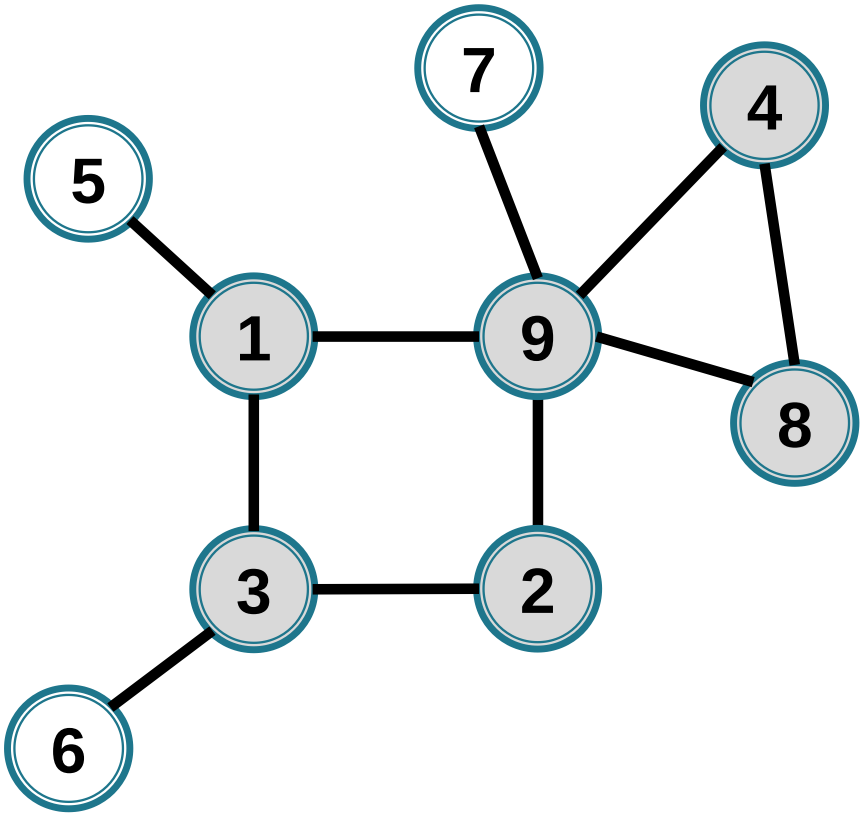
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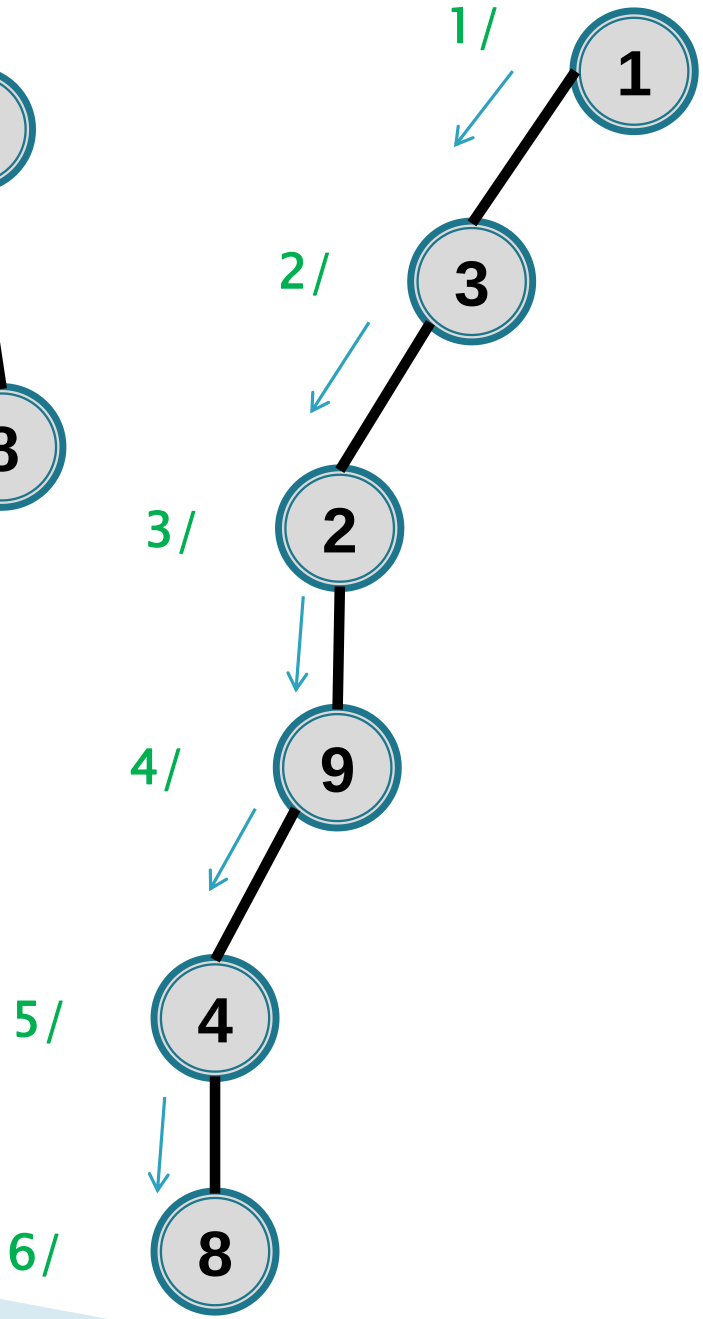
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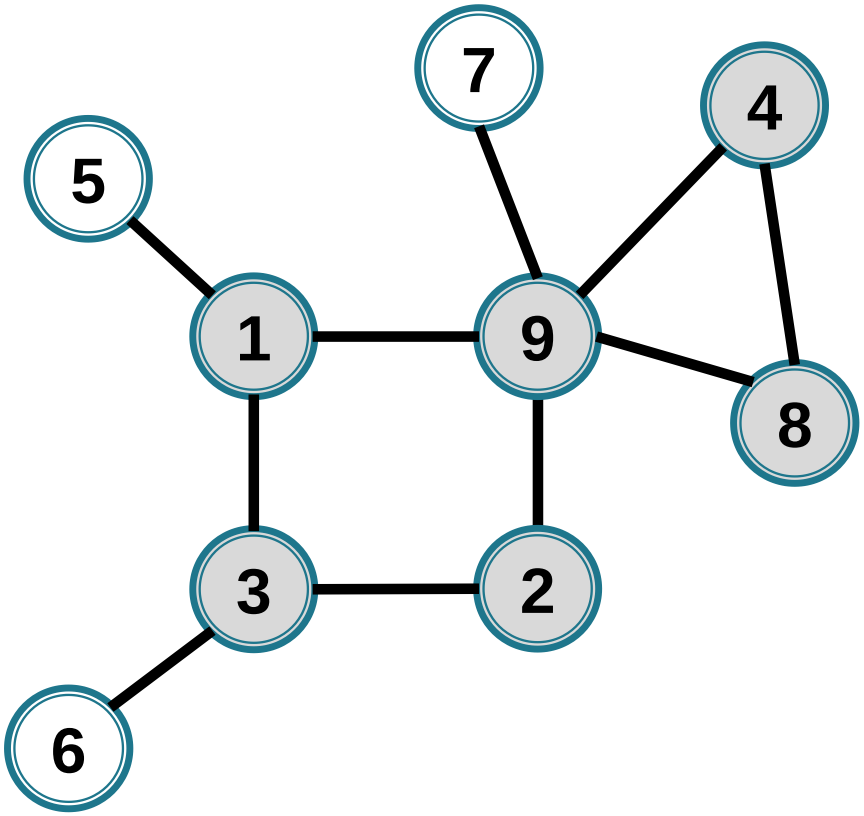
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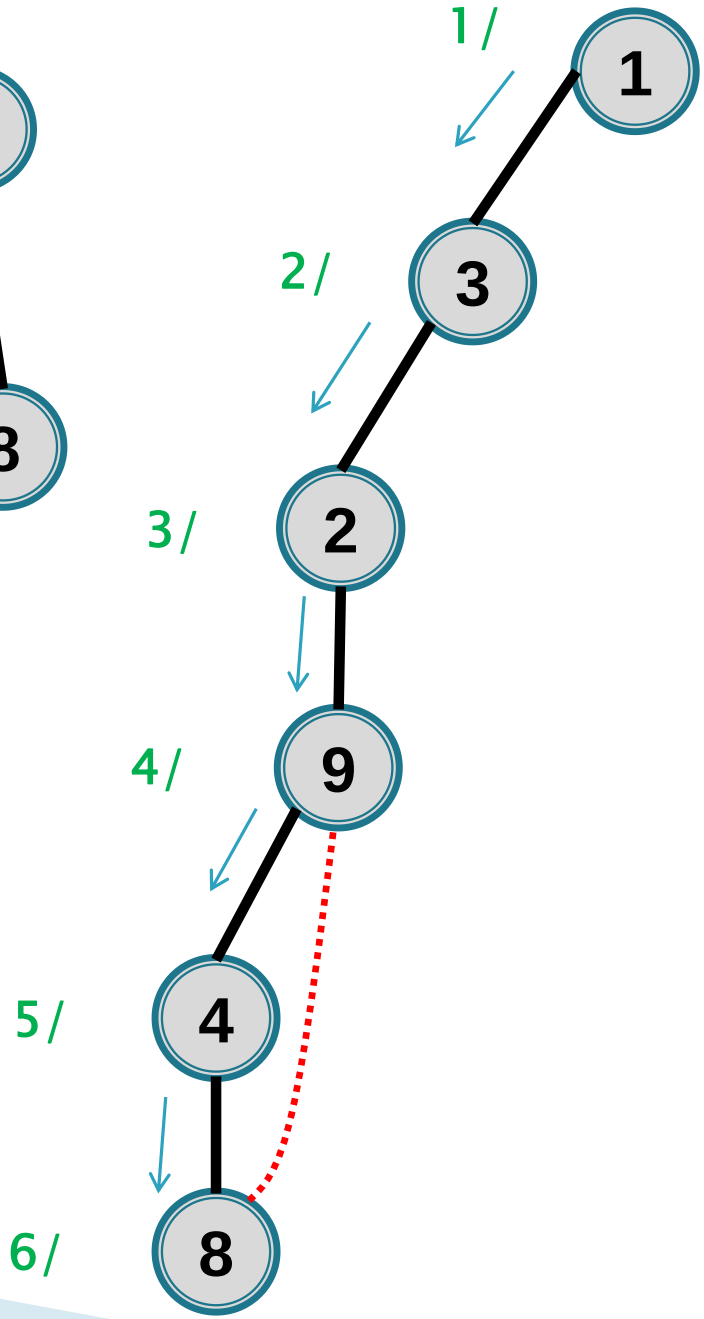
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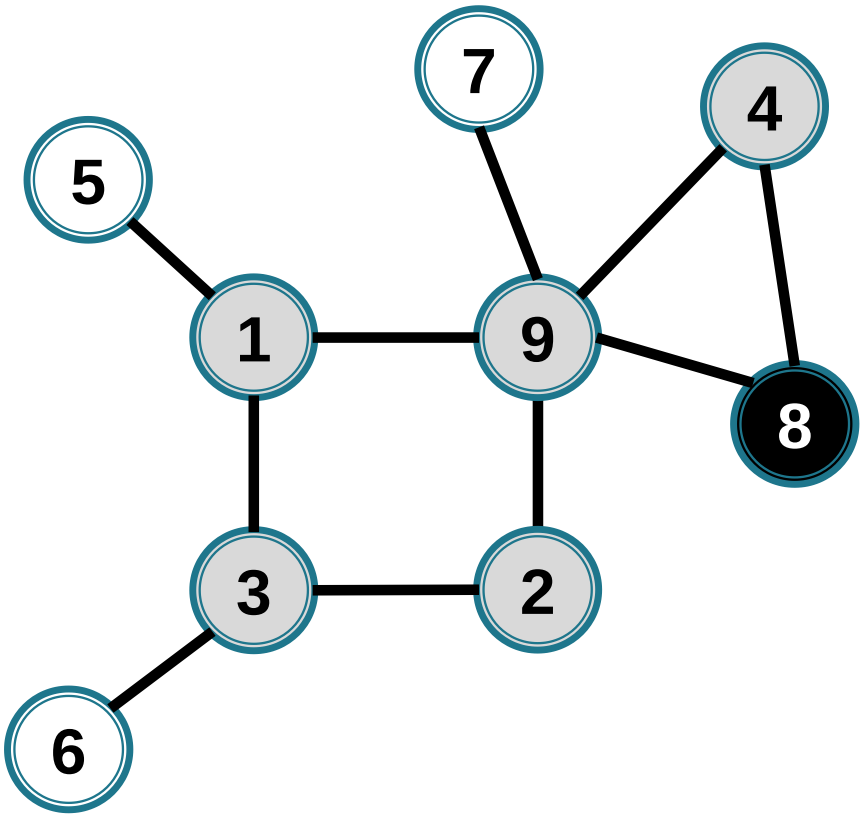
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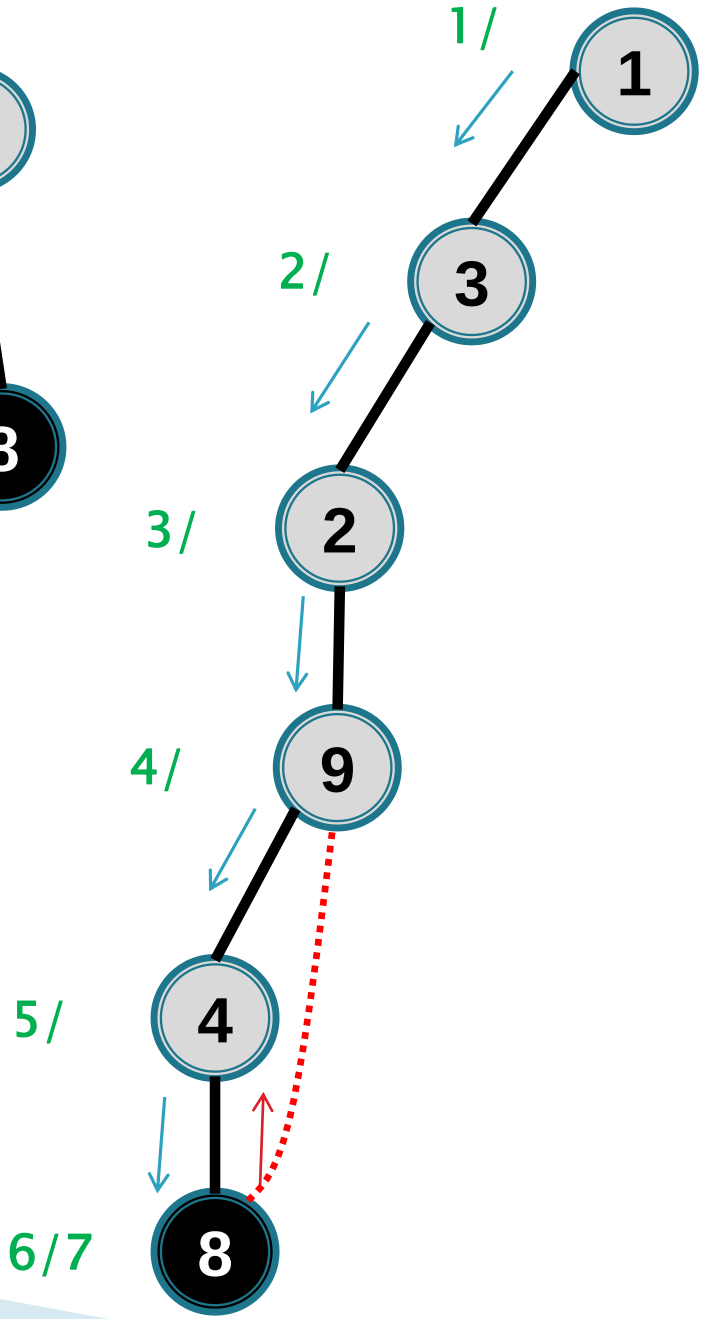
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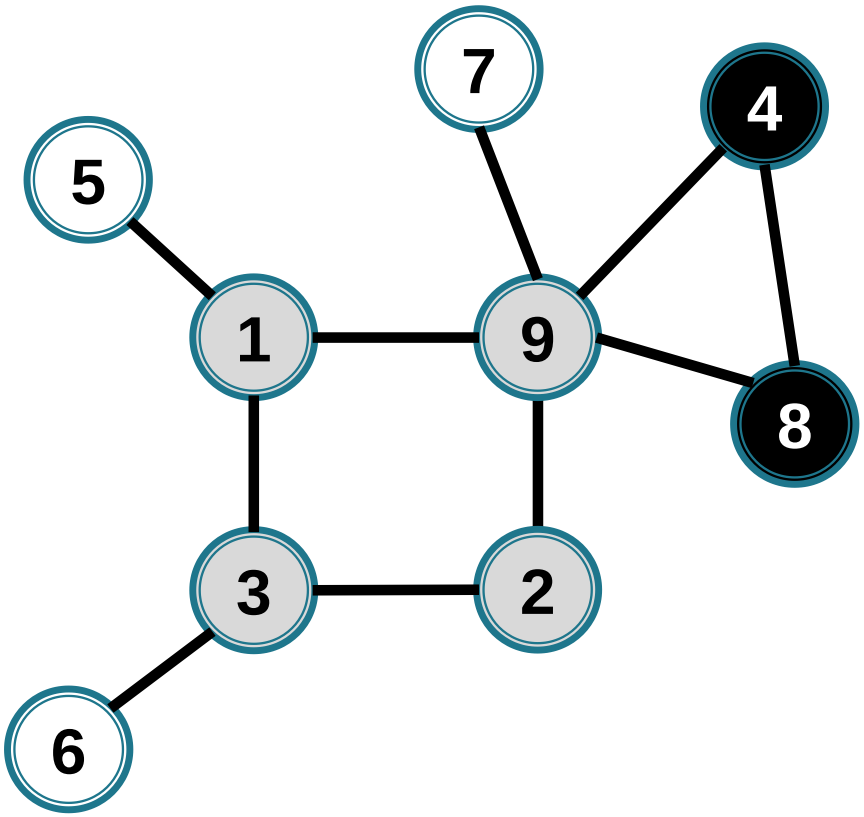
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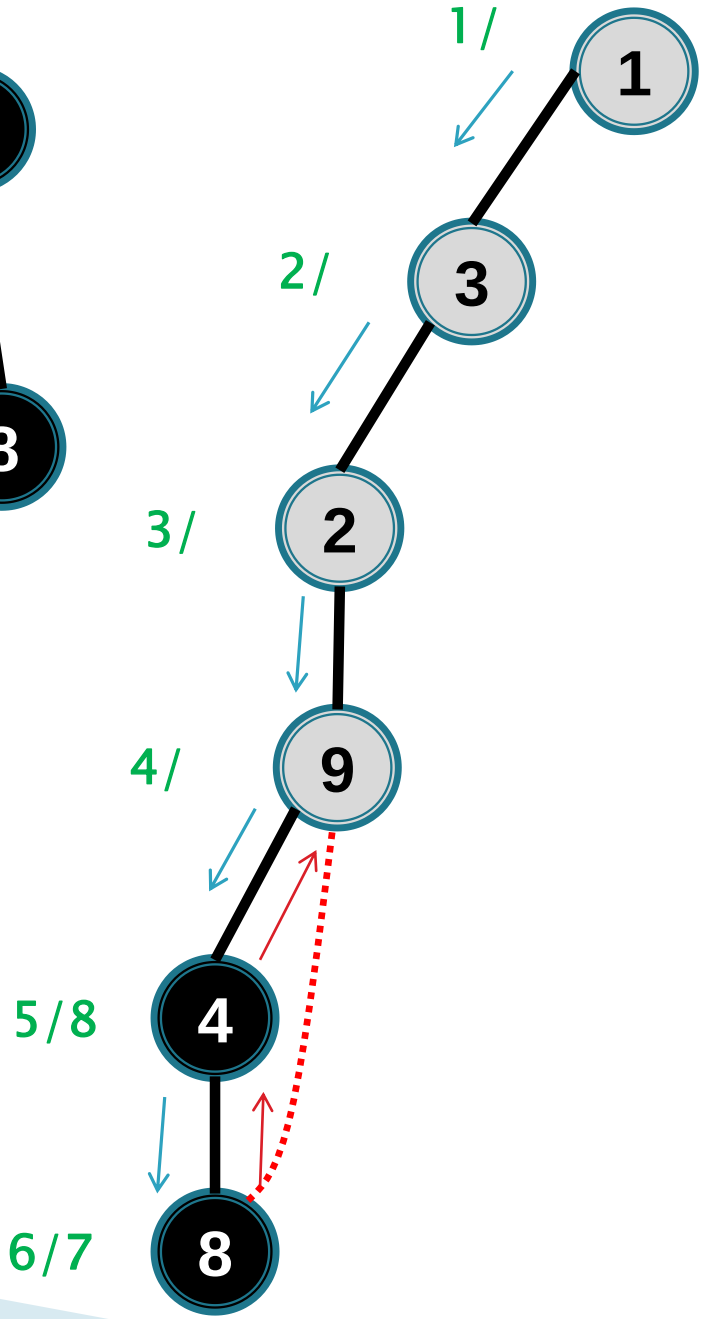
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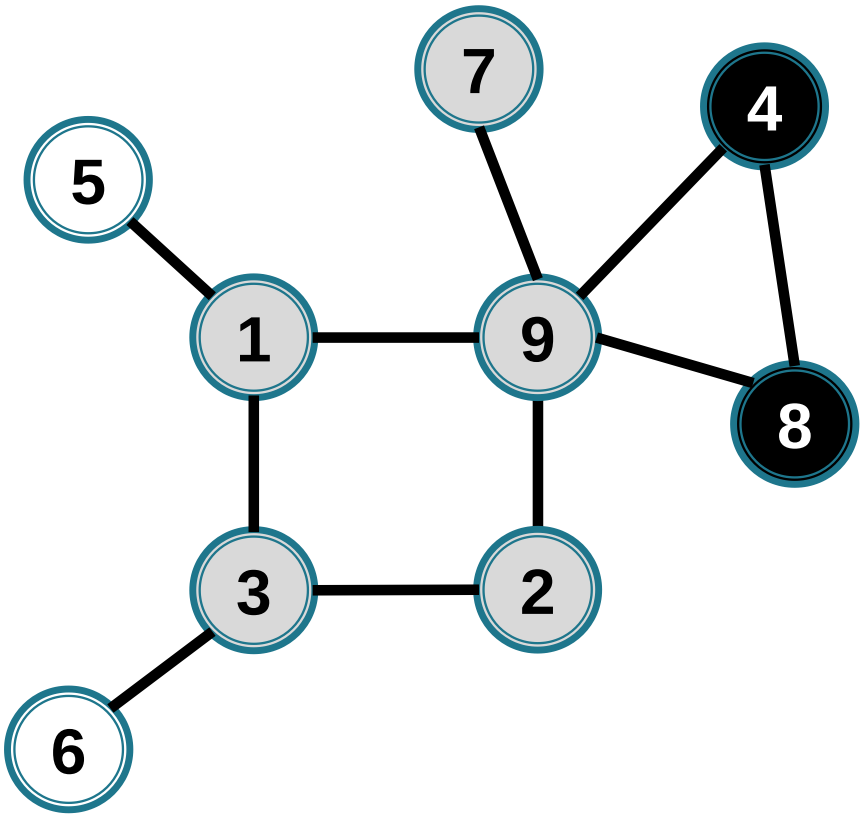
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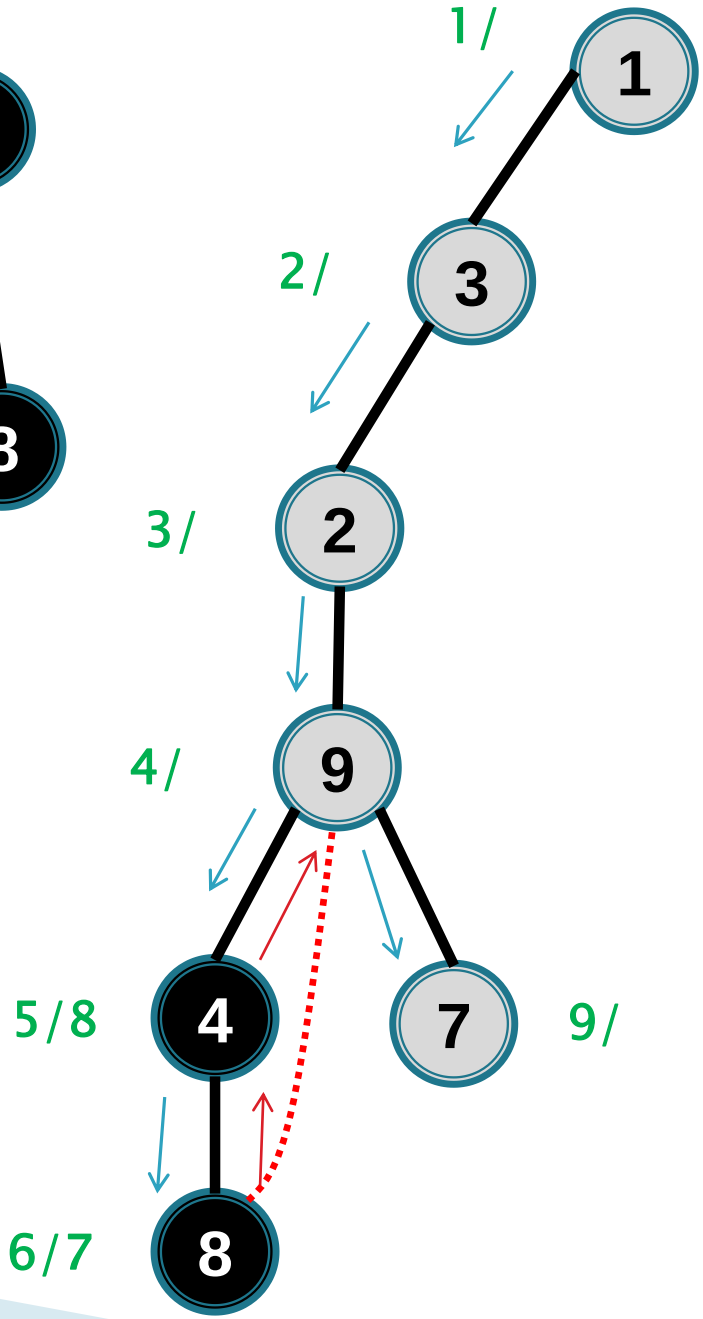
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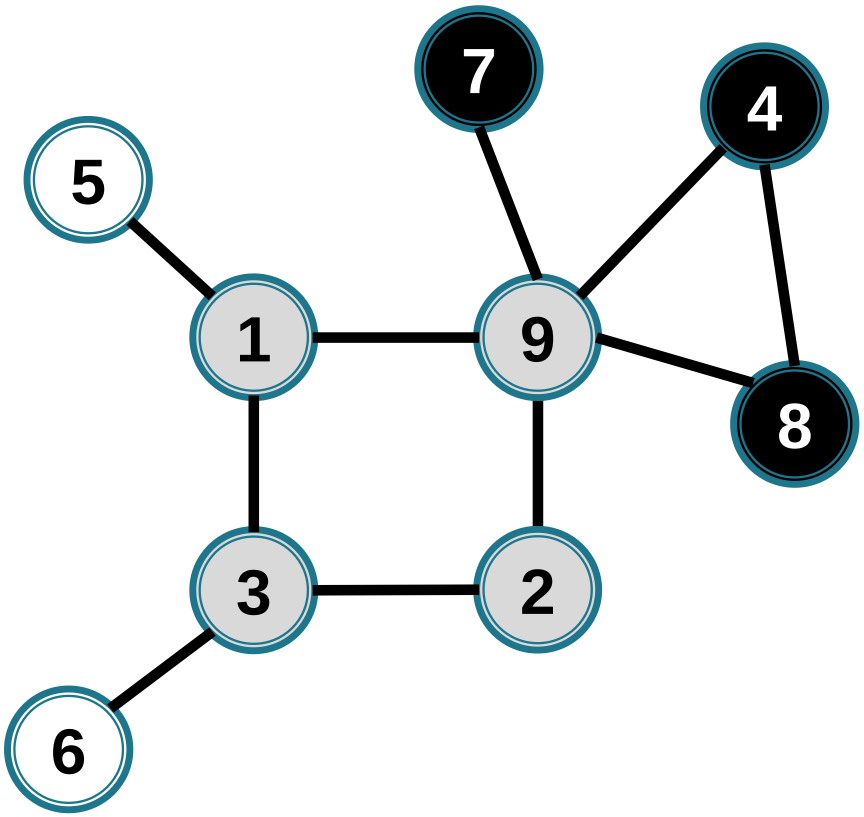
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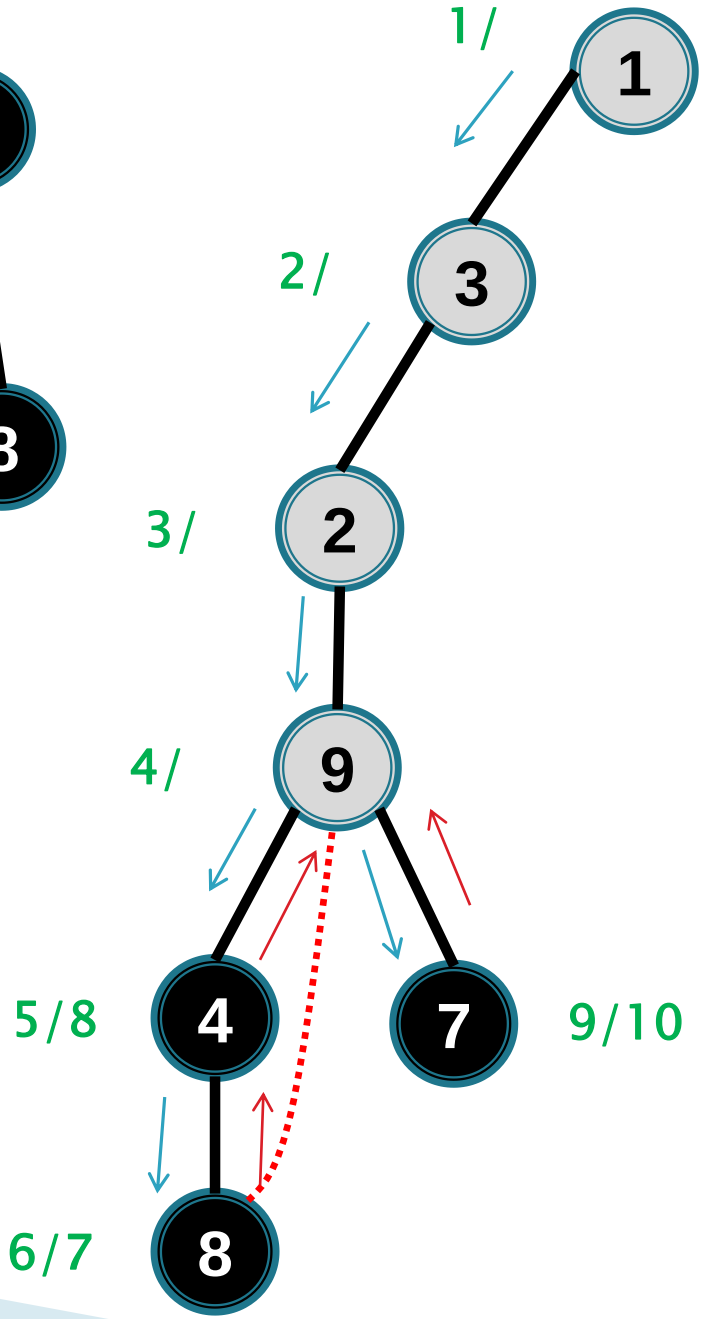
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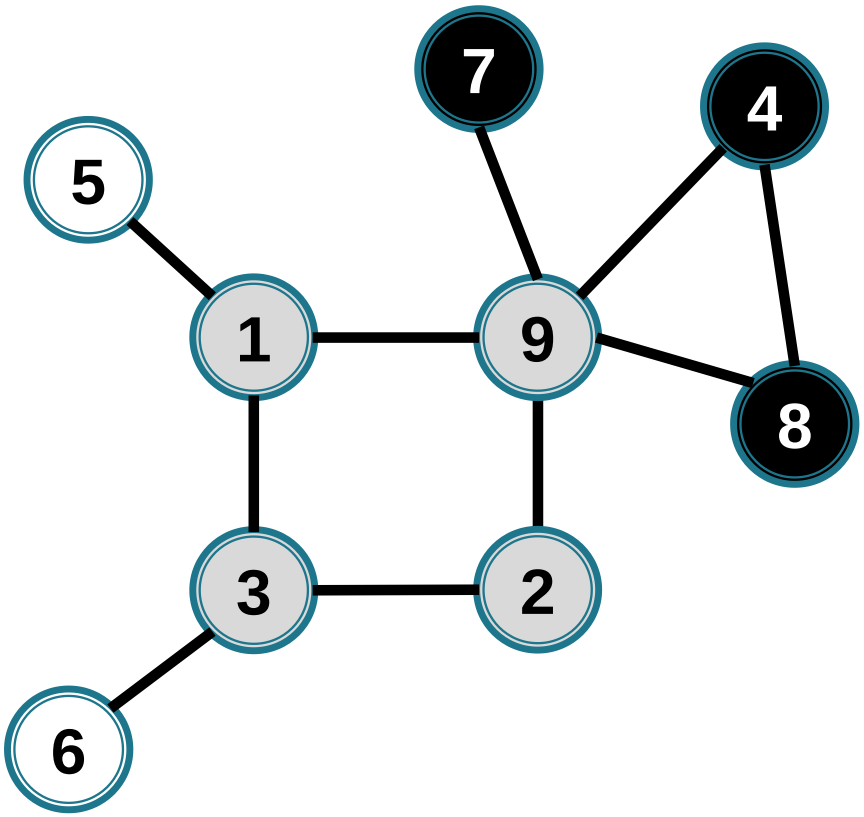
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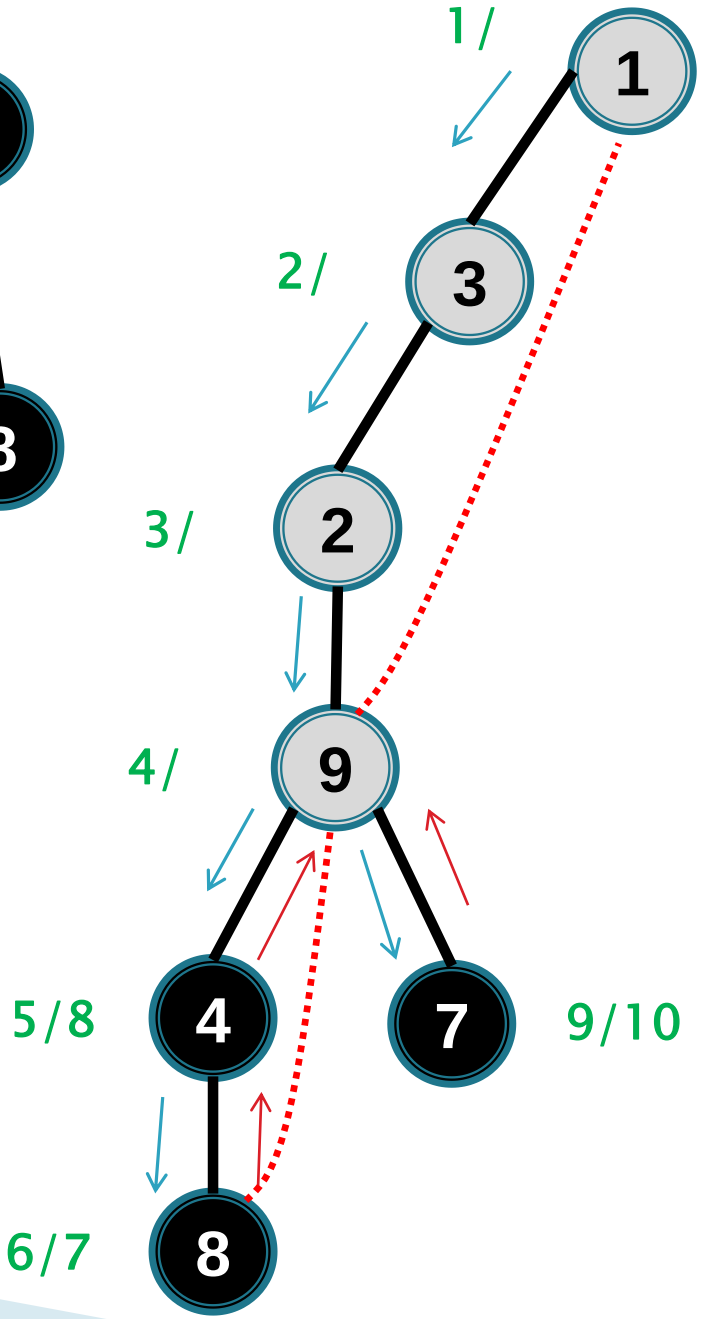
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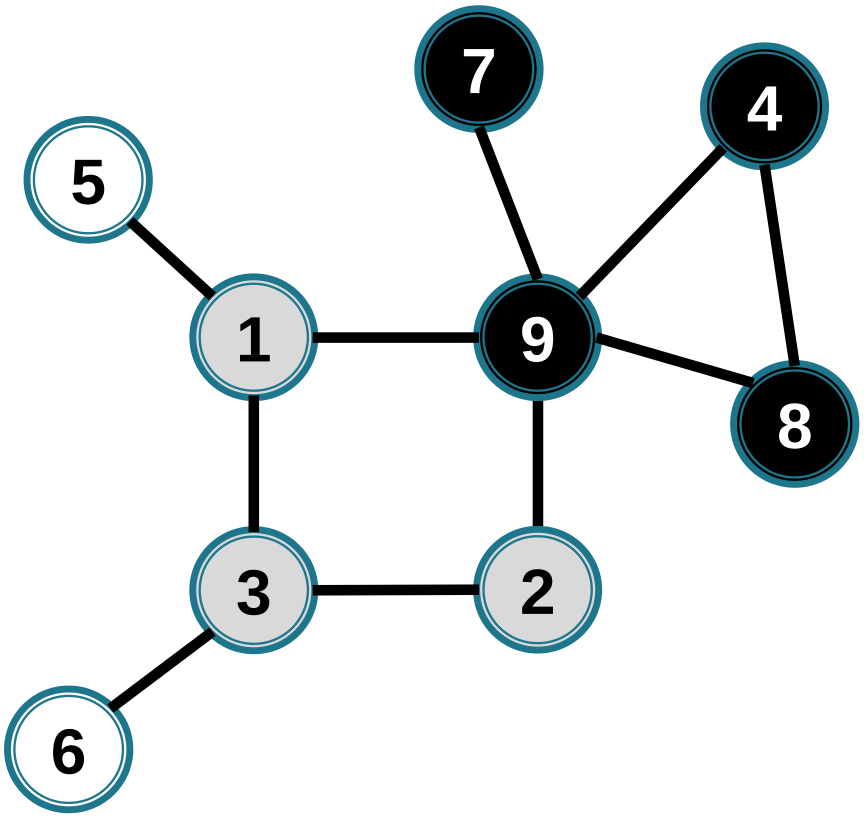
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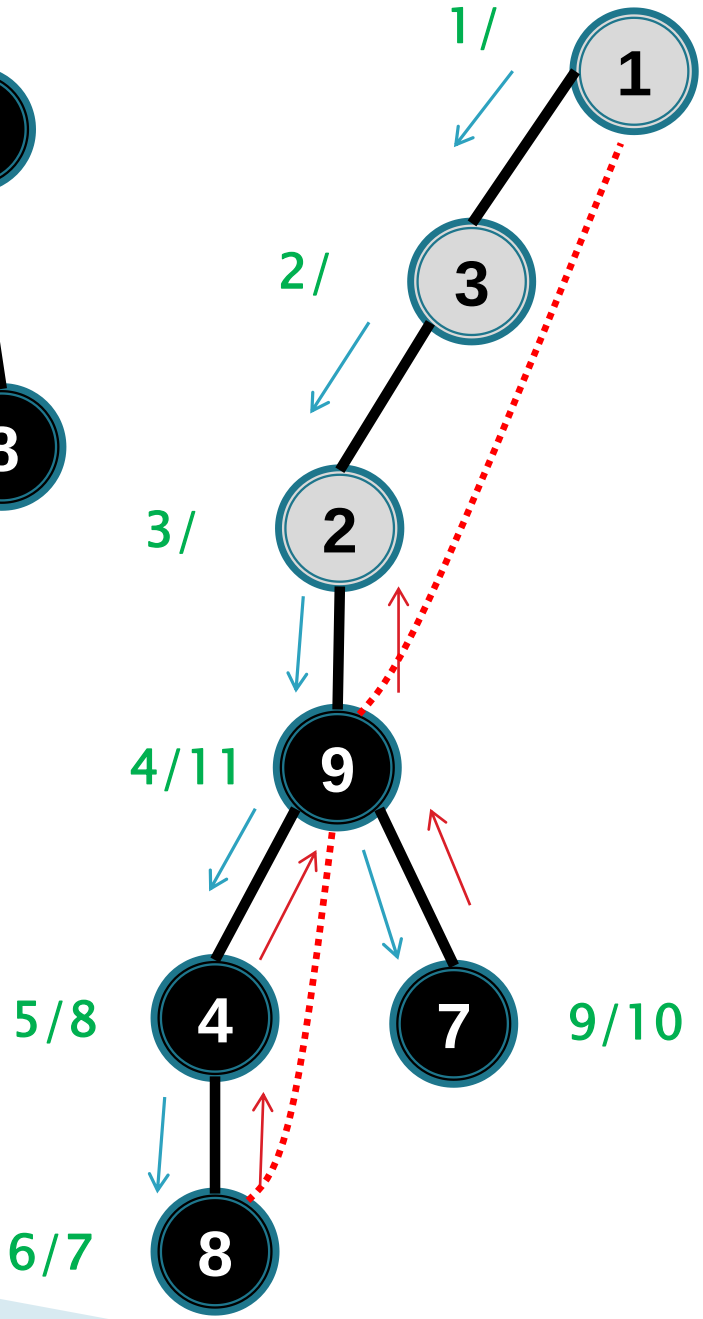
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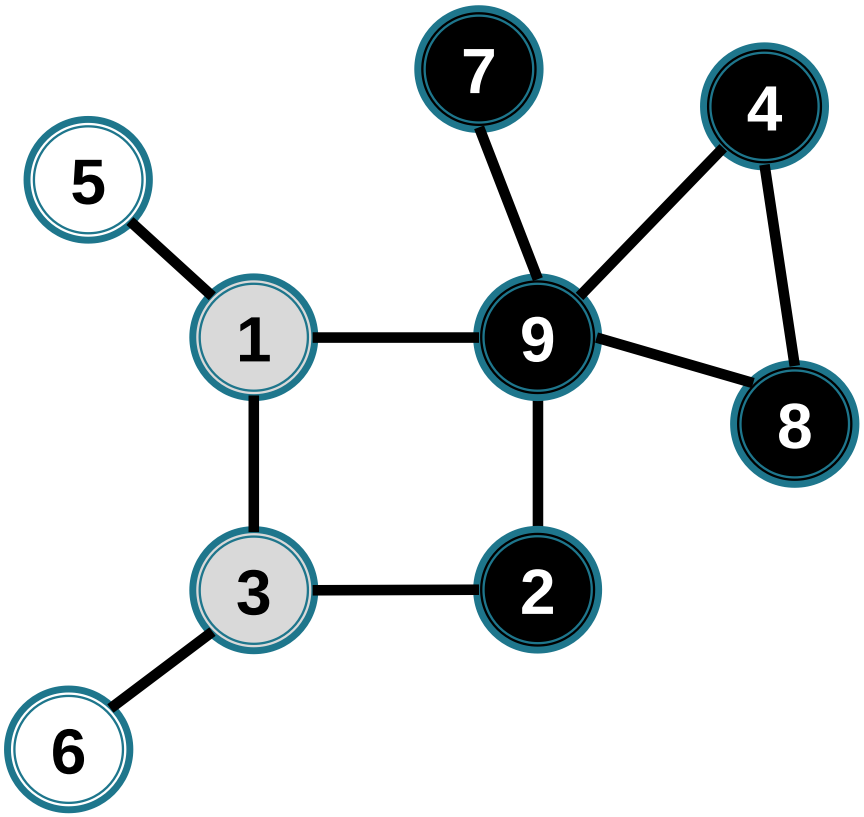
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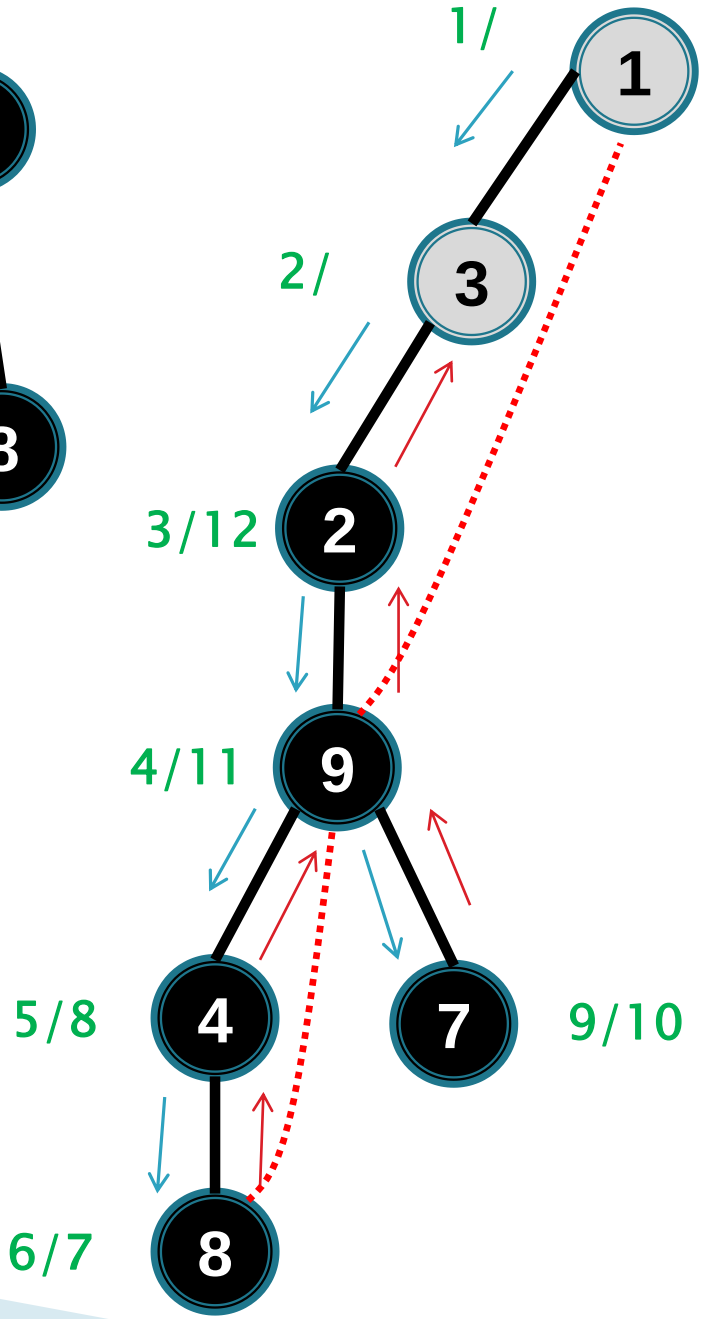
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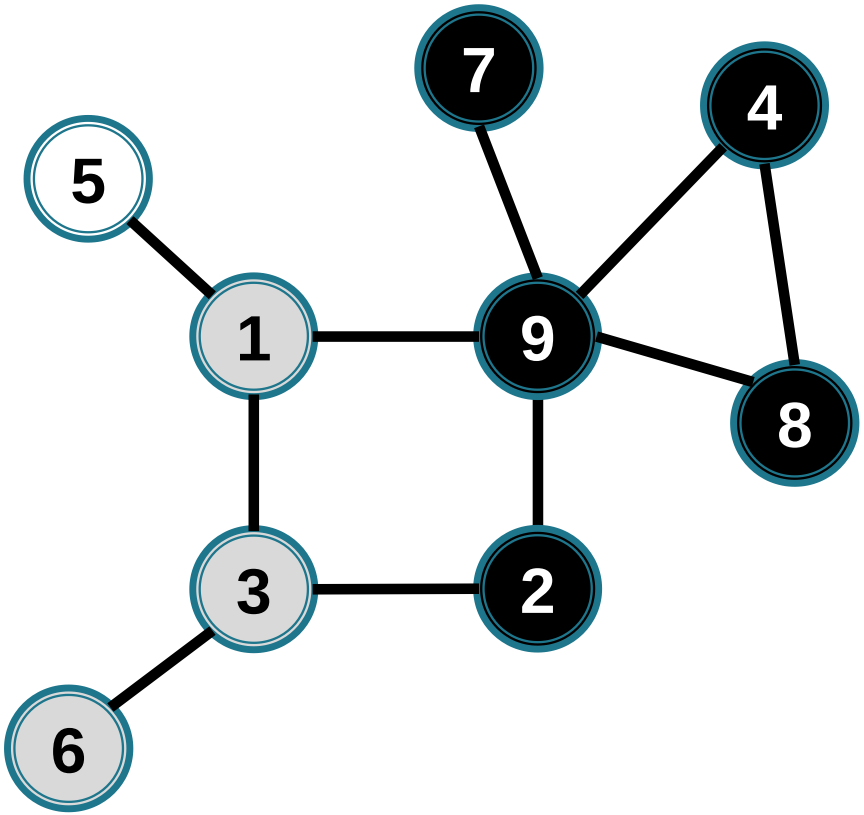
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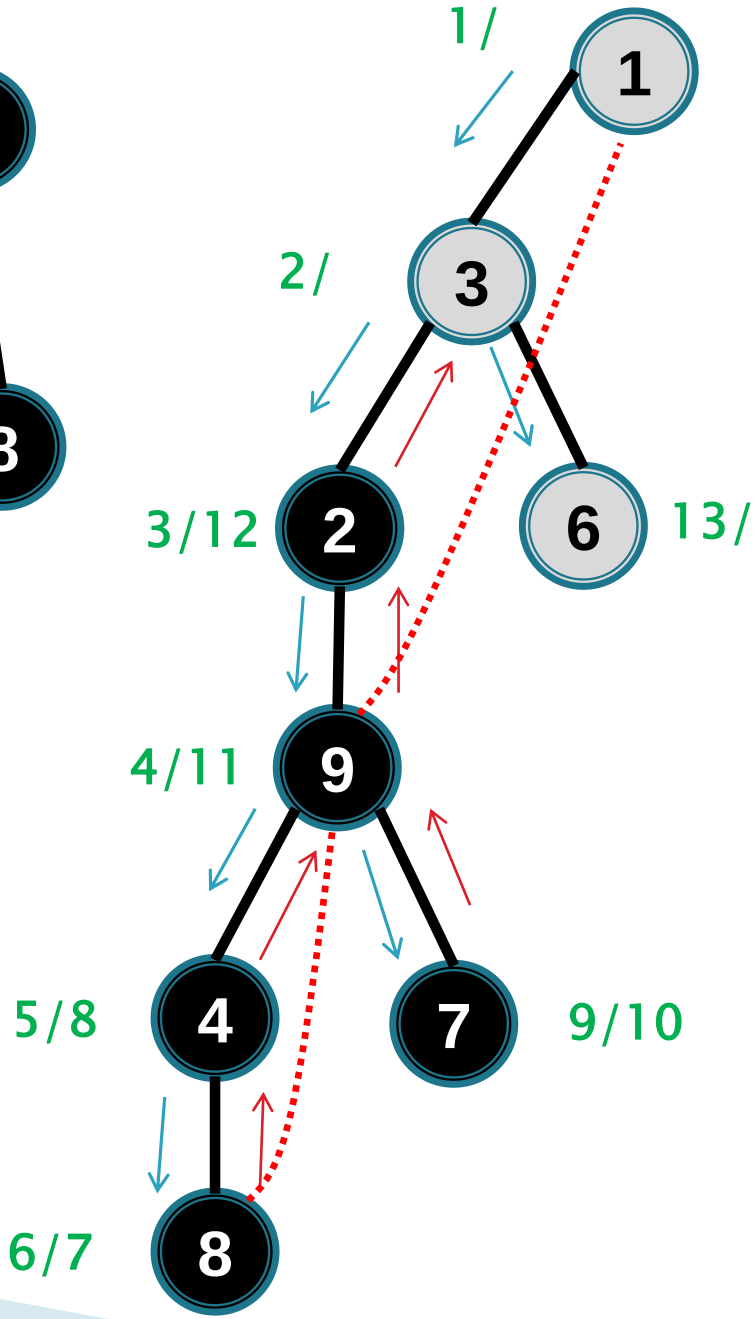
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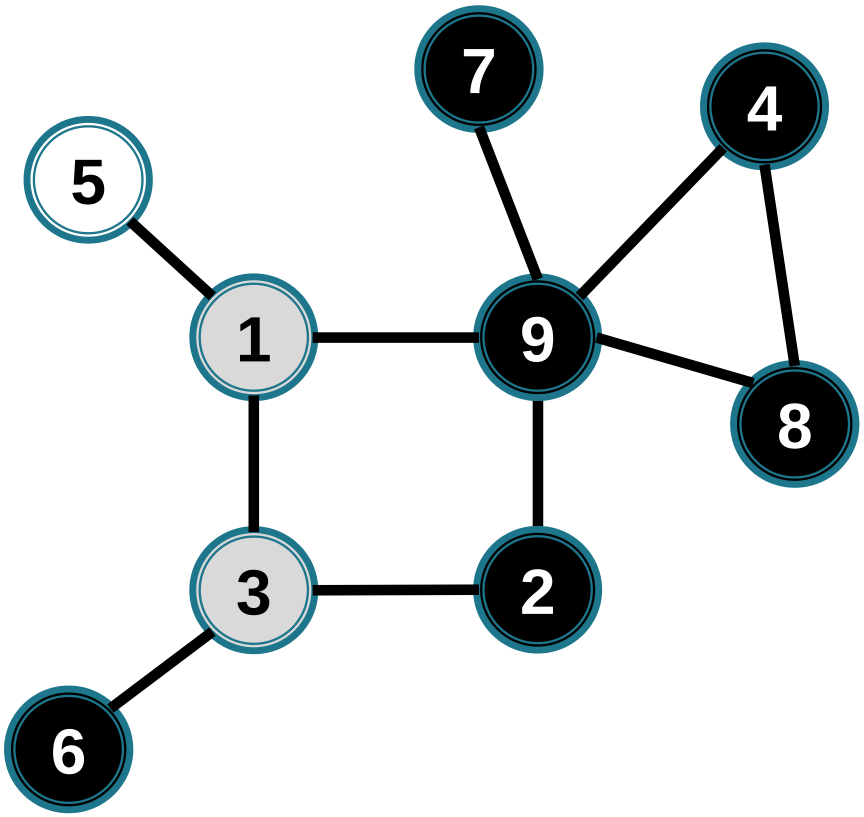
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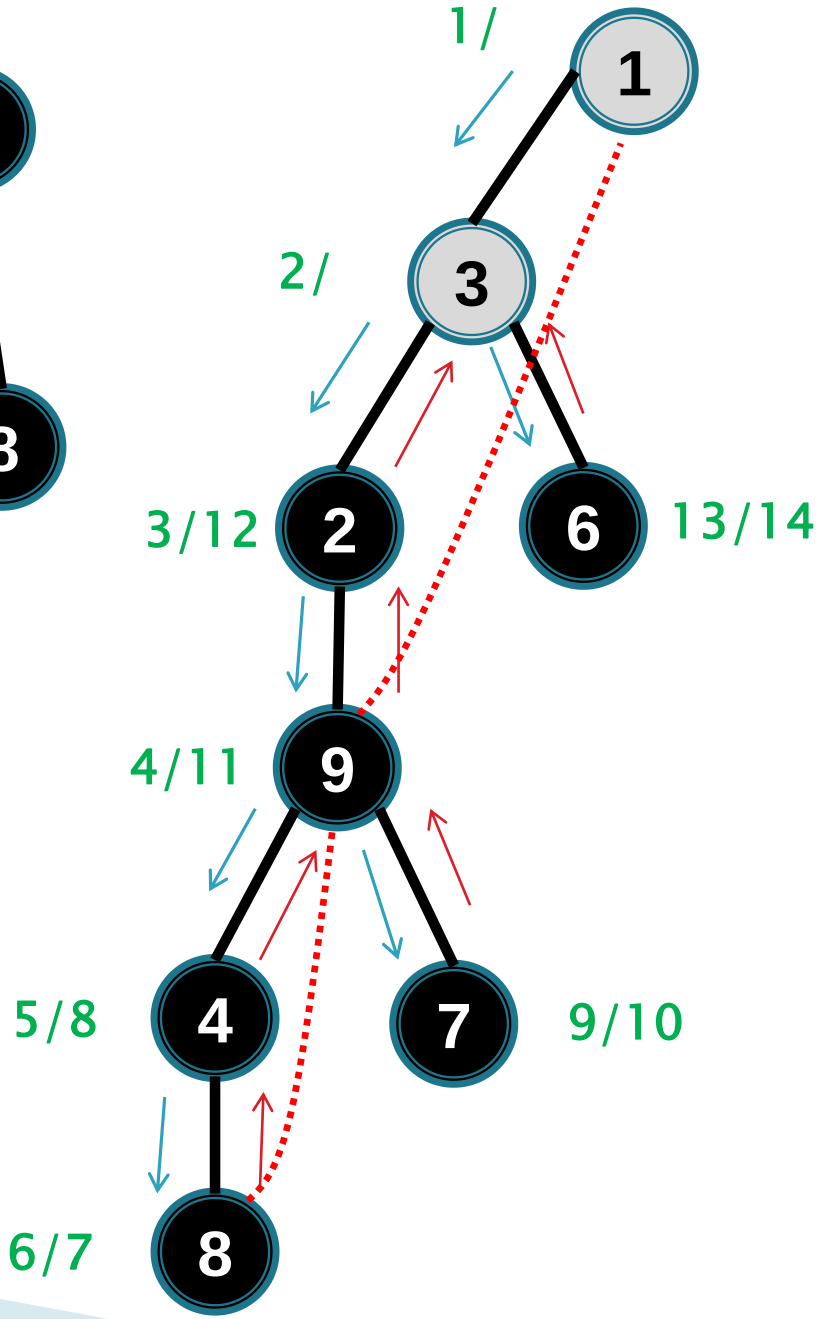
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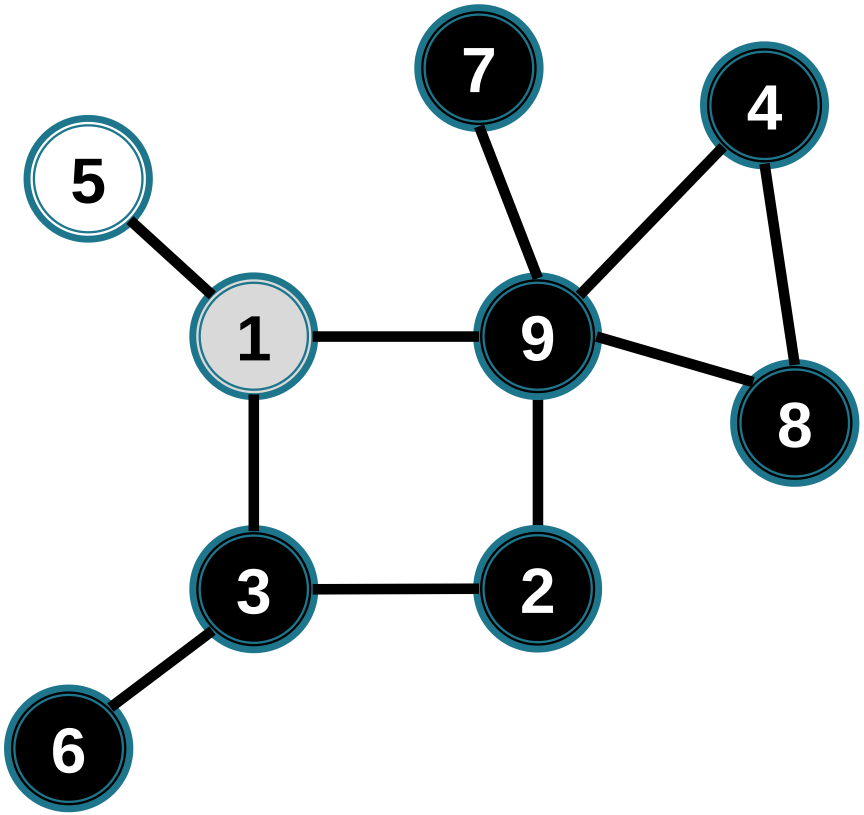
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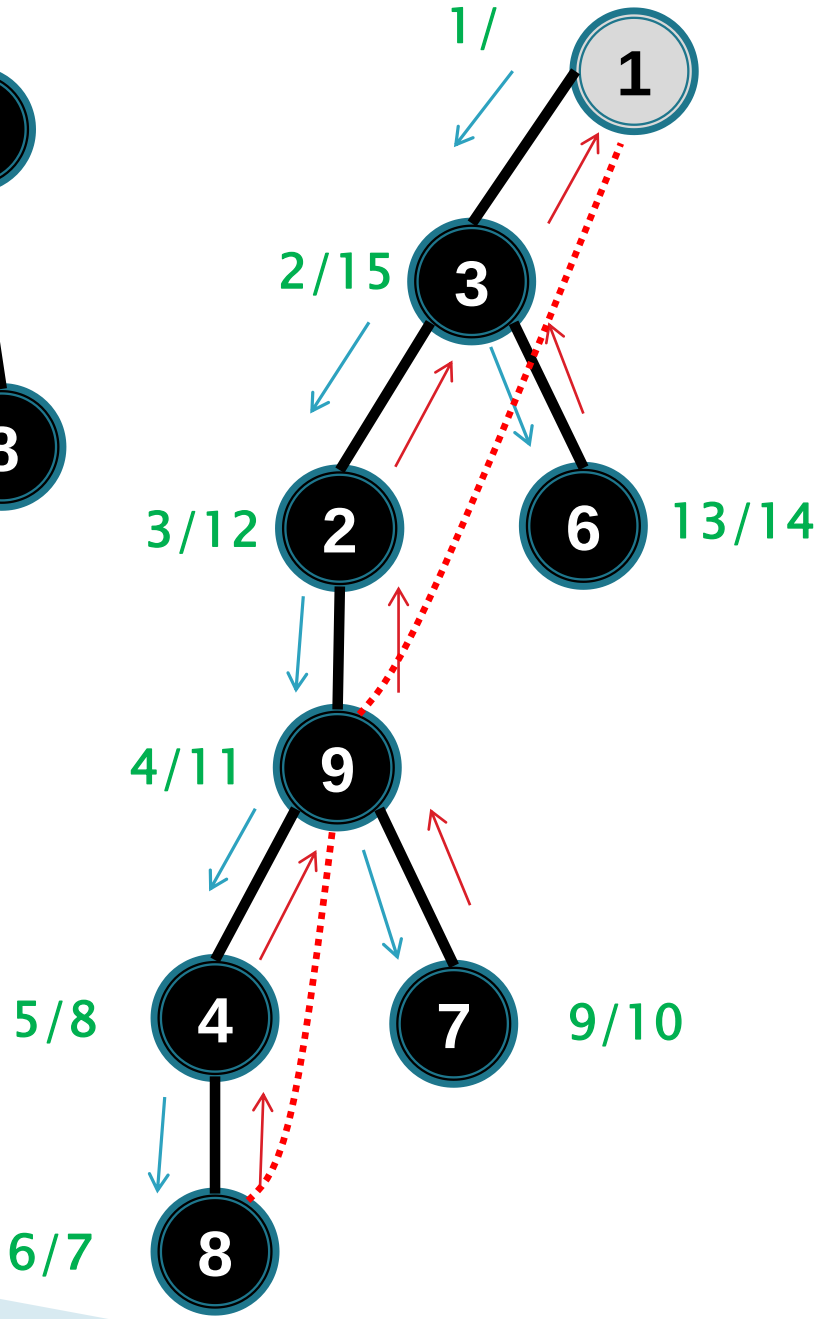
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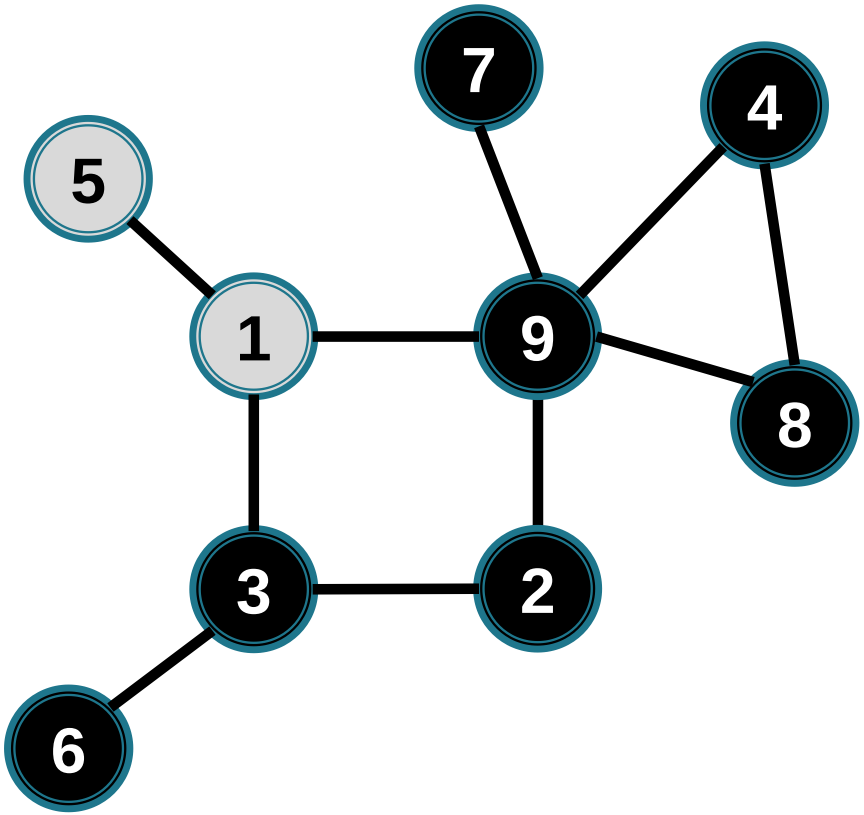
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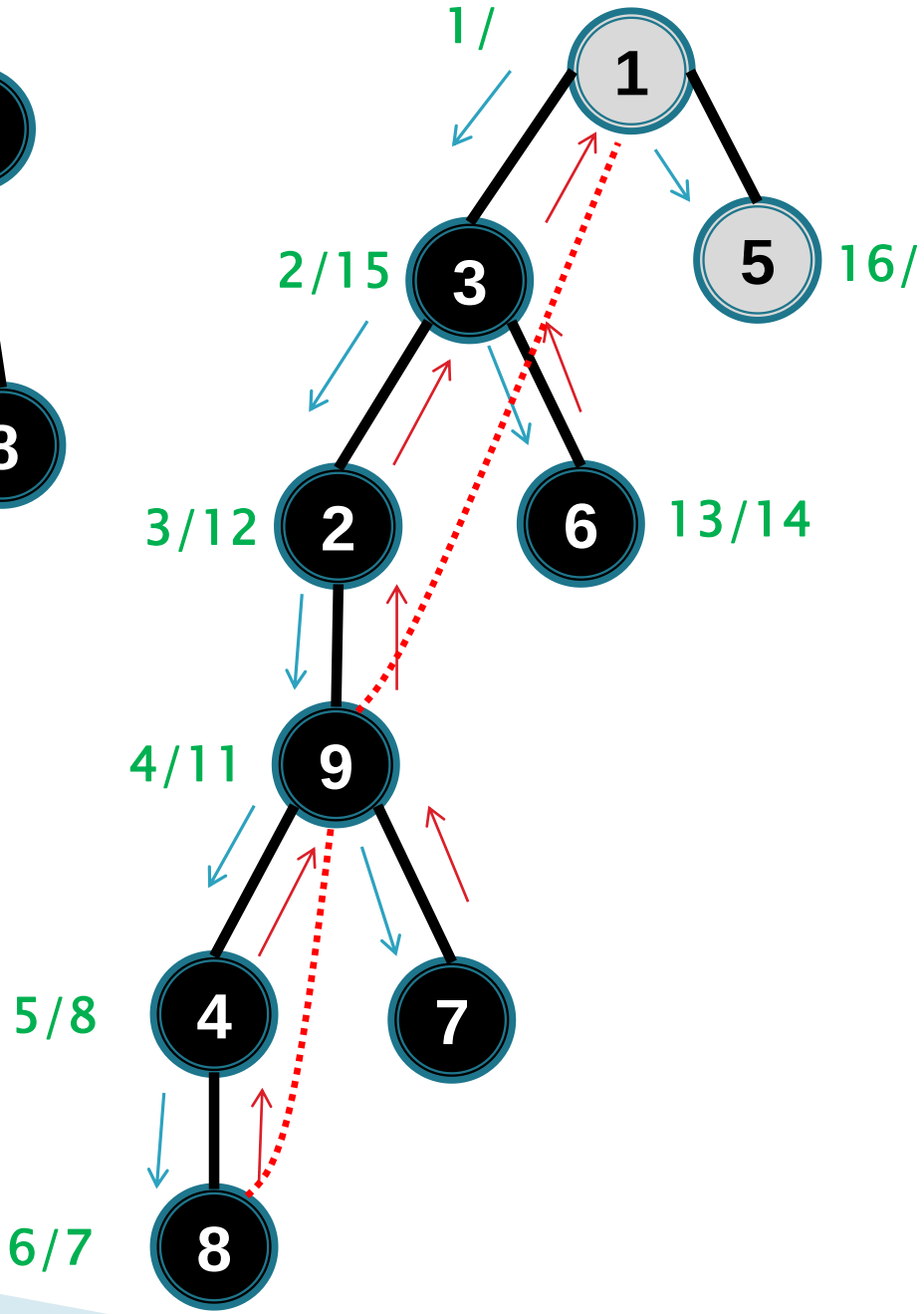
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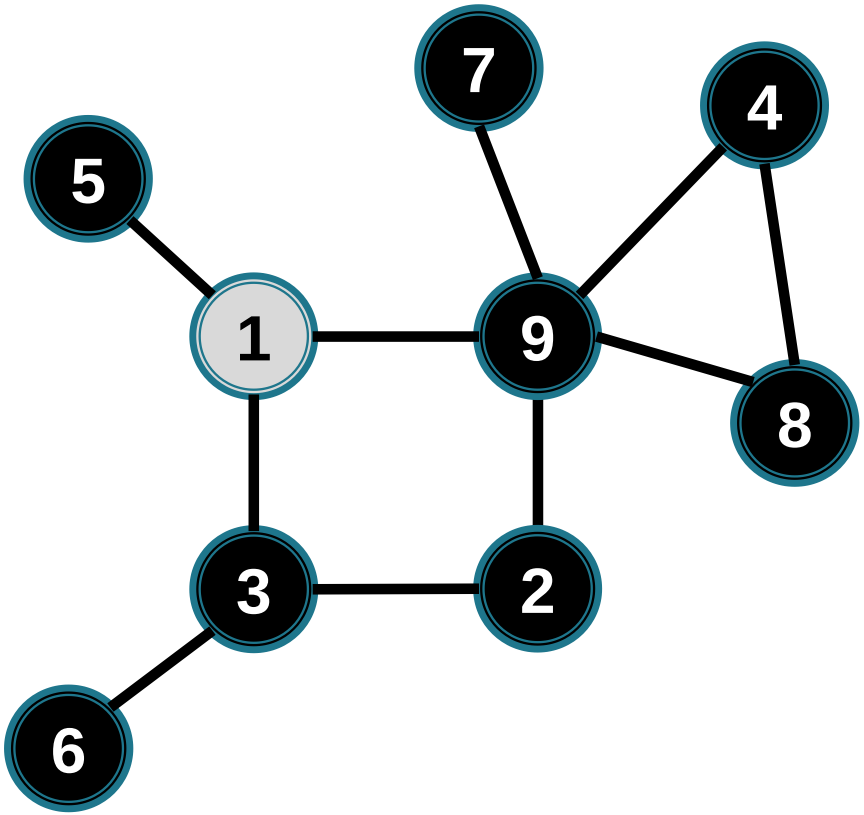
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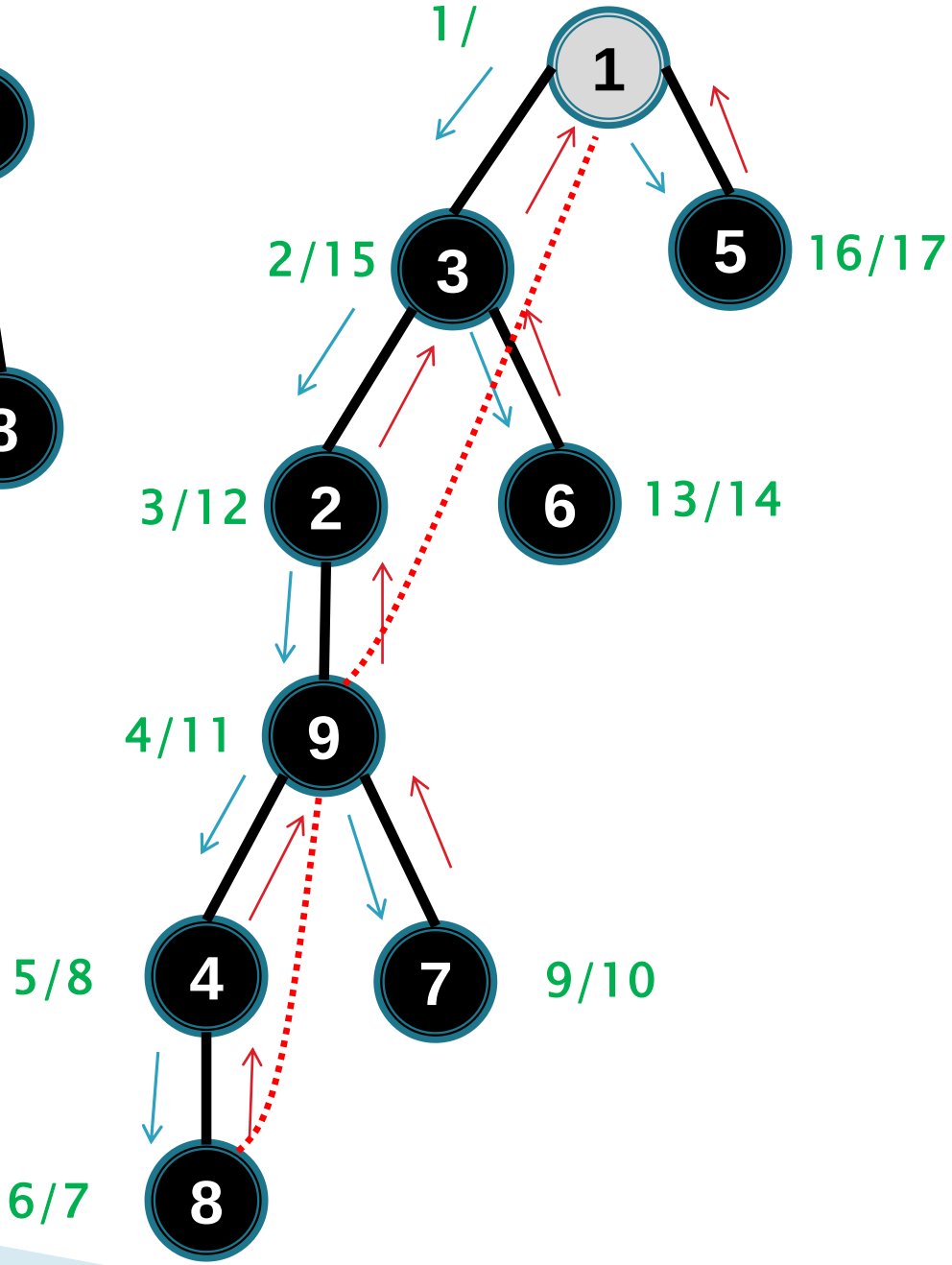
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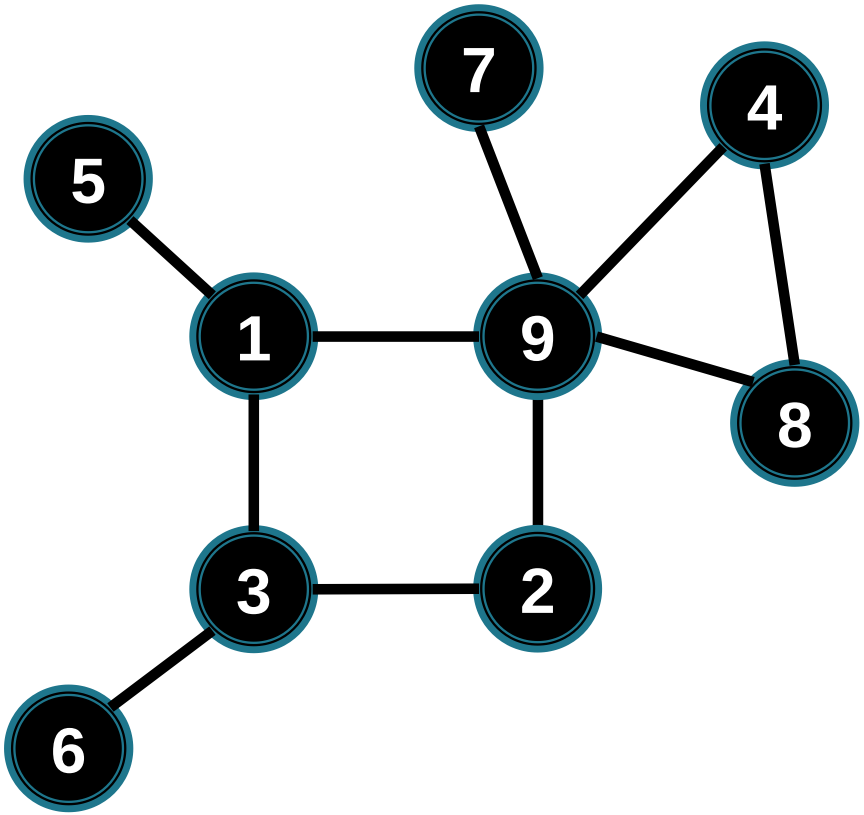
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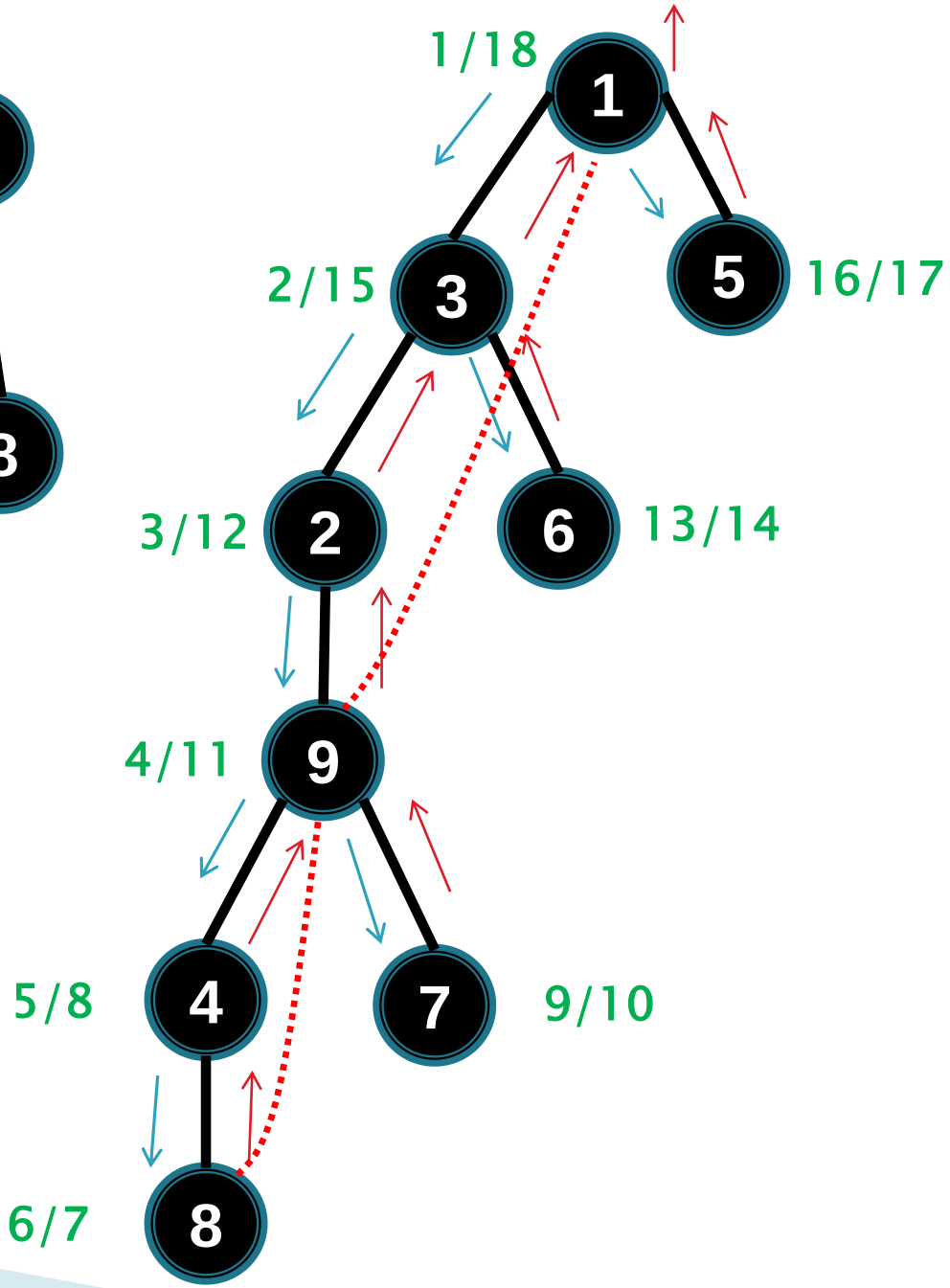
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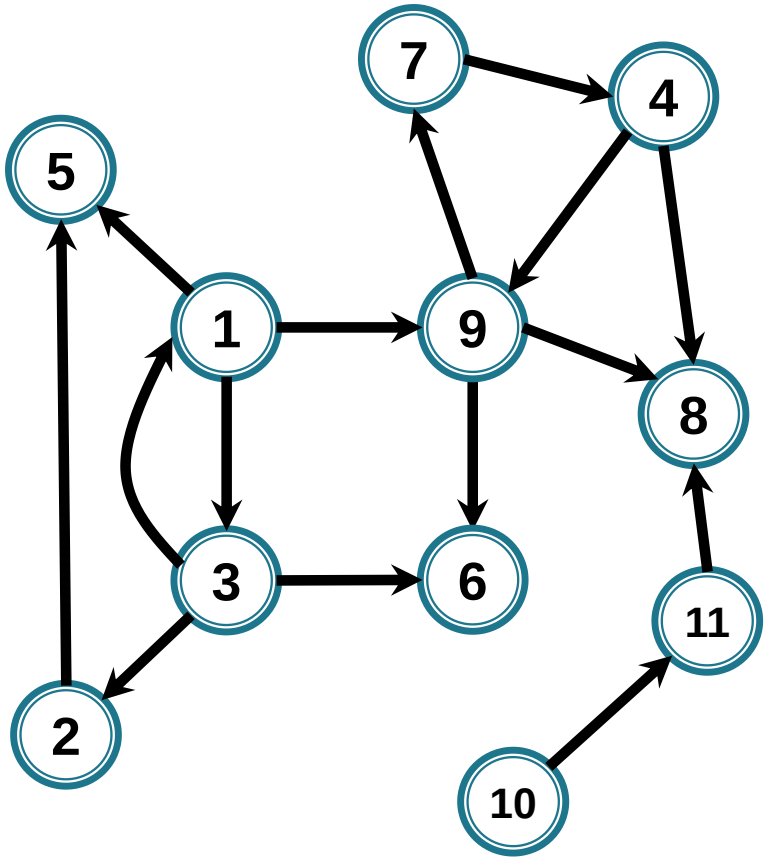

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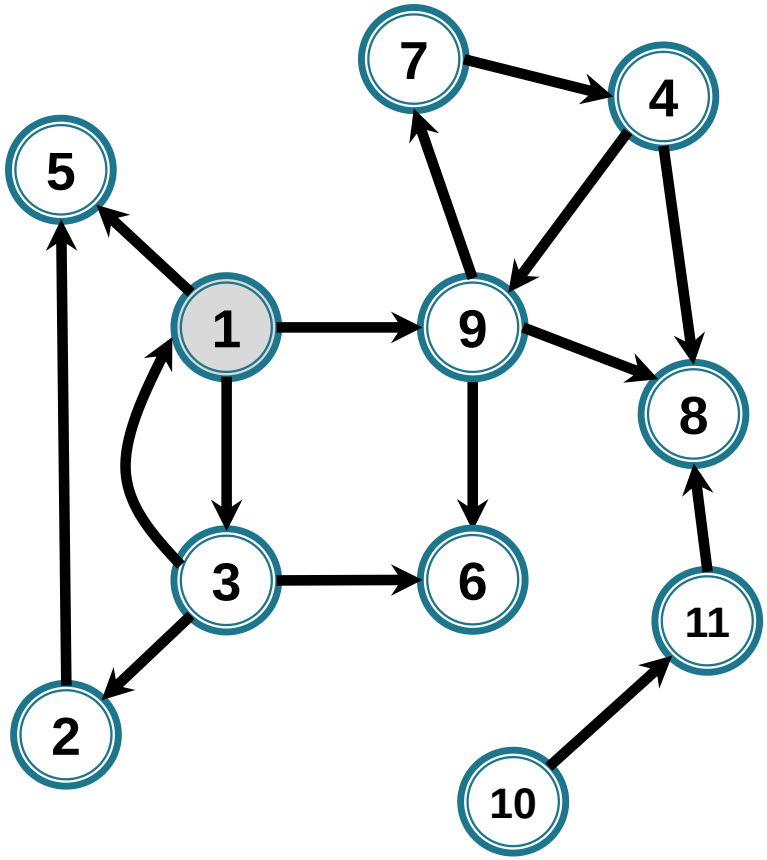

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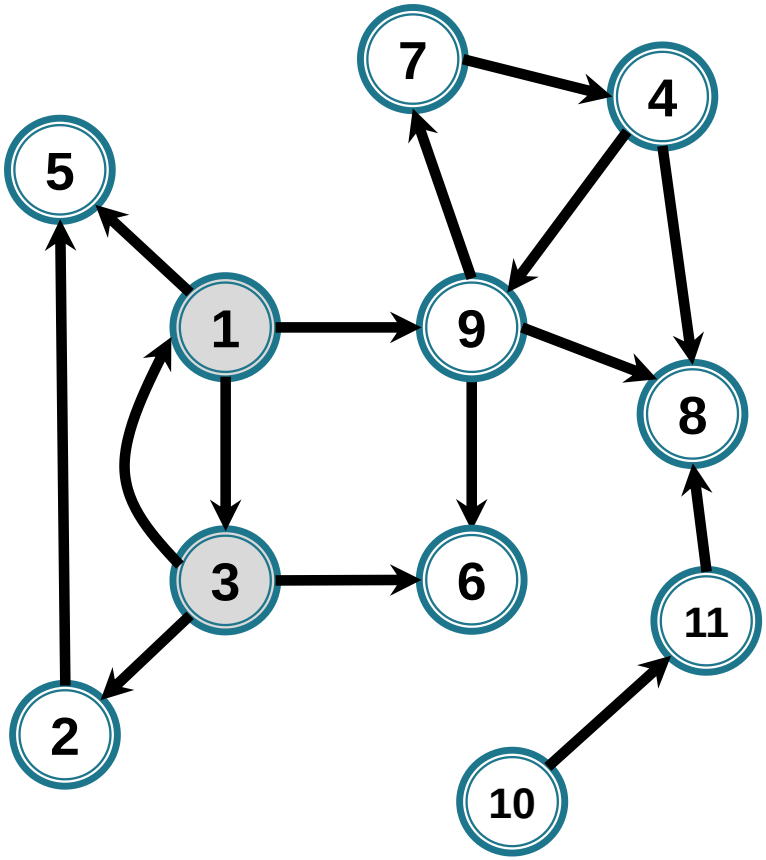

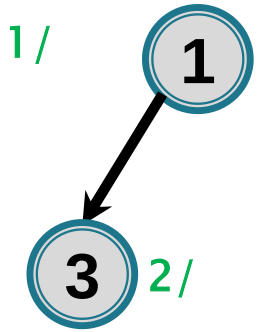

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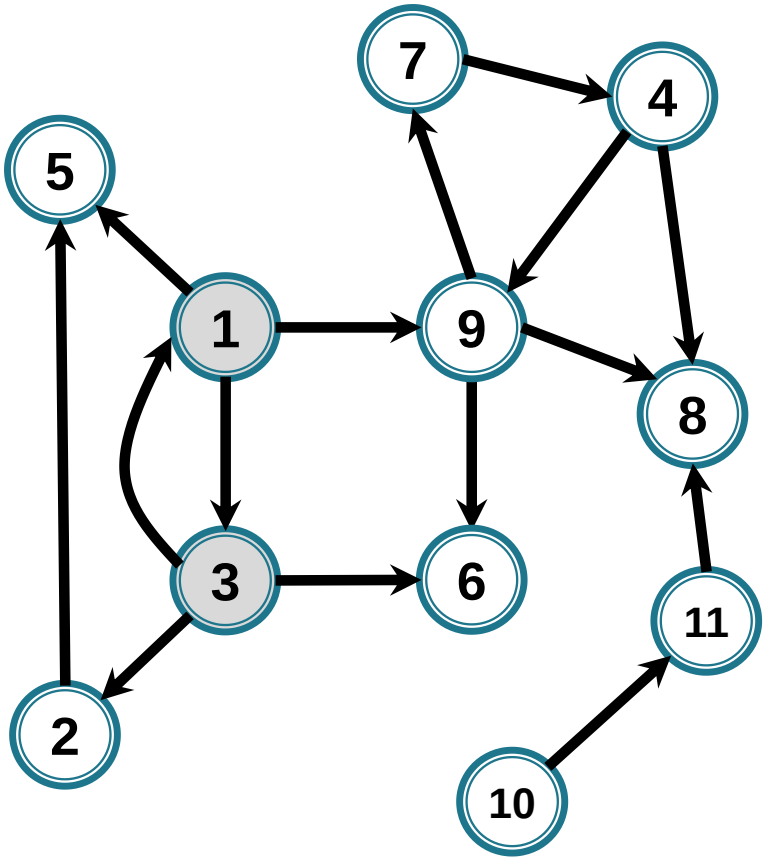

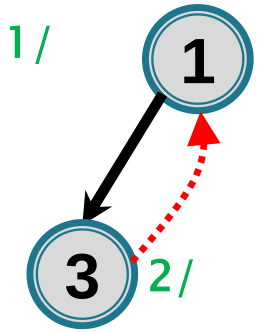

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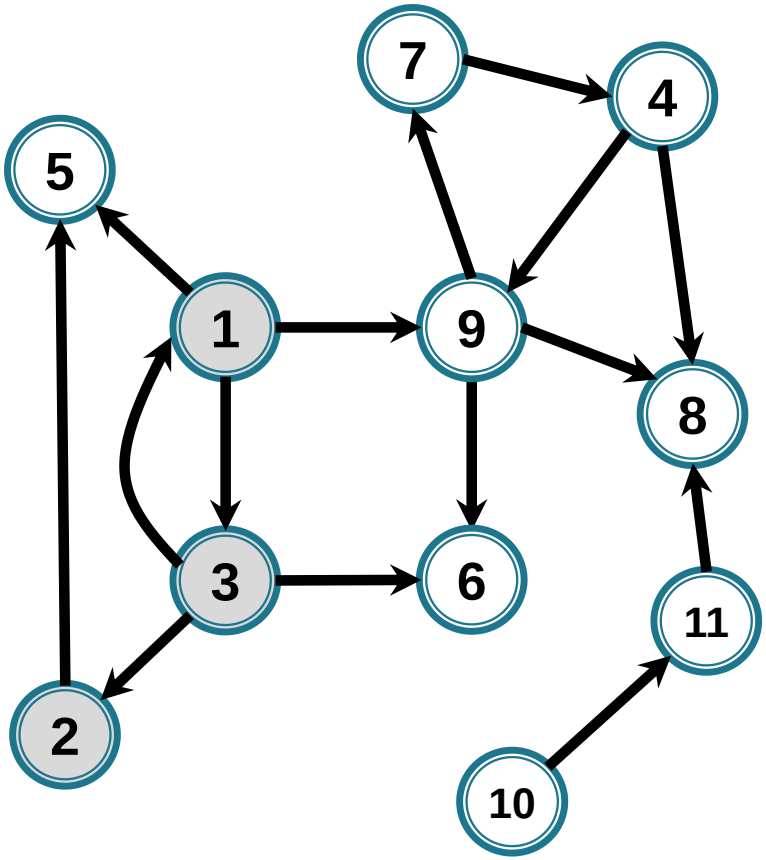

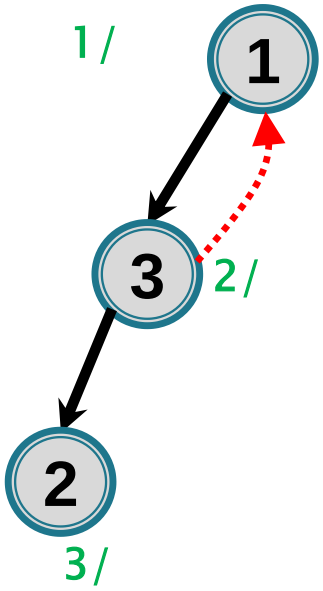

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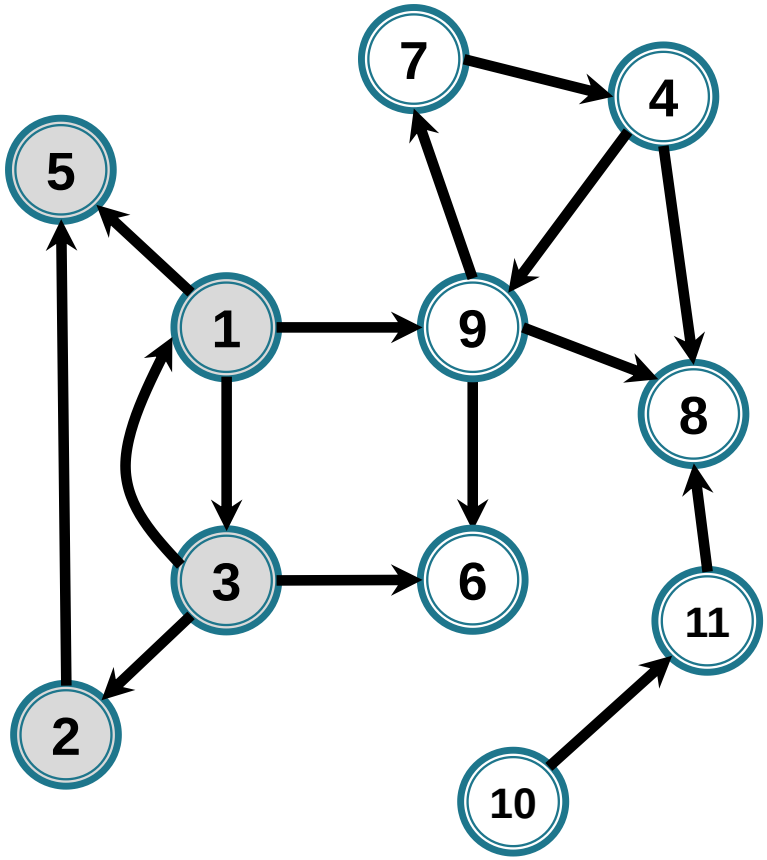

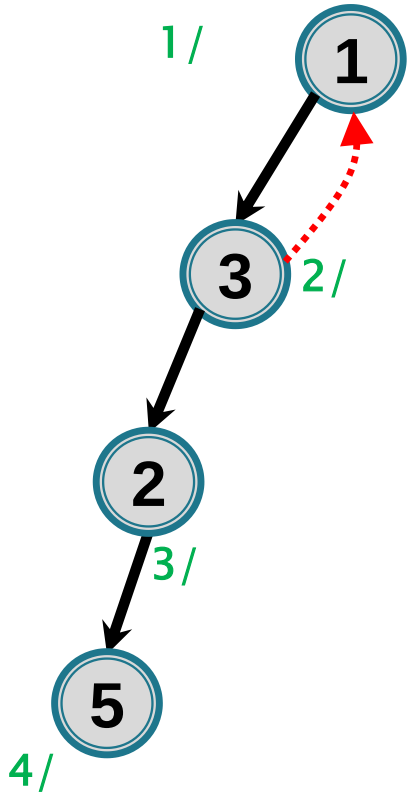

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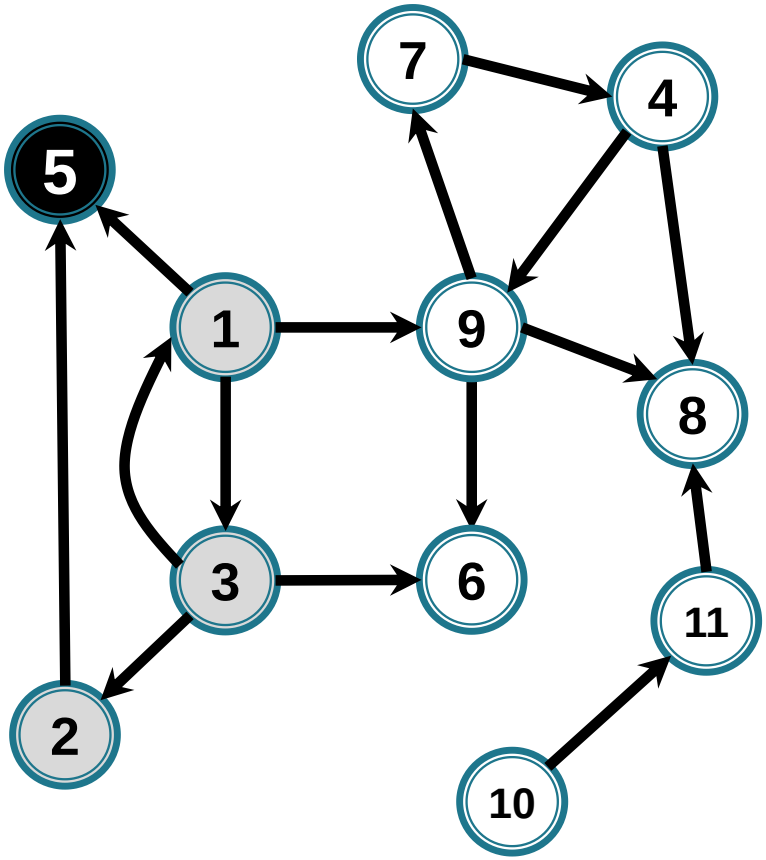

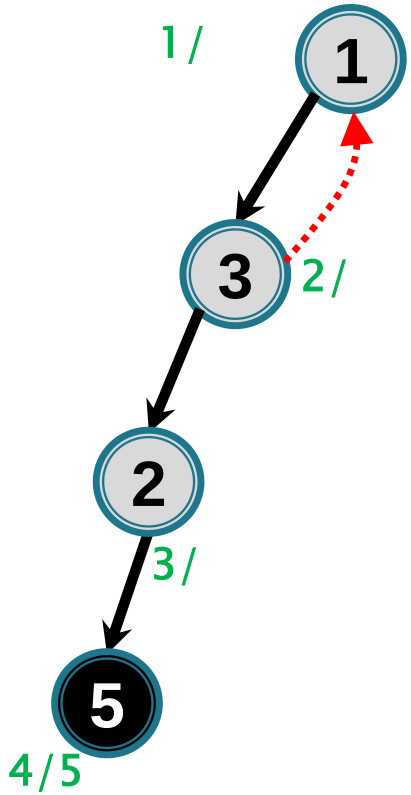

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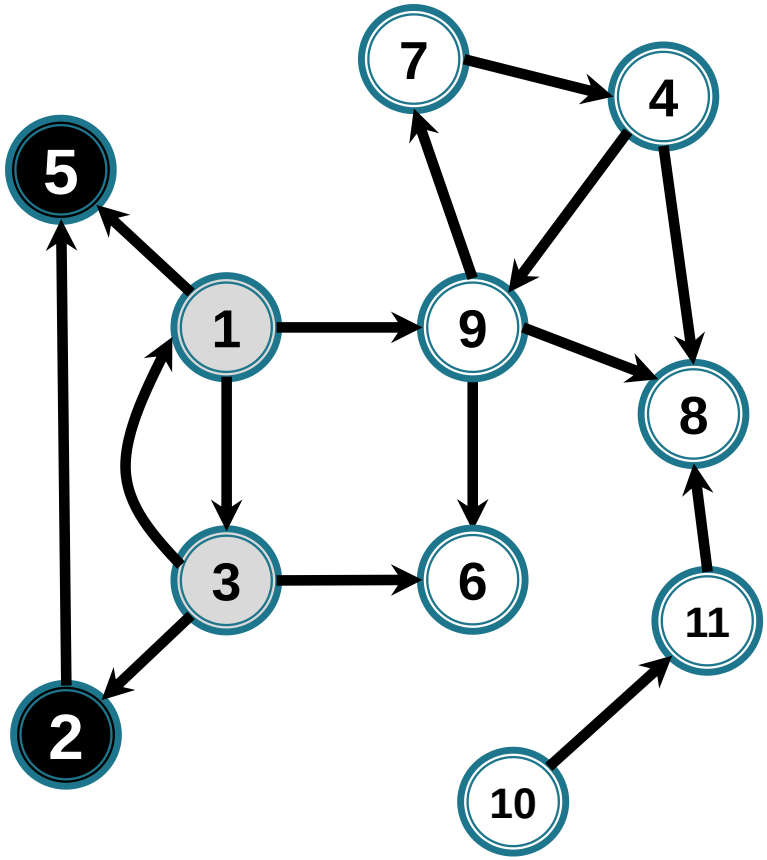

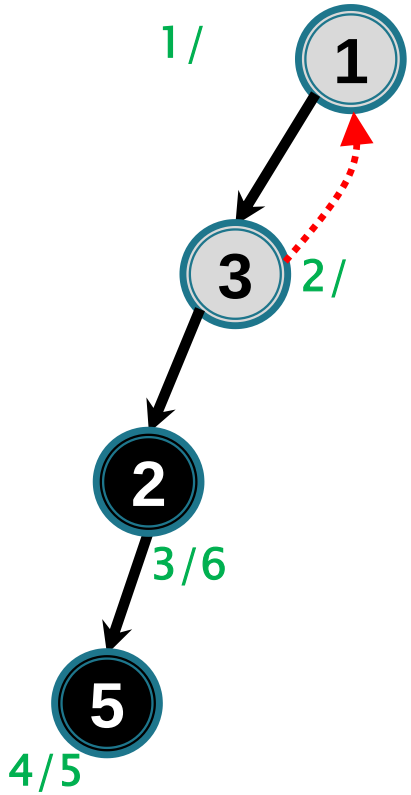

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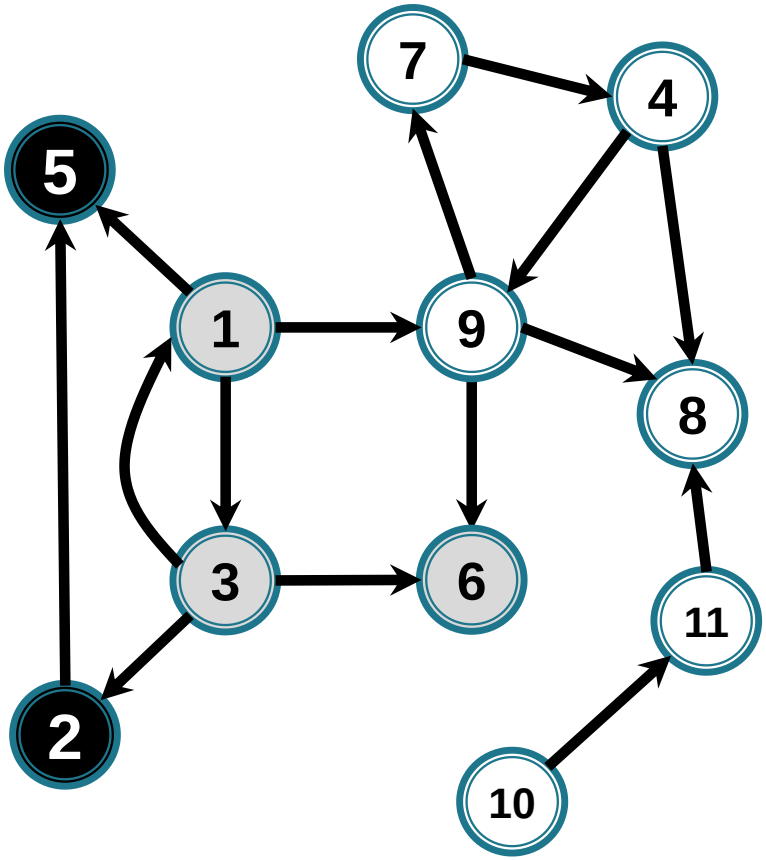

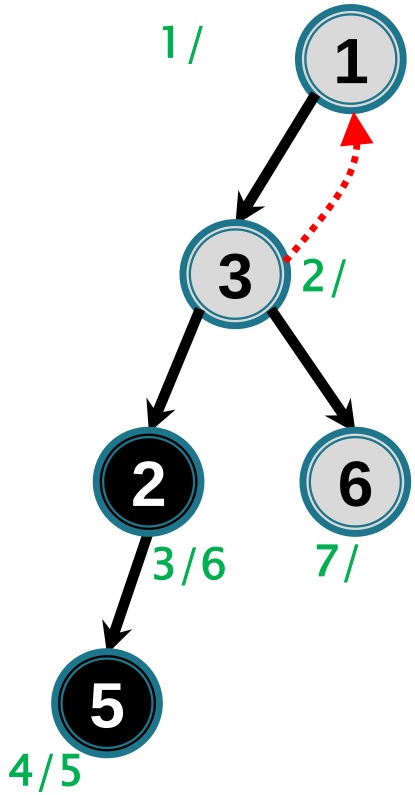

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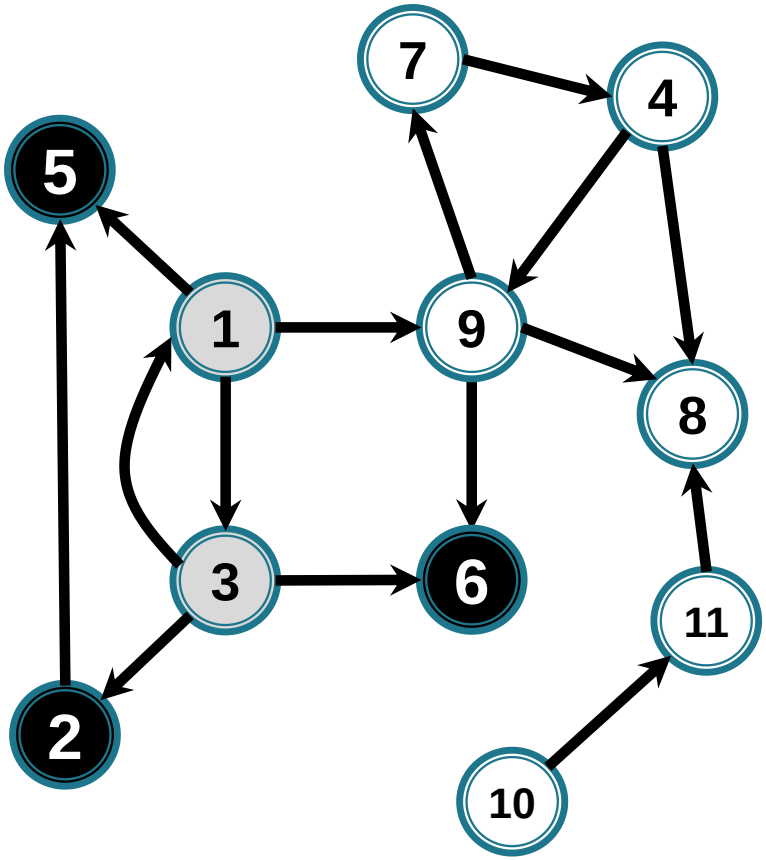

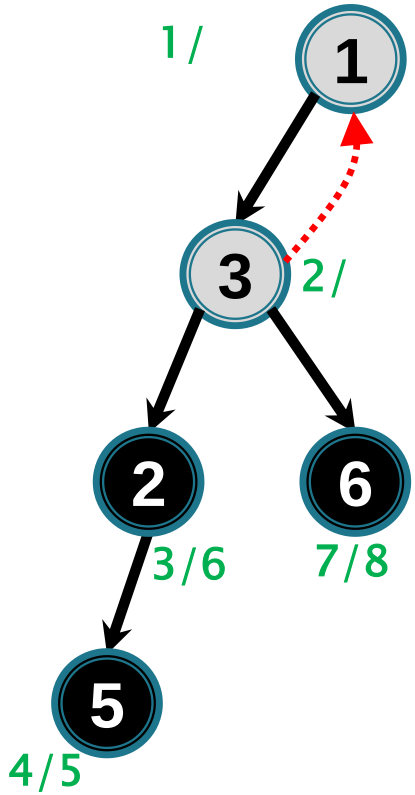

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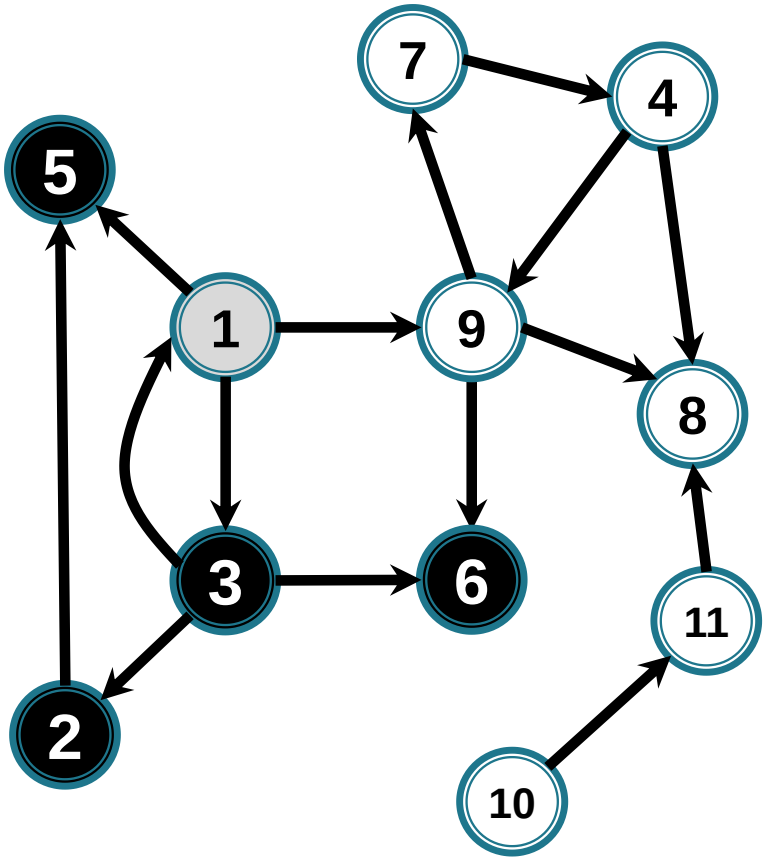

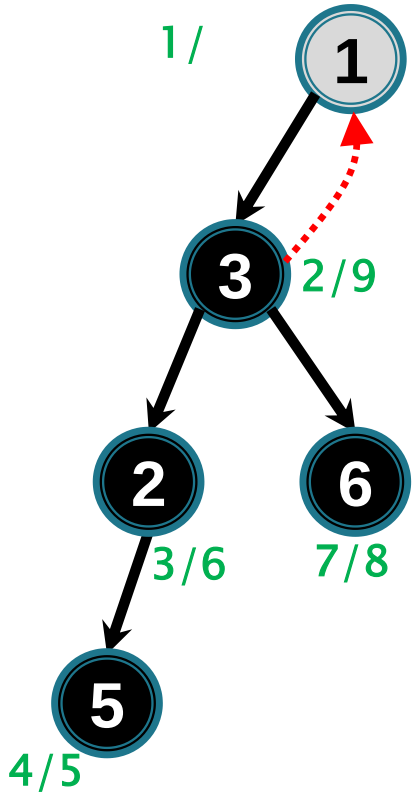

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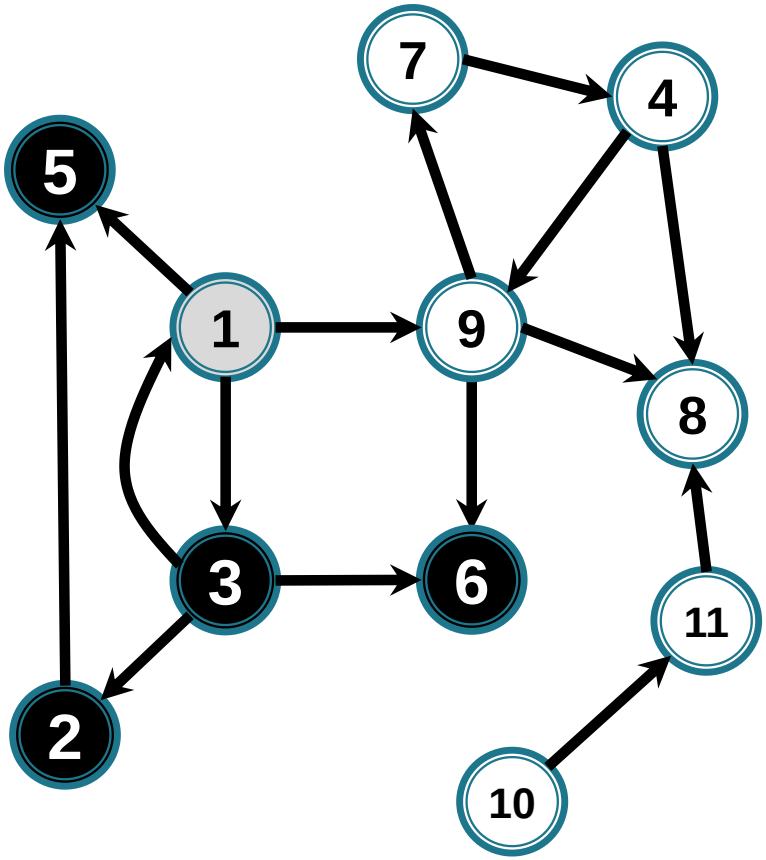

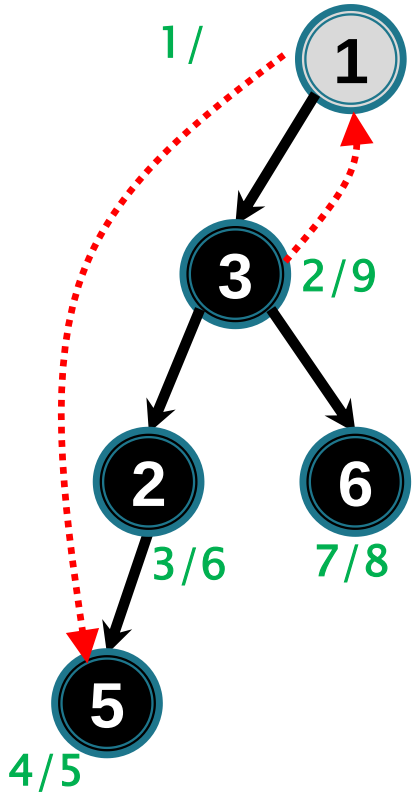

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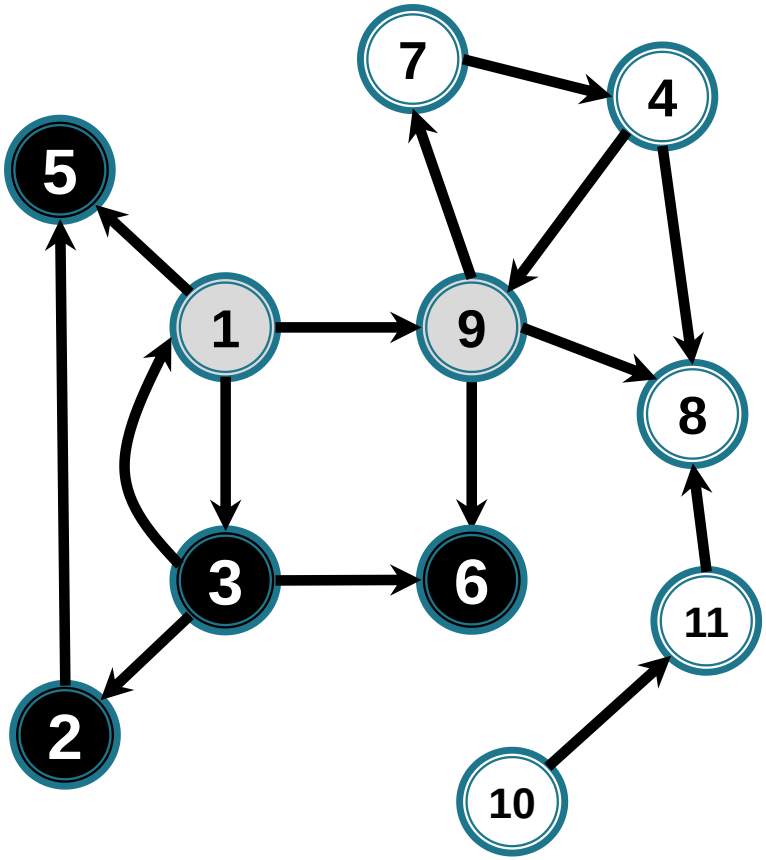

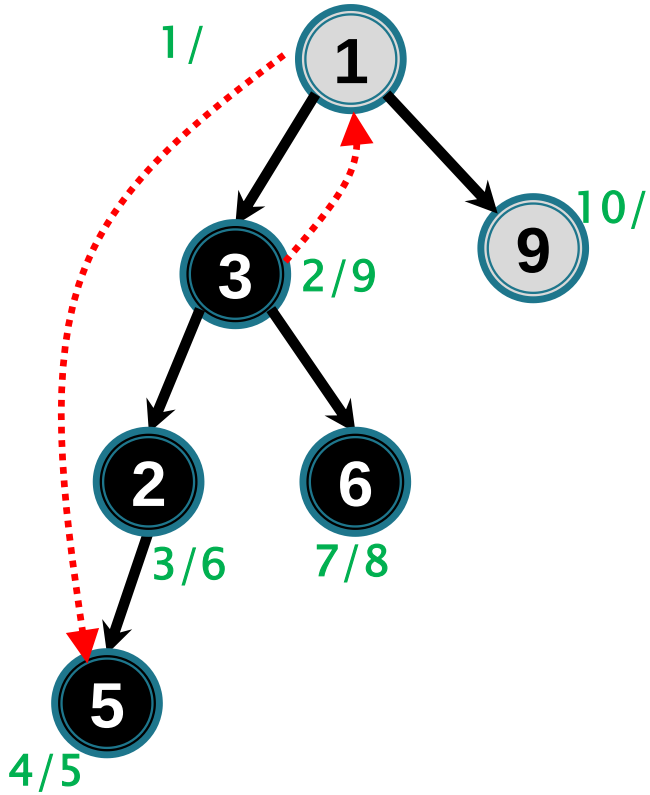

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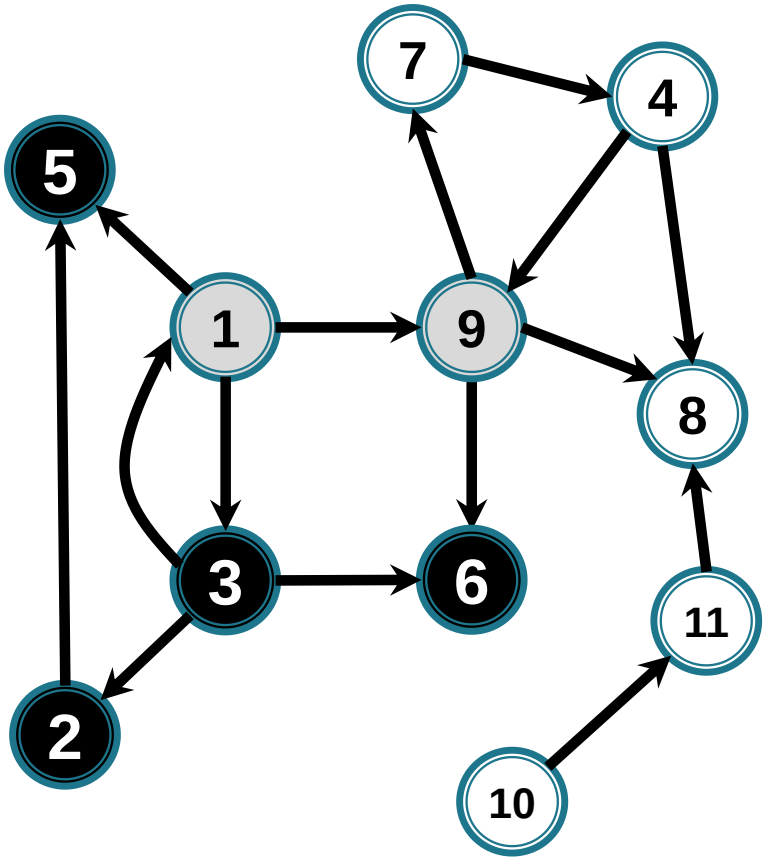

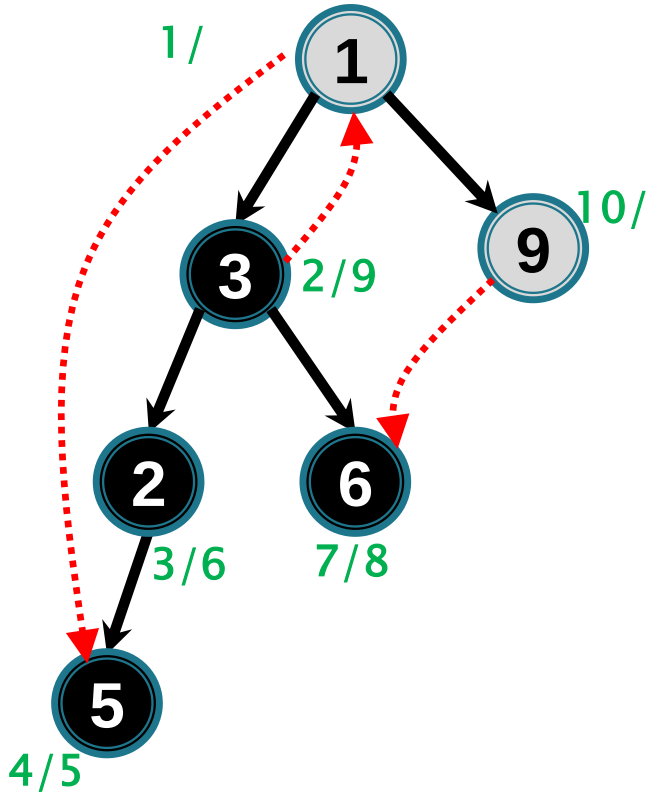

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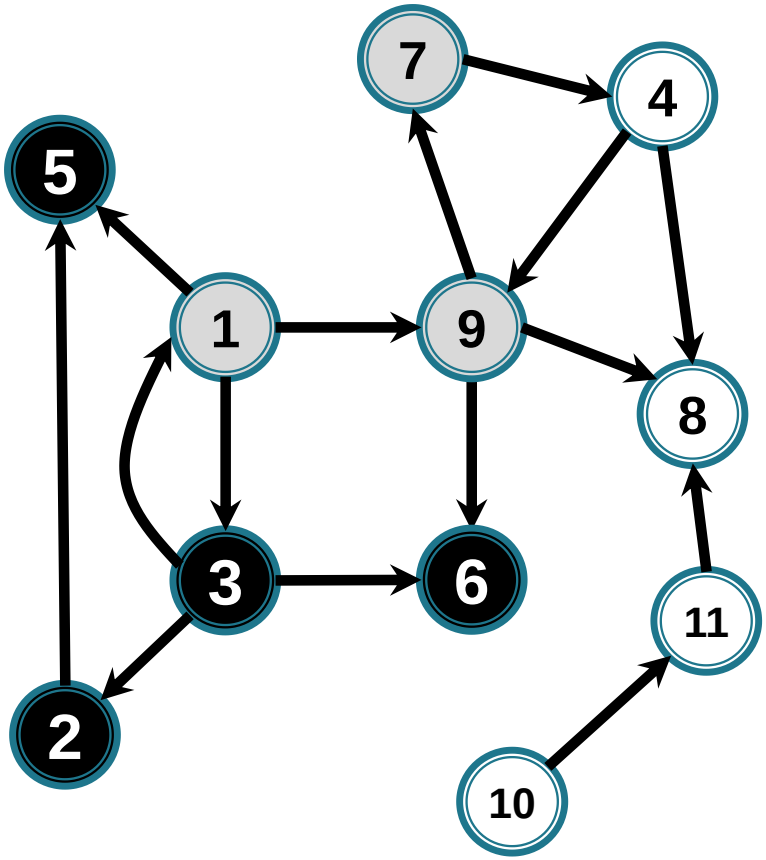

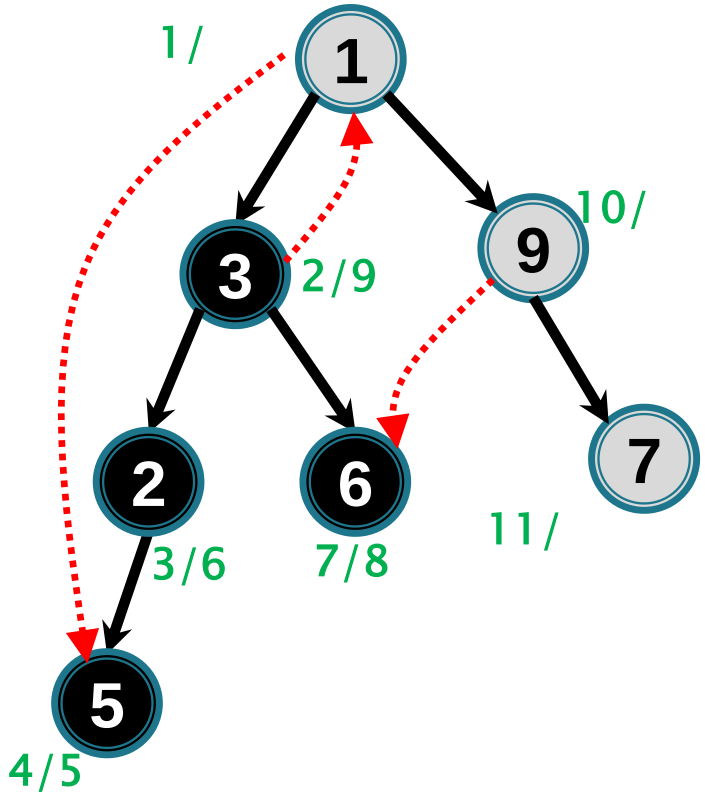

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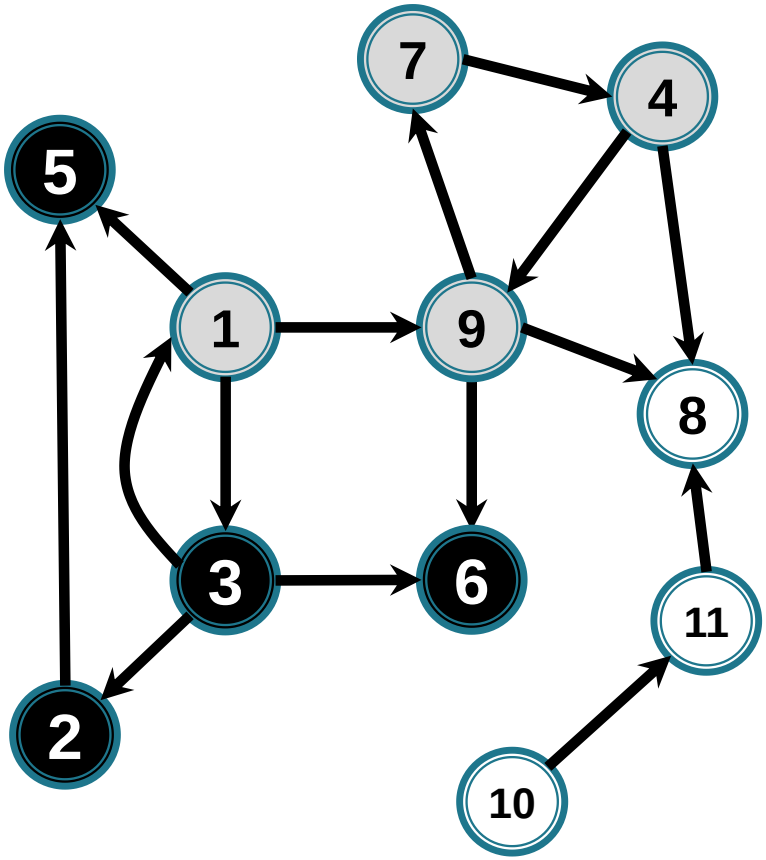

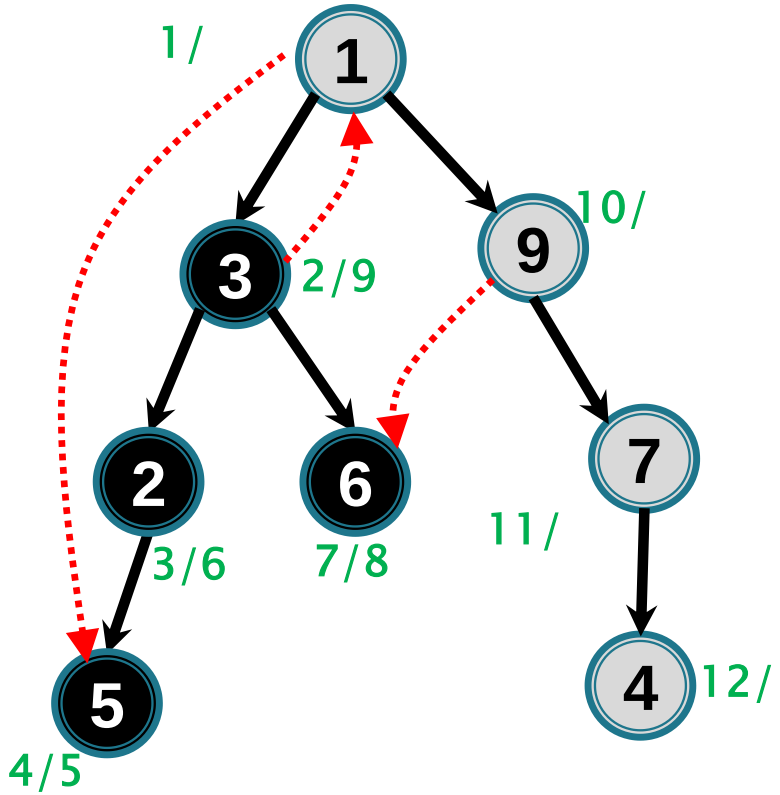

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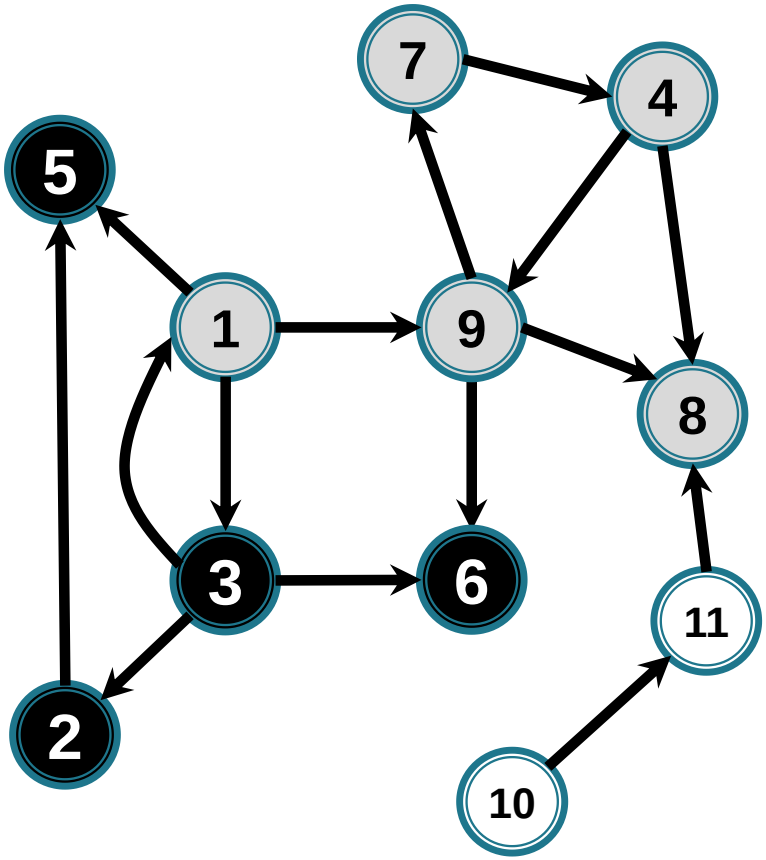

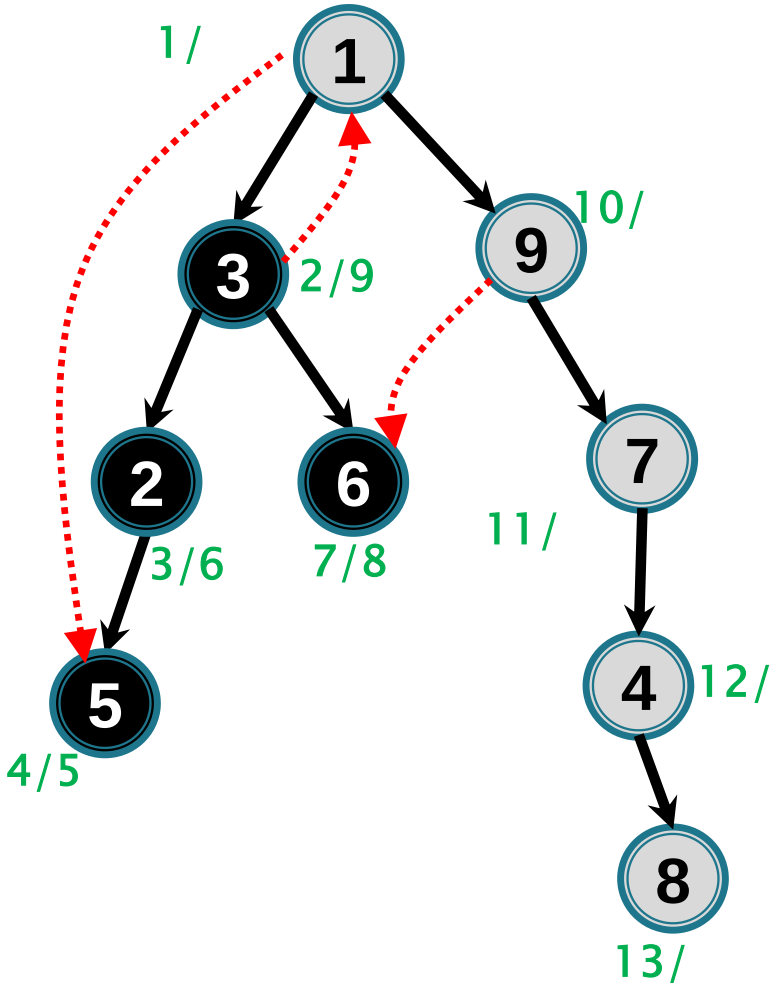

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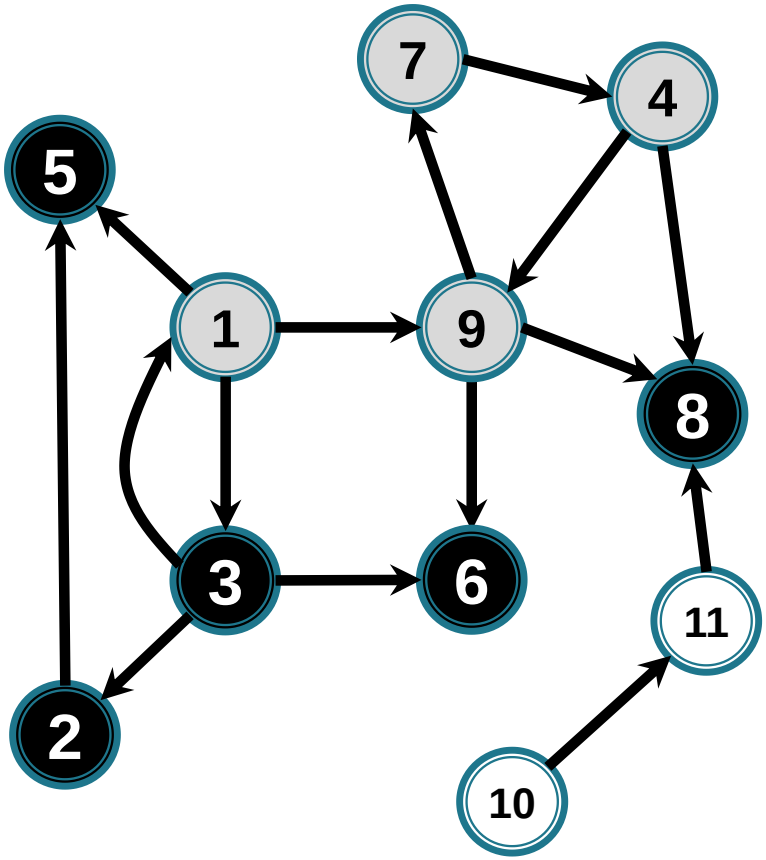

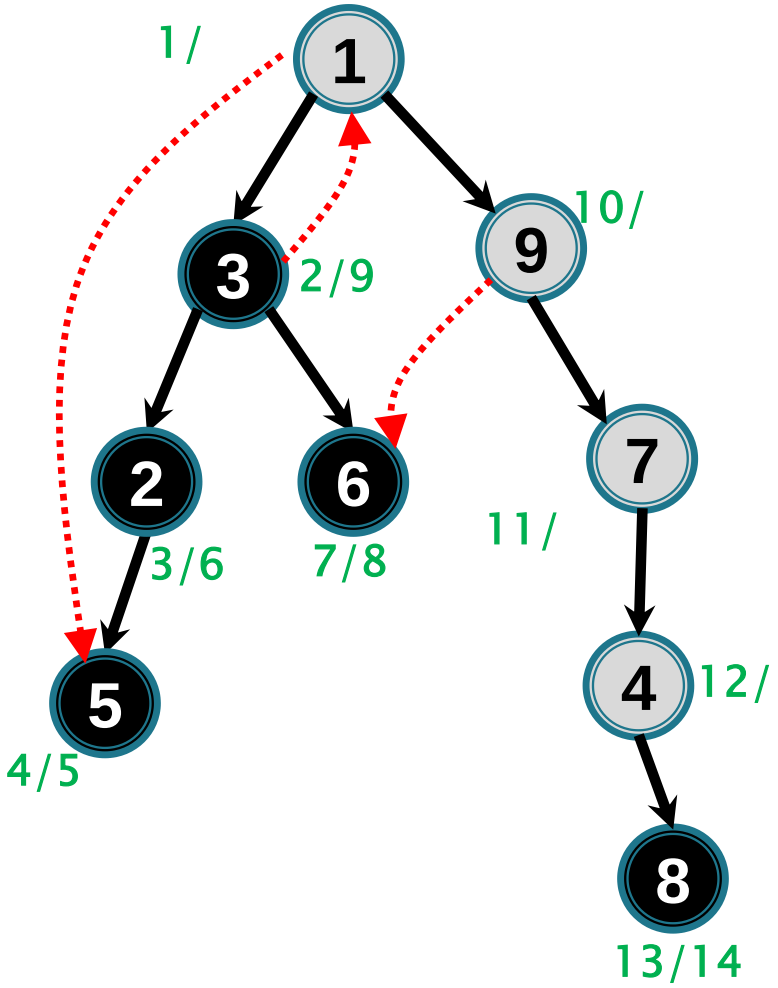

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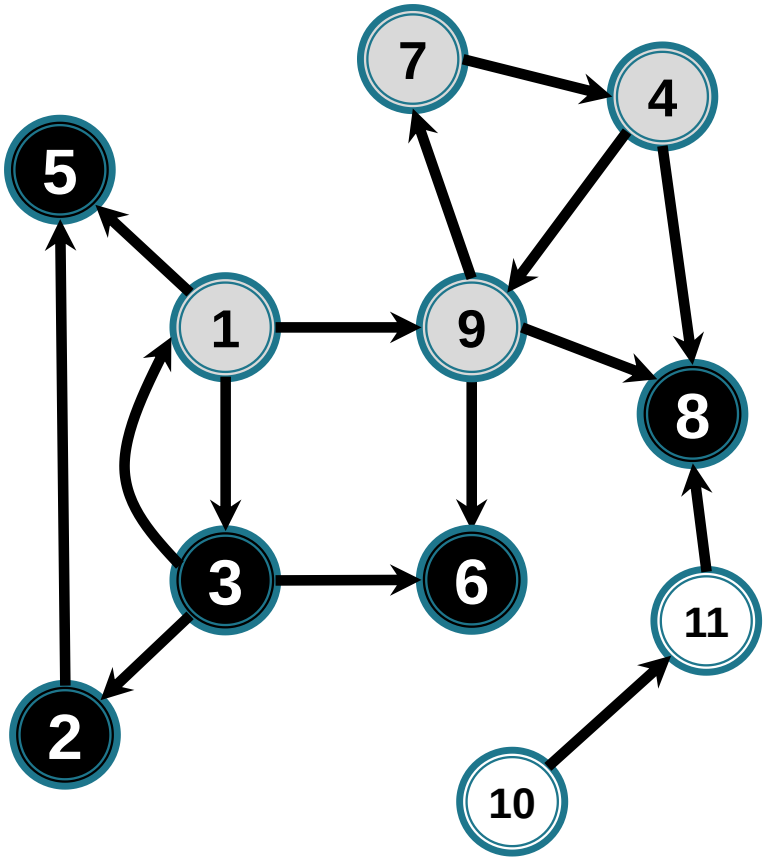

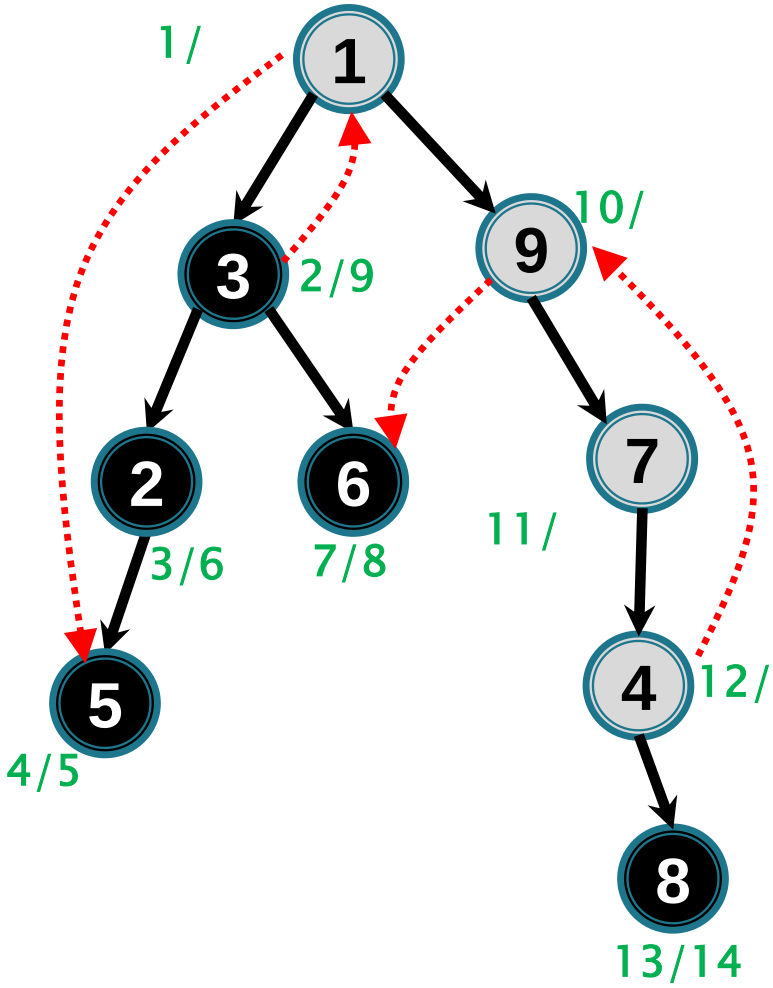

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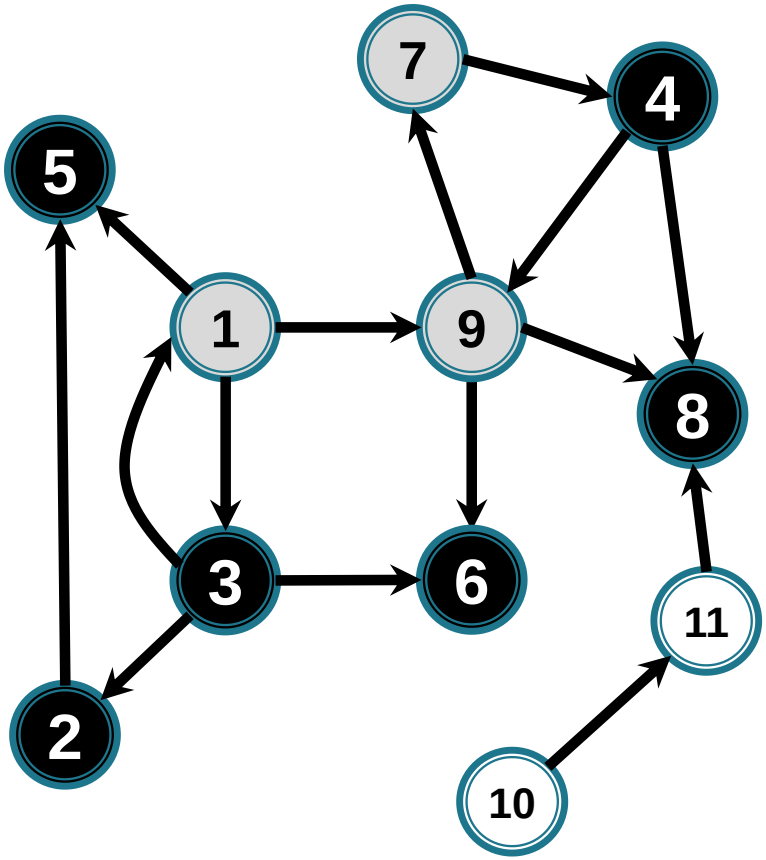

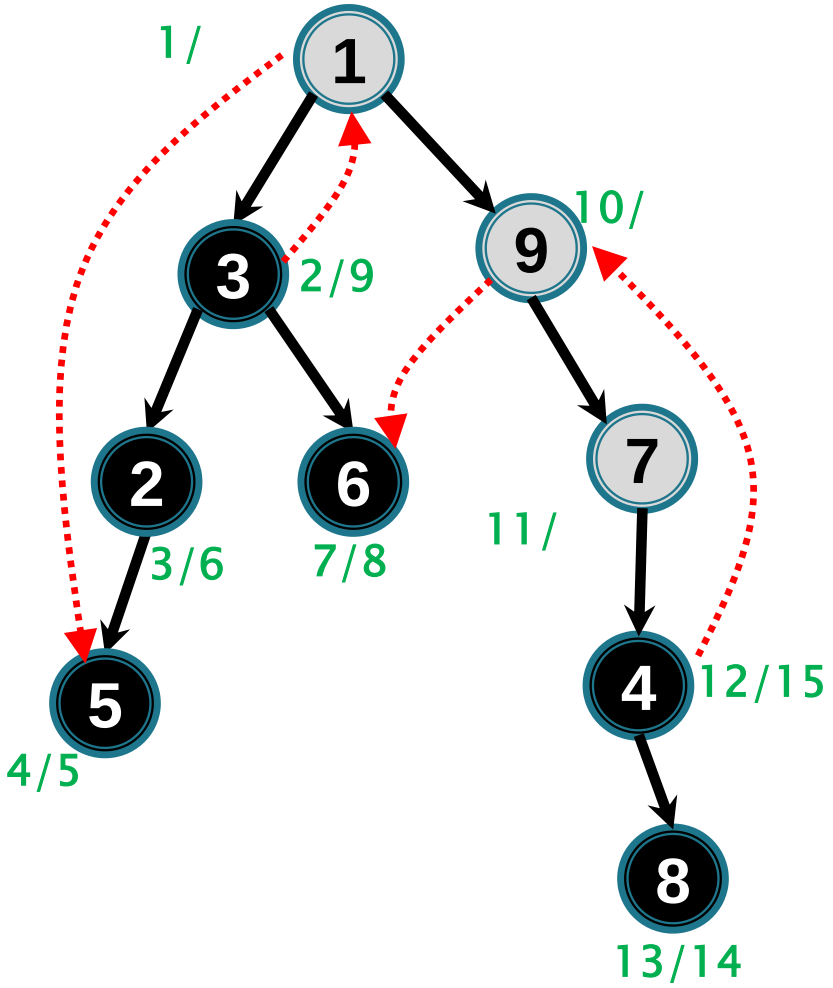

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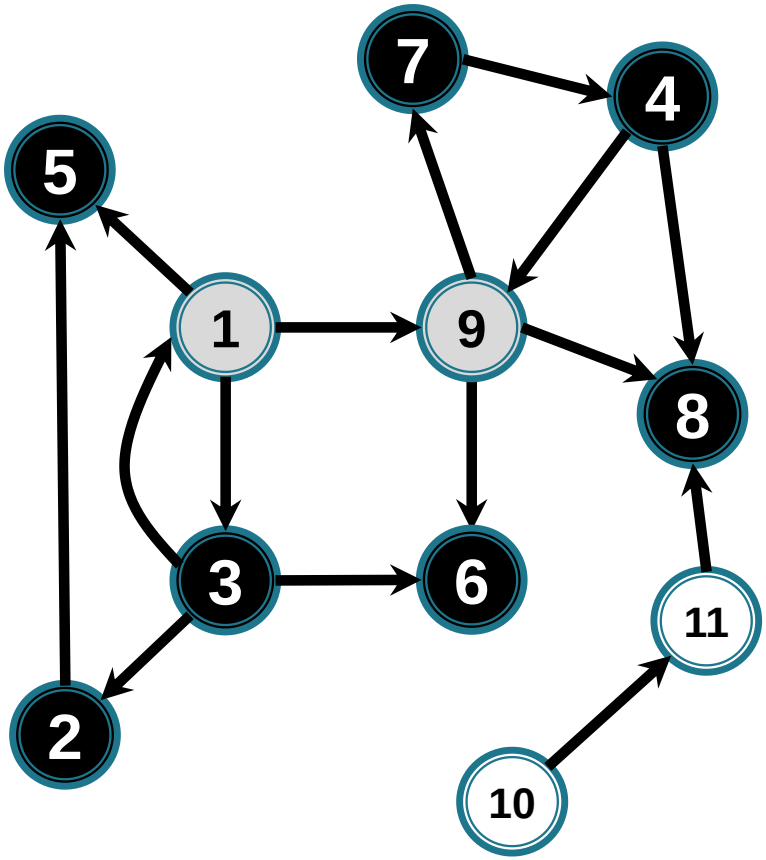

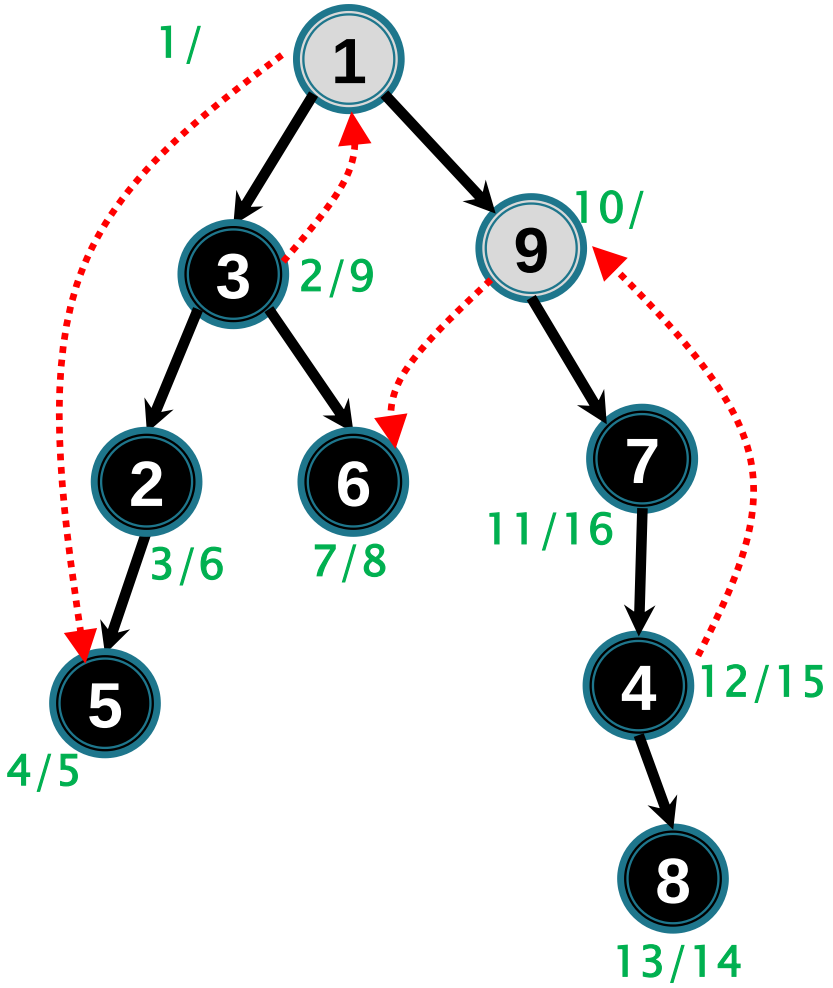

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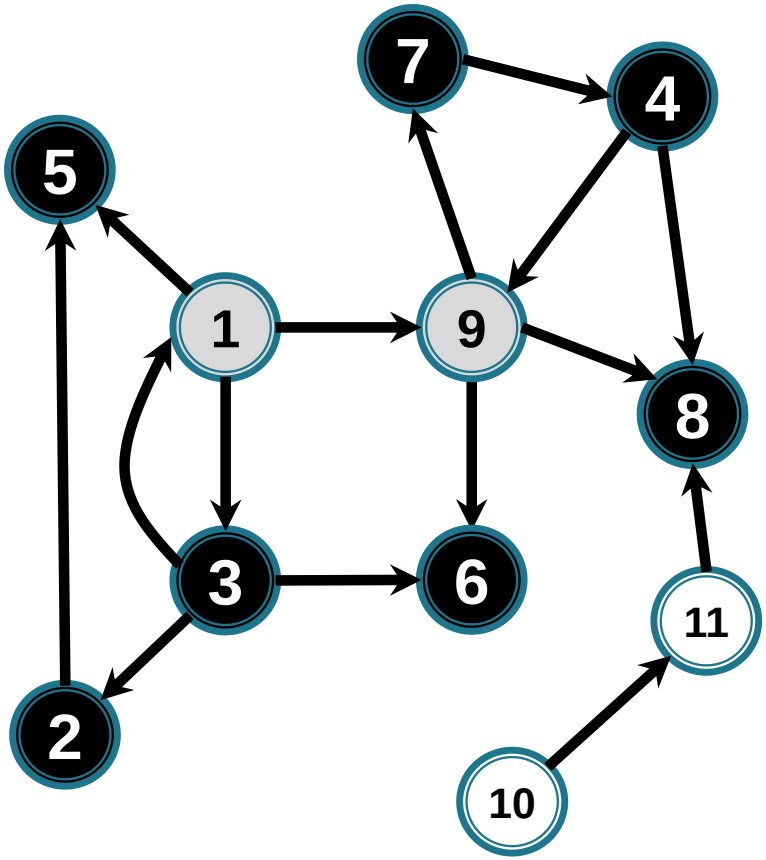

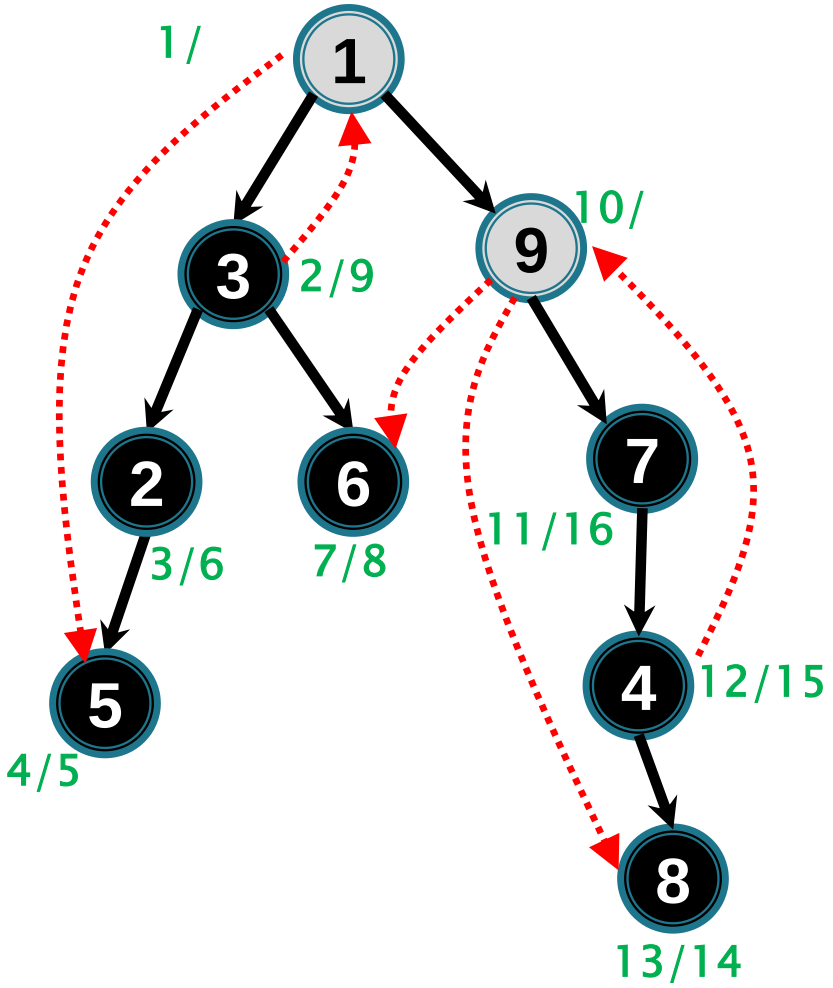

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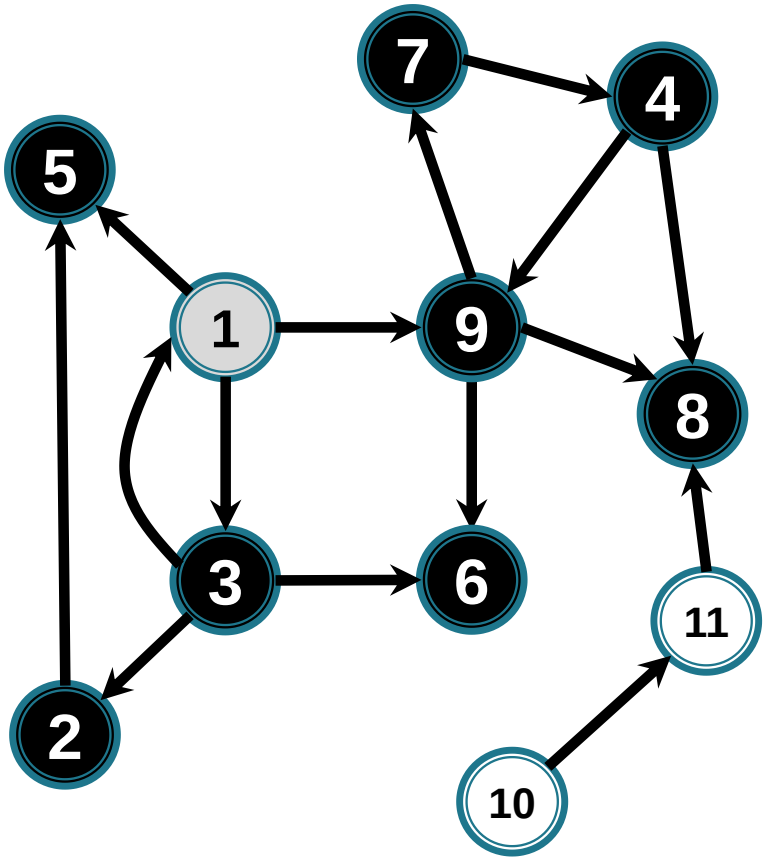

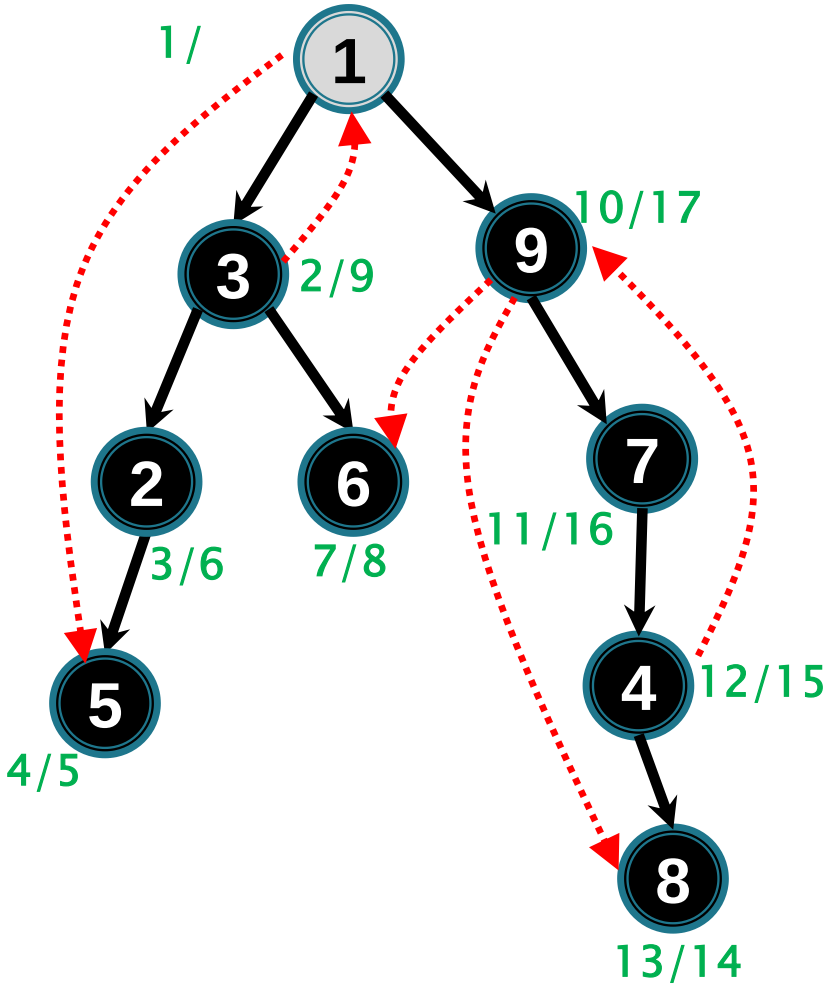

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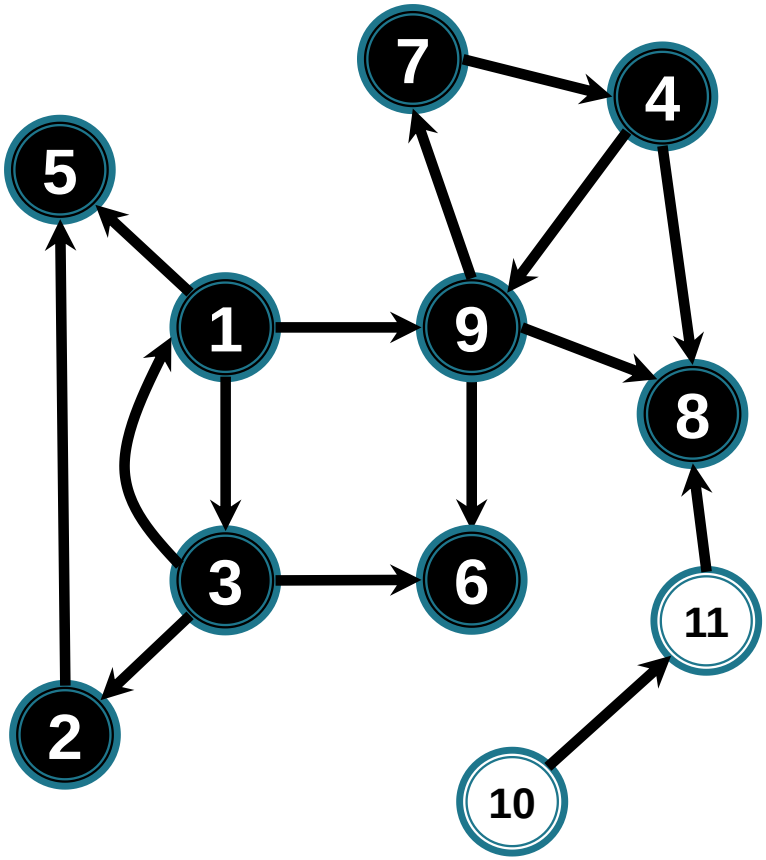

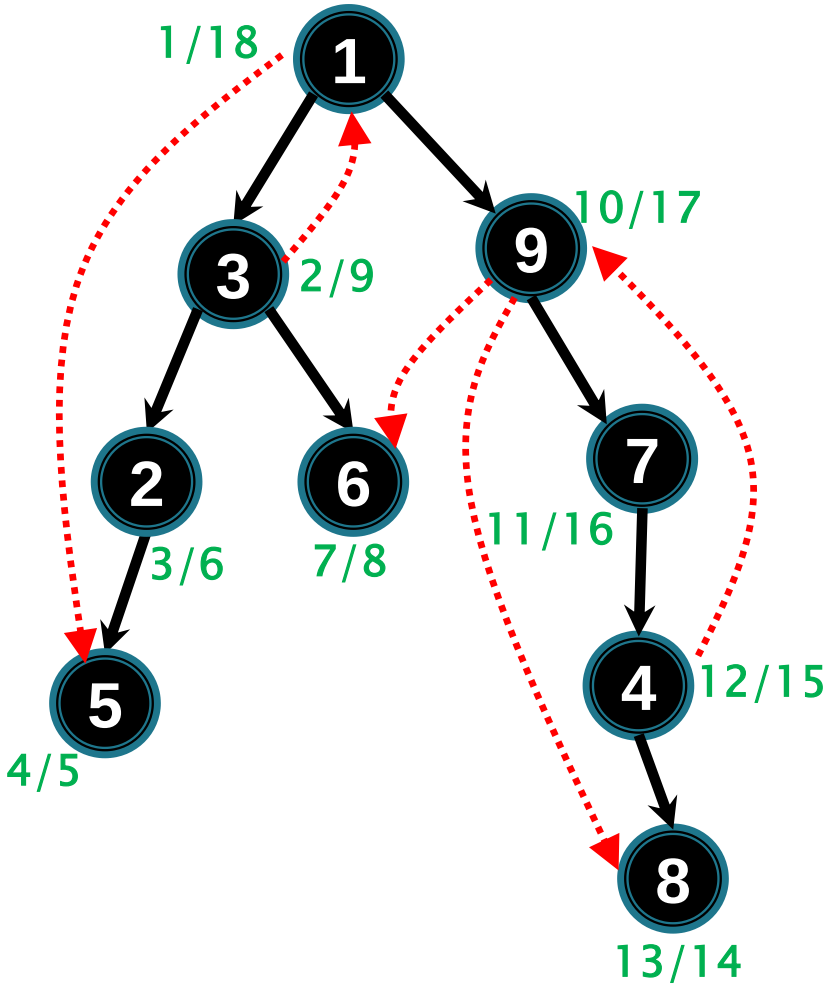

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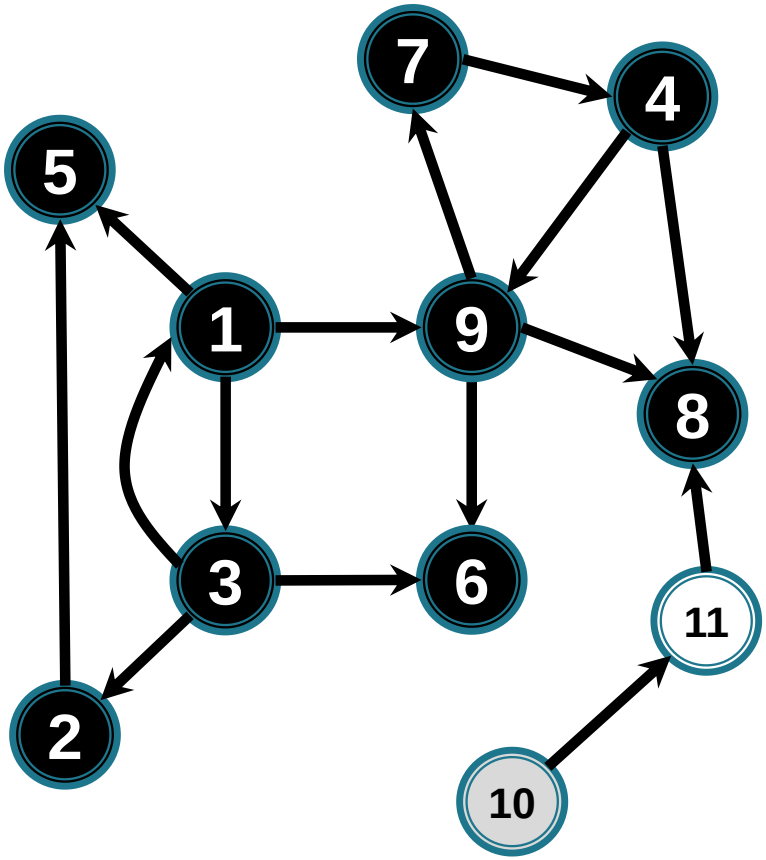

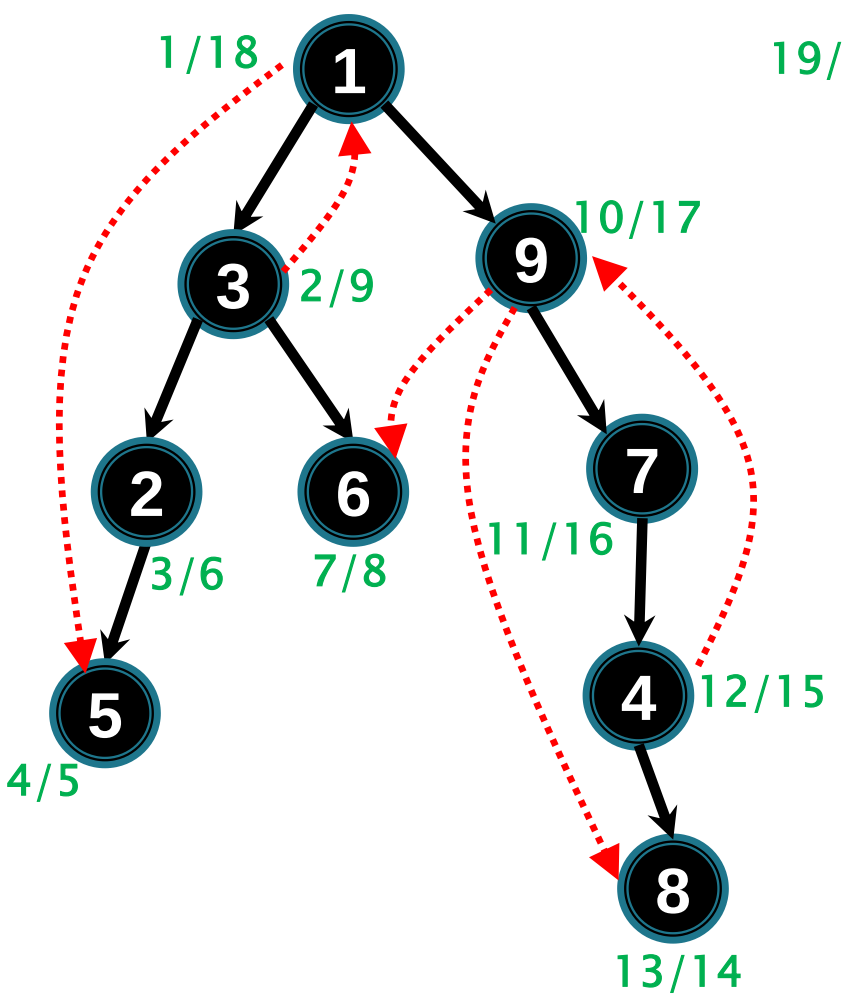

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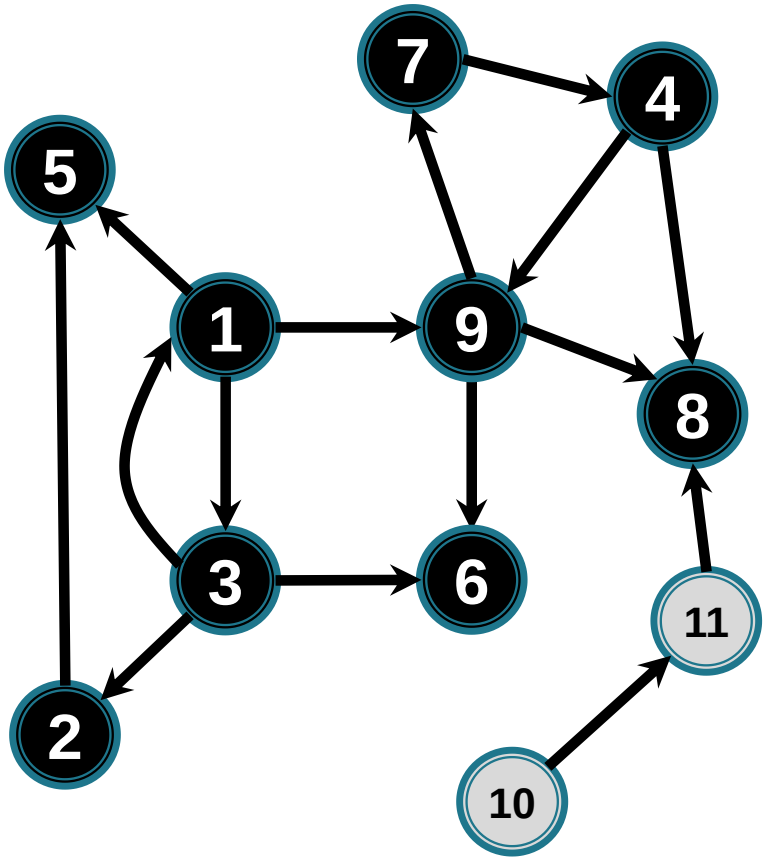

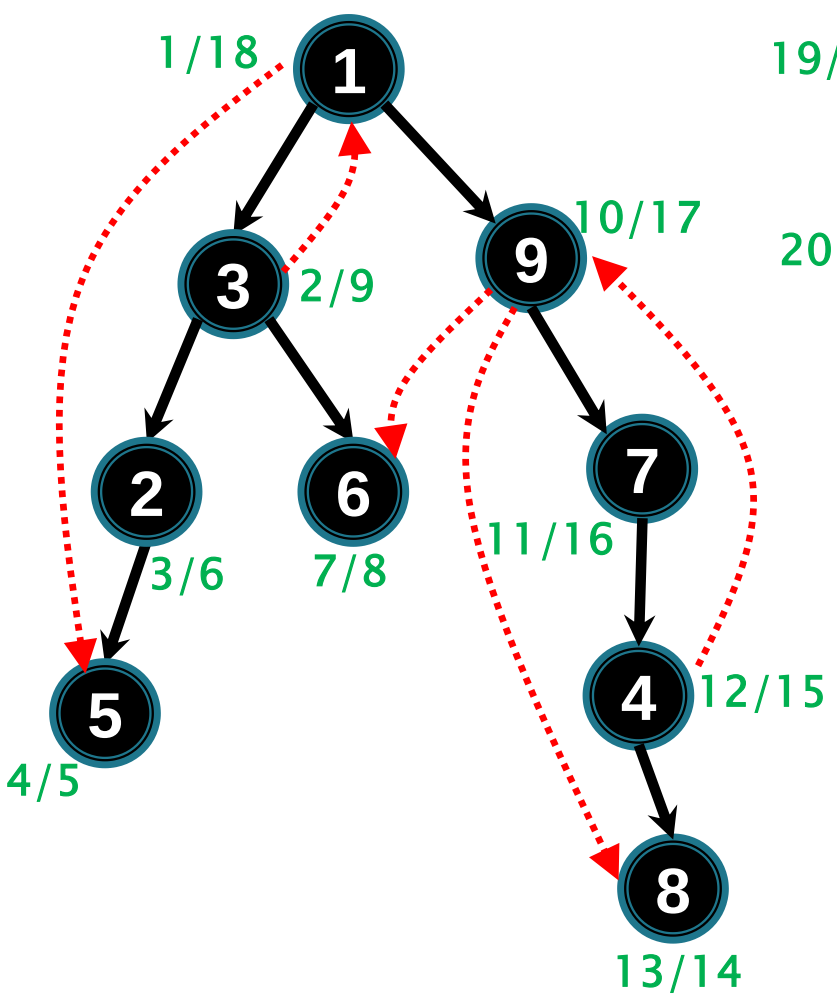

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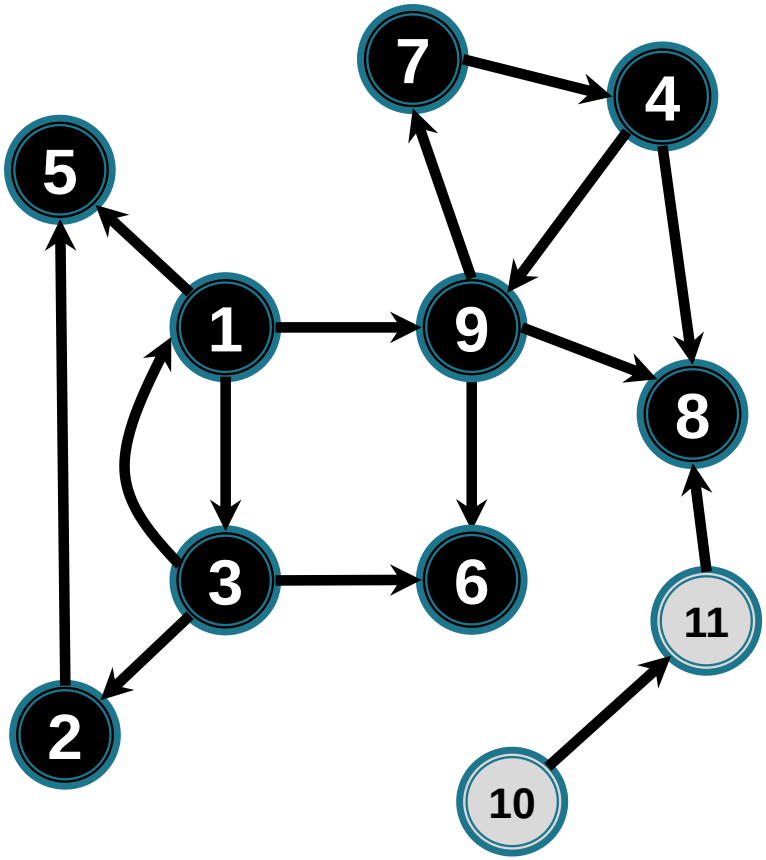

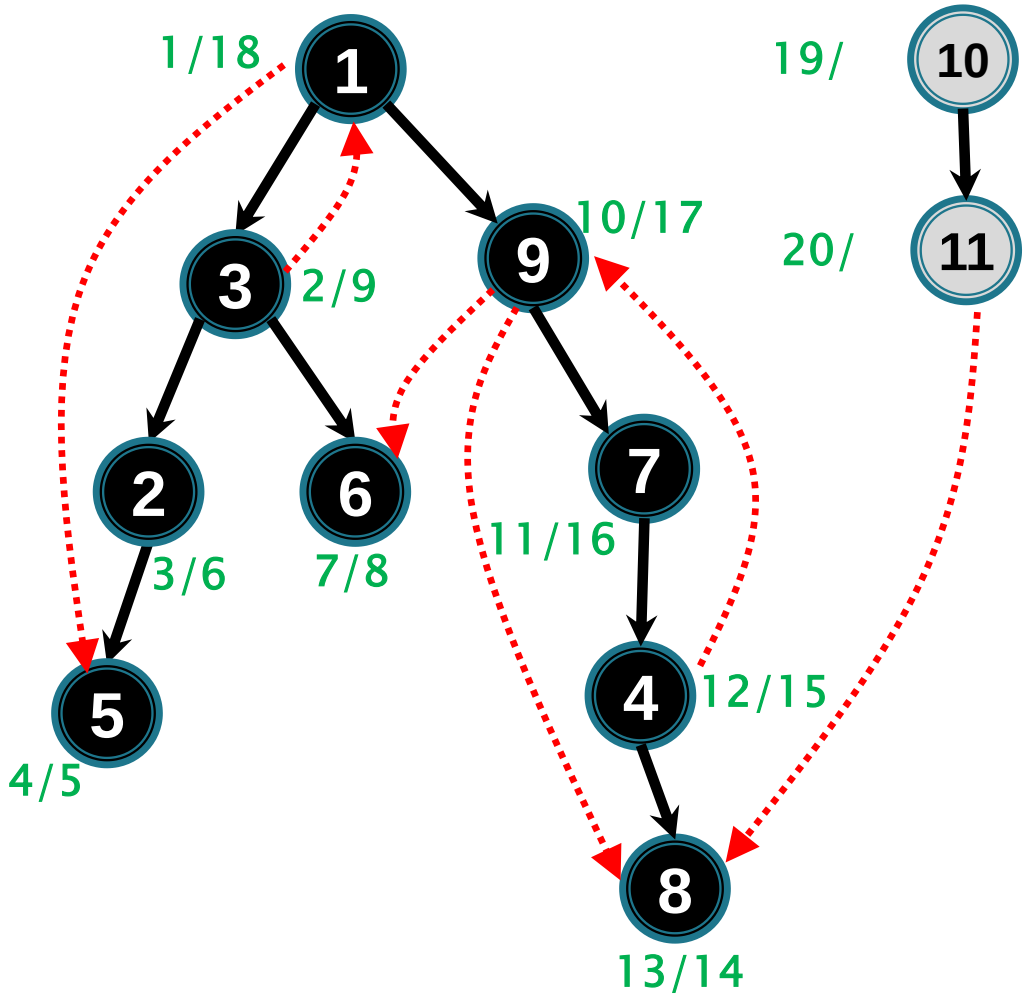

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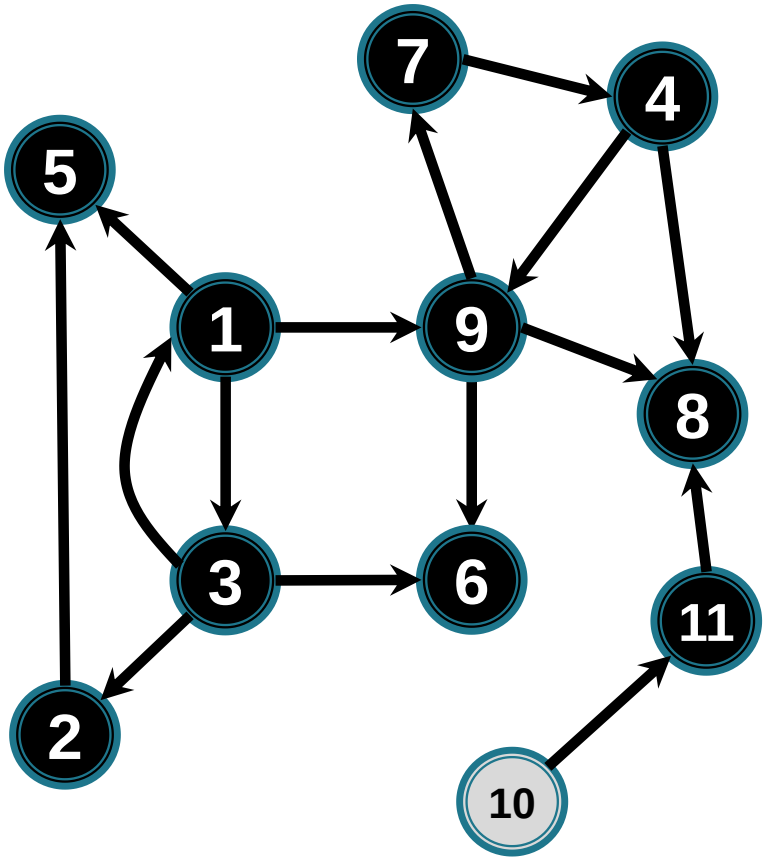

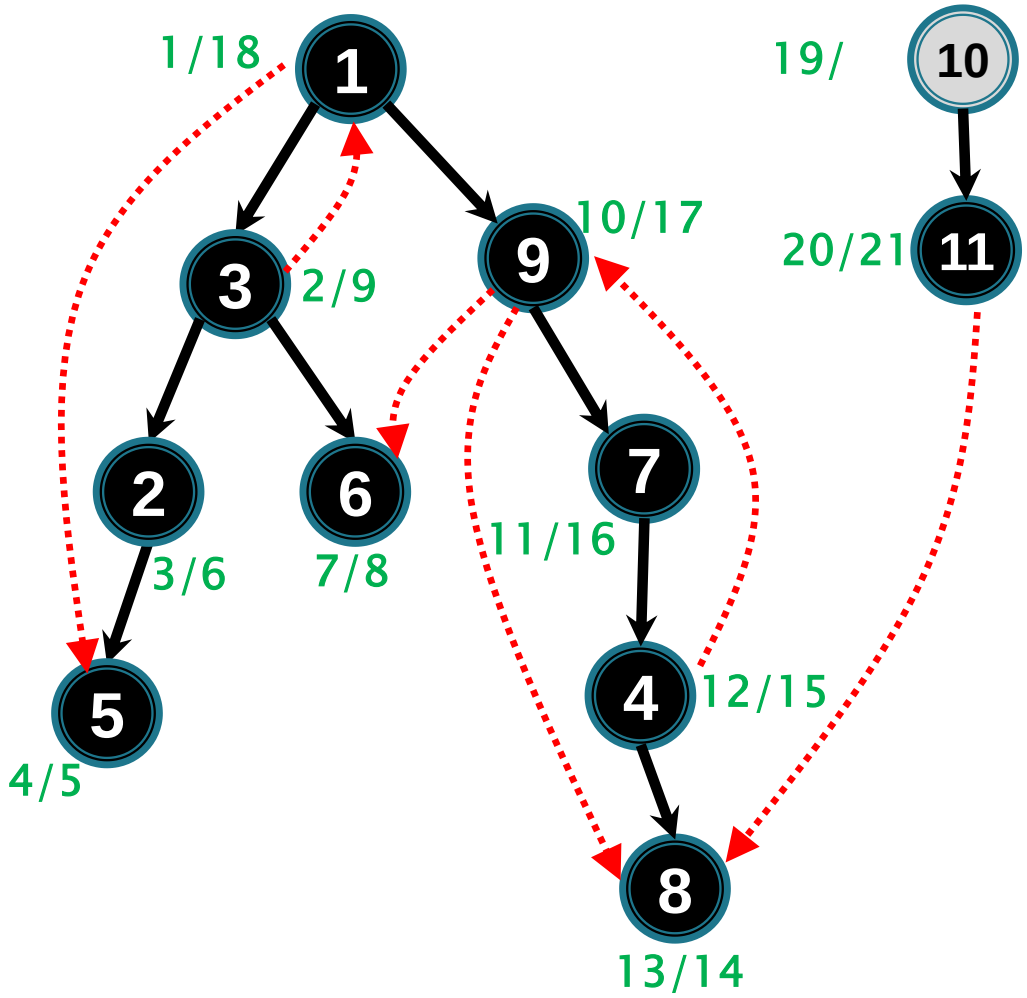

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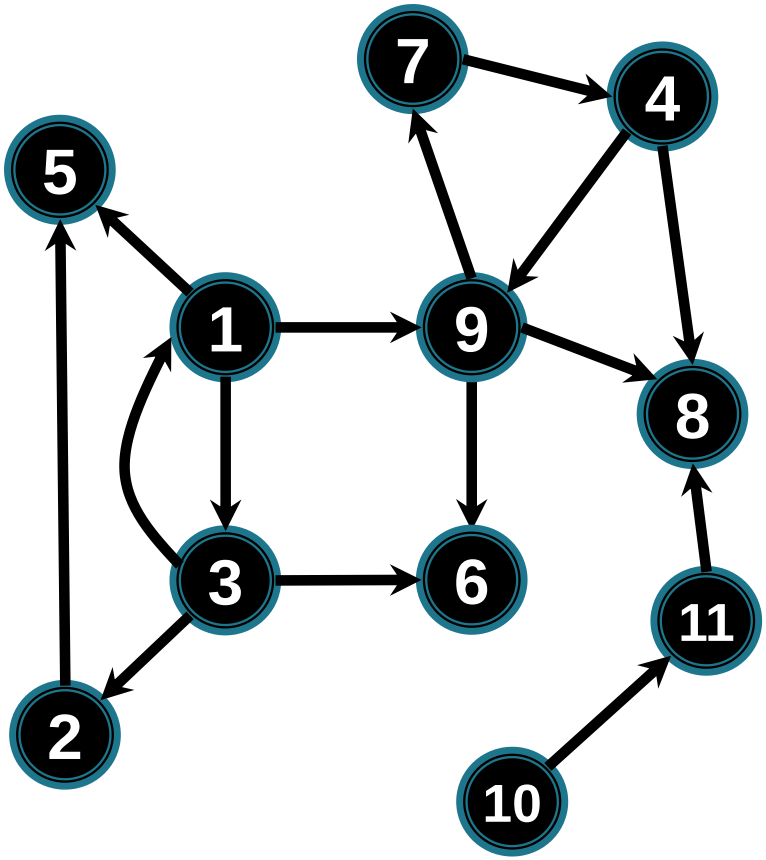
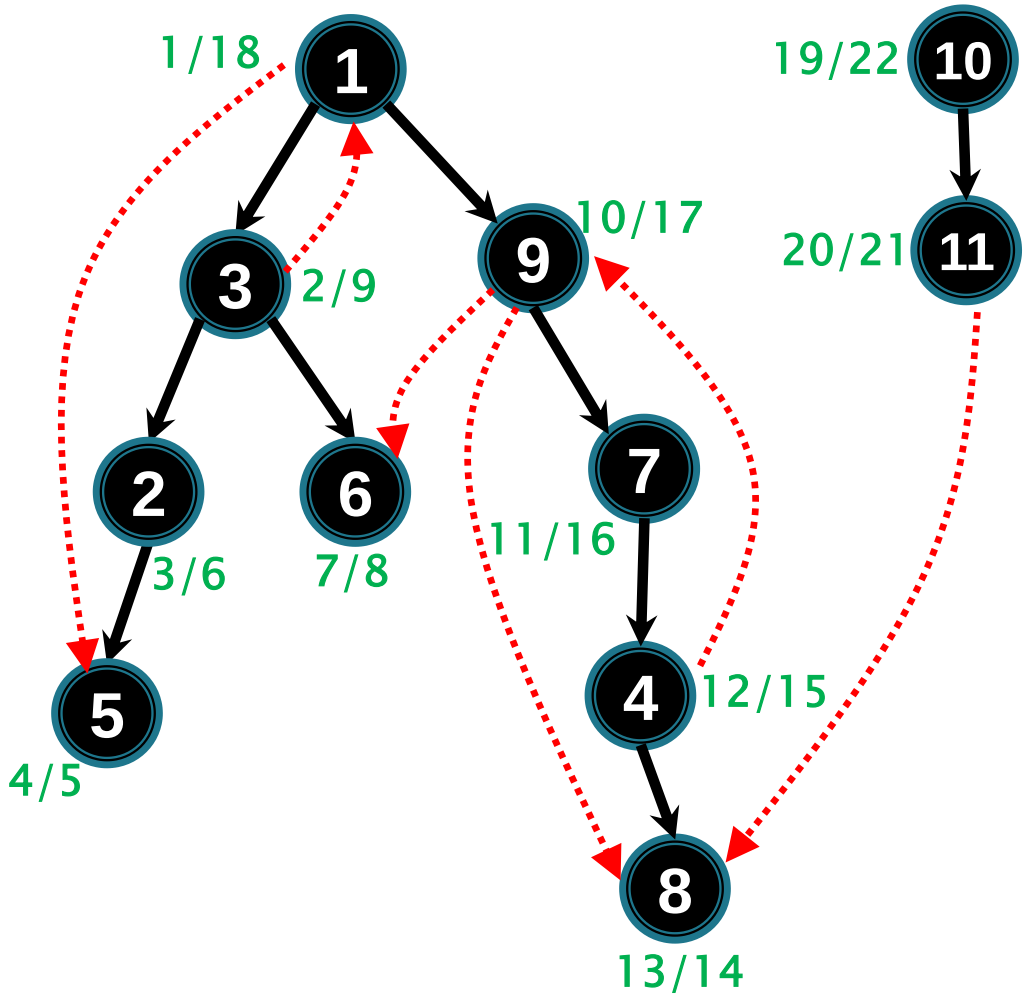




Proprietăți DF

Proprietate

Vârful v este un **descendent** al lui u în pădurea de adâncime DF pentru un graf G (orientat sau neorientat)

dacă şi numai dacă

vârful v este descoperit în timp ce u este gri (este încă în explorare)

Au loc rezultate mai generale:

Proprietăți DF

Teorema parantezelor

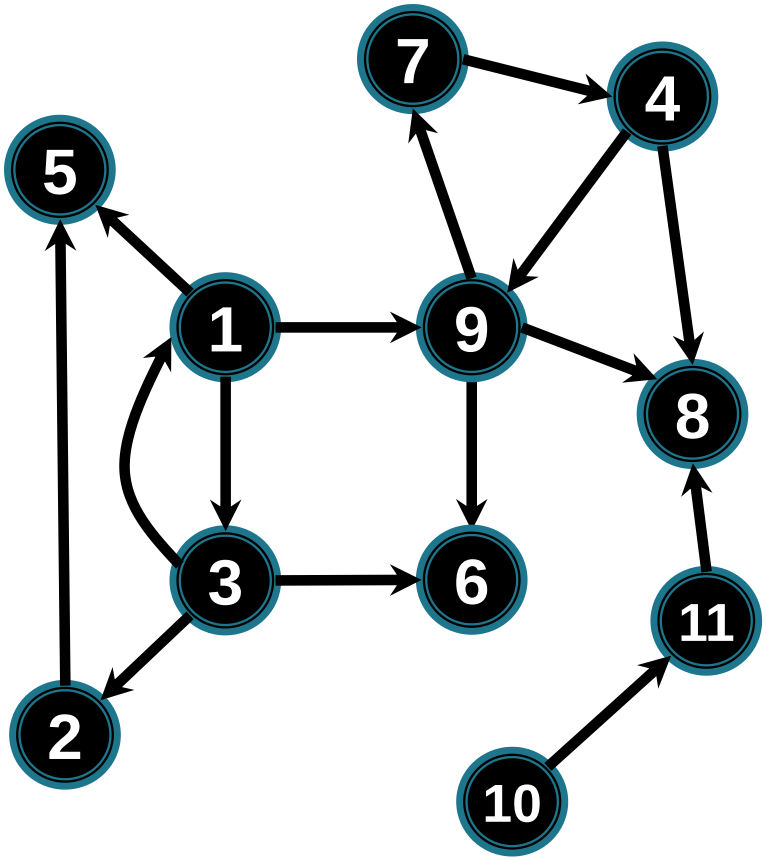
În orice căutare în adâncime a unui graf (orientat sau neorientat) G = (V, E), pentru orice două vârfuri u şi v cu

```
desc[u] < desc[v]
```

exact una din următoarele condiții este adevărată:

•

•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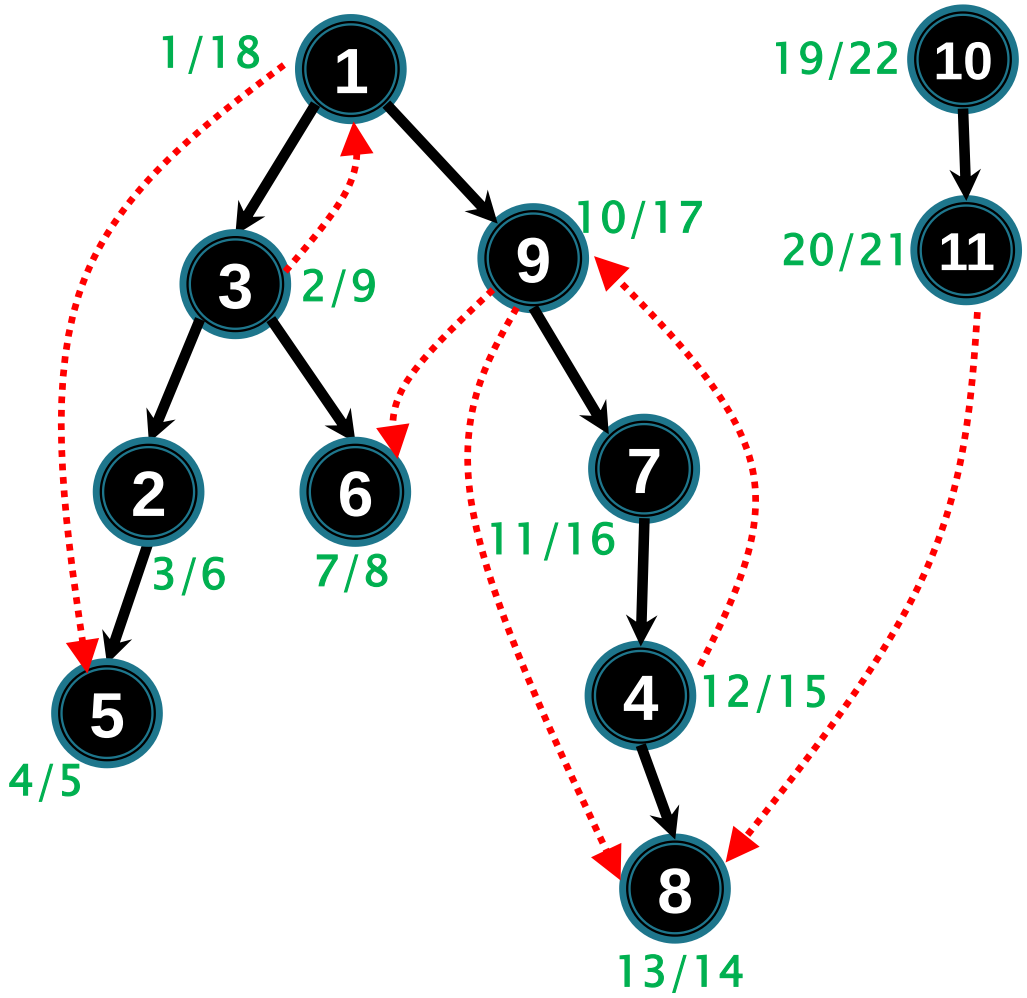
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Proprietăți DF

Teorema parantezelor

În orice căutare în adâncime a unui graf (orientat sau neorientat) G = (V, E), pentru orice două vârfuri u şi v cu

`desc[u] < desc[v]`

exact una din următoarele condiții este adevărată:

- intervalele **`[desc[u], fin[u]]`** şi **`[desc[v], fin[v]]`** sunt **disjuncte și u și v nu sunt unul descendentul celuilalt** în arborele/pădurea DF

- **`[desc[v], fin[v]]`** $\subset$ **`[desc[u], fin[u]]`**,
caz în care v este un descendent al lui u în arborele/pădurea DF

Proprietăți DF

Idee de demonstrație

Avem

$$\texttt{desc[u]} < \texttt{desc[v]}$$

- **`desc[v] > fin[u]`:** intervalele sunt disjuncte; u este deja negru când v a fost descoperit, deci v nu este descendent al lui u și nici invers
- **`desc[v] < fin[u]`:** v este descoperit în timp ce u este gri, deci este descendent al lui u; atunci v va fi finalizat inaintea lui u , deci

$$[\texttt{desc[v]}, \texttt{fin[v]}] \subset [\texttt{desc[u]}, \texttt{fin[u]}]$$

Proprietăți DF

Proprietate (Incluziunea intervalelor descendenților)

Vârful v este un **descendent** al lui u în pădurea de adâncime DF pentru un graf G (orientat sau neorientat)

⇔

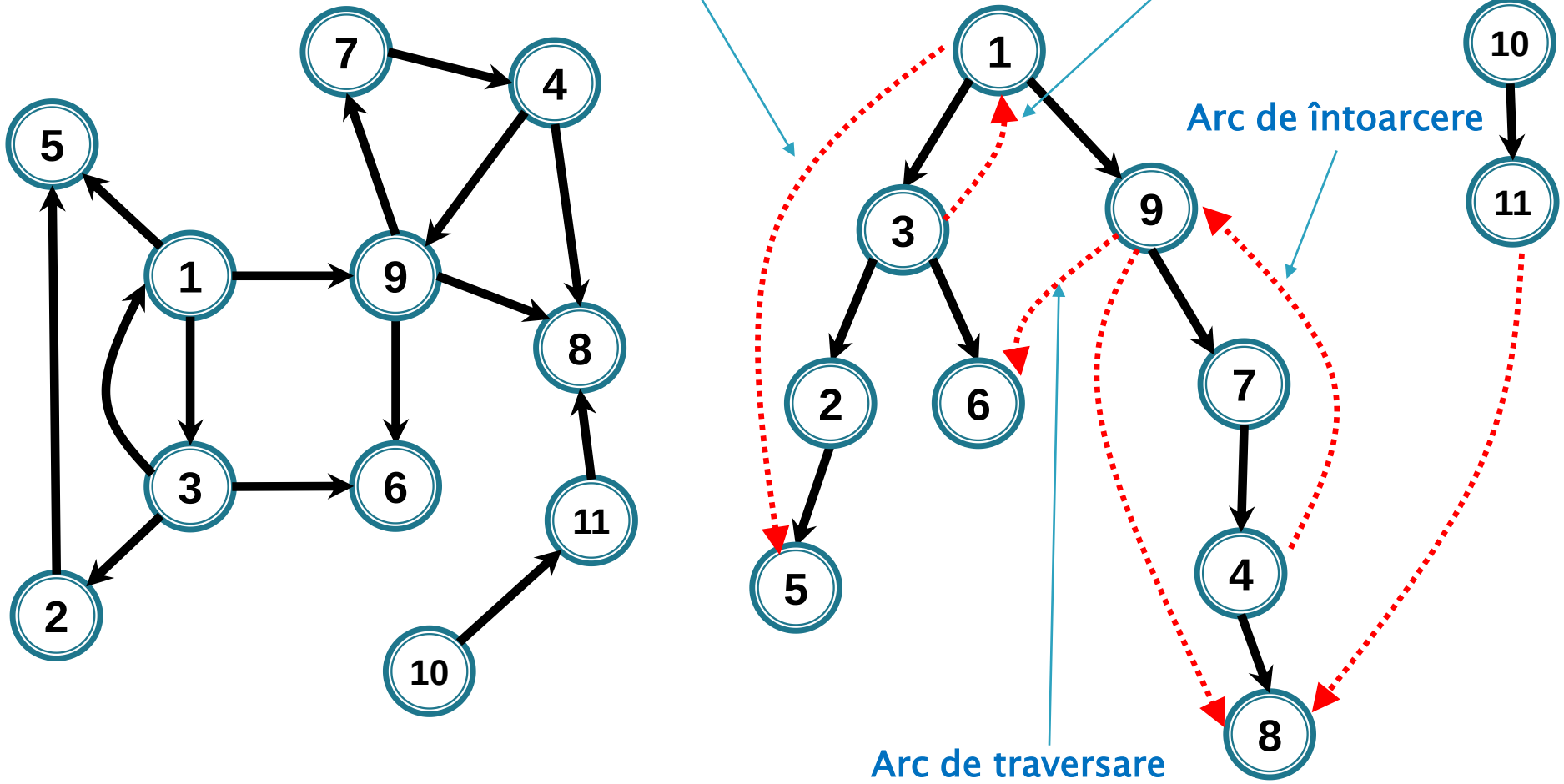
vârful v este descoperit în timp ce u este gri (este încă în explorare)

⇔

`[desc[v], fin[v]] ⊂ [desc[u], fin[u]]`

Proprietăți DF

- În raport cu pădurea DF muchiile/arcele se împart în 4 categorii:



Proprietăți DF

În raport cu pădurea DF muchiile/arcele se împart în 4 categorii:

- **de arbore DF (de avansare directă/ de arbore):**

  (u, v) cu v fiu al lui u (v a fost descoperit din u)

- **de întoarcere (înapoi) :**

  (u, v) cu v strămoș al lui u (și care nu este de arbore)

- **de avansare (de avansare înainte) :**

  (u, v) cu v descendent al lui u care nu este însă fiu al lui

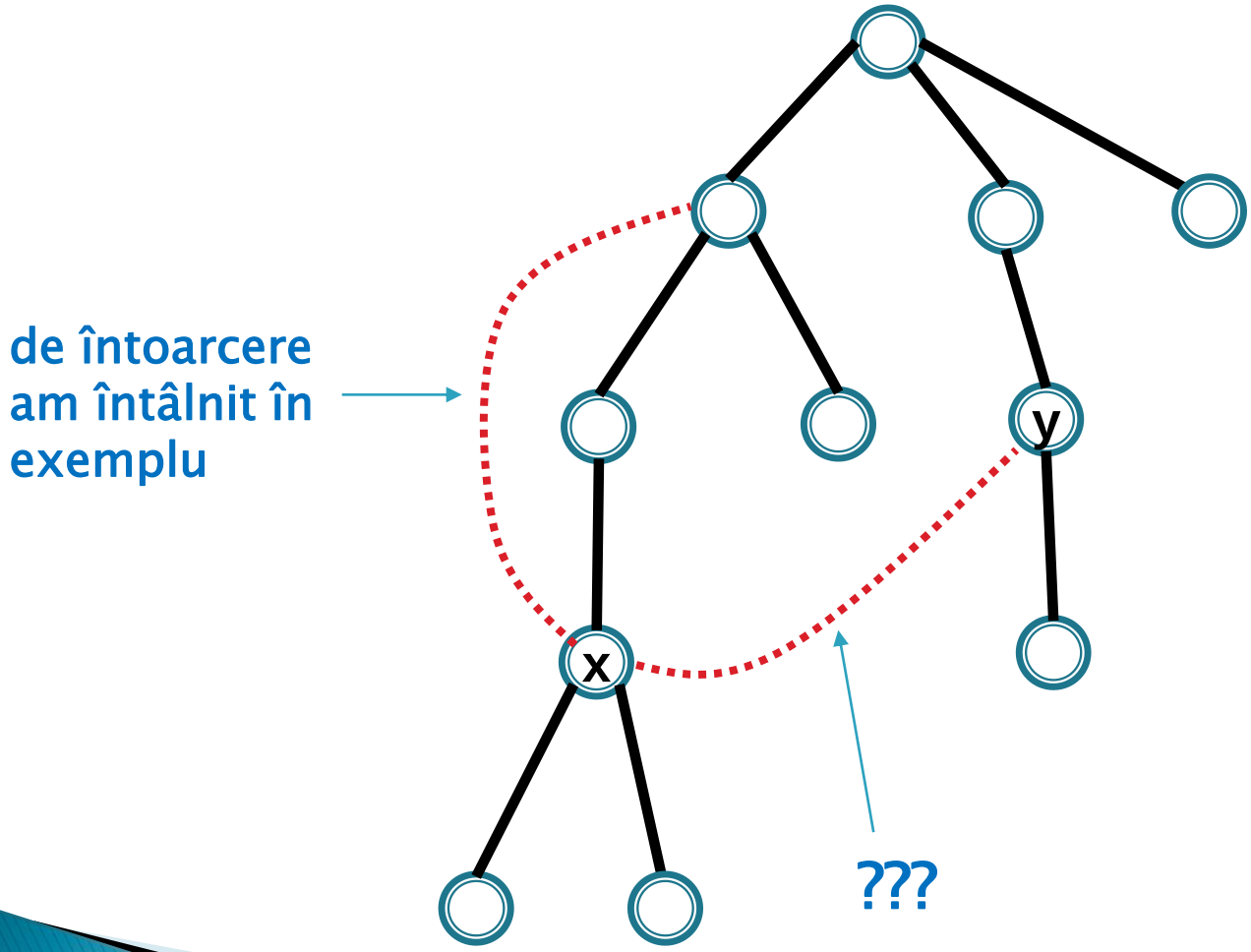
- **de traversare (transversale) :**

  toate celelalte muchii;

  pot fi între vârfuri din același arbore DF cu condiția ca unul să nu fie strămoșul celuilalt sau pot uni vârfuri din arbori DF diferiți

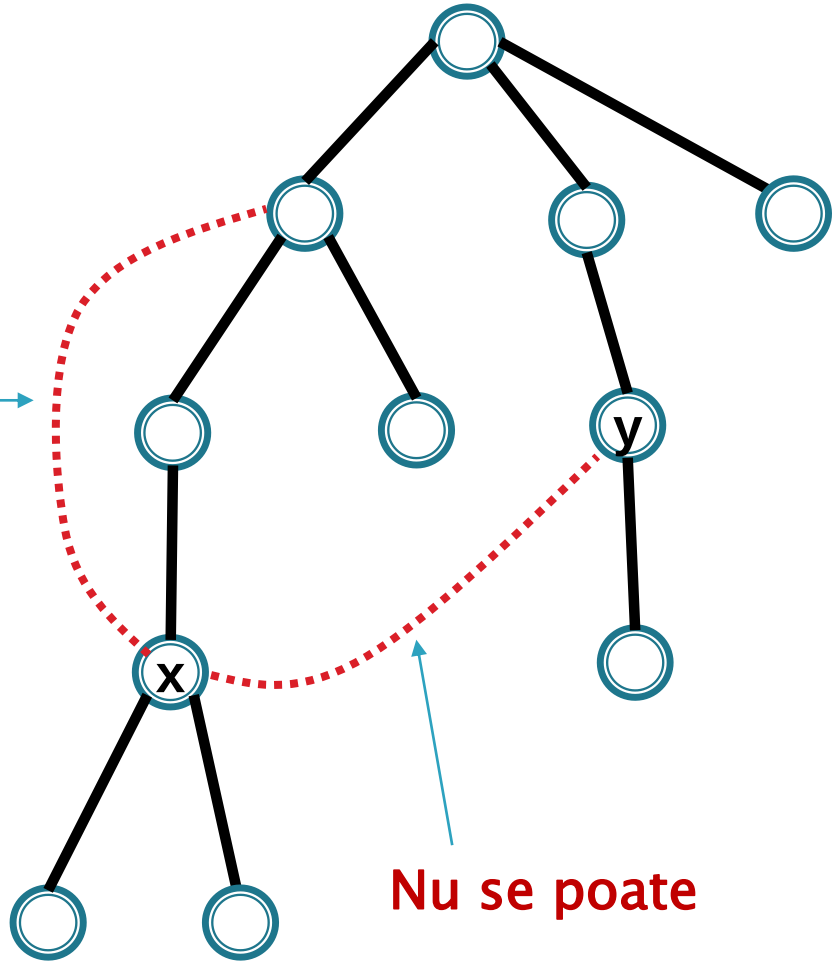
Proprietăți DF

Ce tipuri de muchii pot aparea în cazul unui graf **neorientat** ?



Proprietăți DF

Ce tipuri de muchii pot aparea în cazul unui graf **neorientat** ?



de întoarcere am întâlnit în exemplu

Nu se poate

Orice vecin al lui x este vizitat până cand x este finalizat

Proprietăți DF

În cazul unui graf **neorientat** există doar două tipuri de muchii în raport cu pădurea DF:

- muchii de arbore (**de avansare)**
- **muchii de întoarcere (către un ascendent)**
  - **!! care nu este tata**

Proprietăți DF

În cazul unui graf **neorientat** există doar două tipuri de muchii în raport cu pădurea DF:

- muchii de arbore (**de avansare)**
- **muchii de întoarcere (către un ascendent)**

Proprietăți DF

În cazul unui graf **neorientat** există doar două tipuri de muchii în raport cu pădurea DF:

- muchii de arbore (**de avansare)**
- **muchii de întoarcere (către un ascendent)**

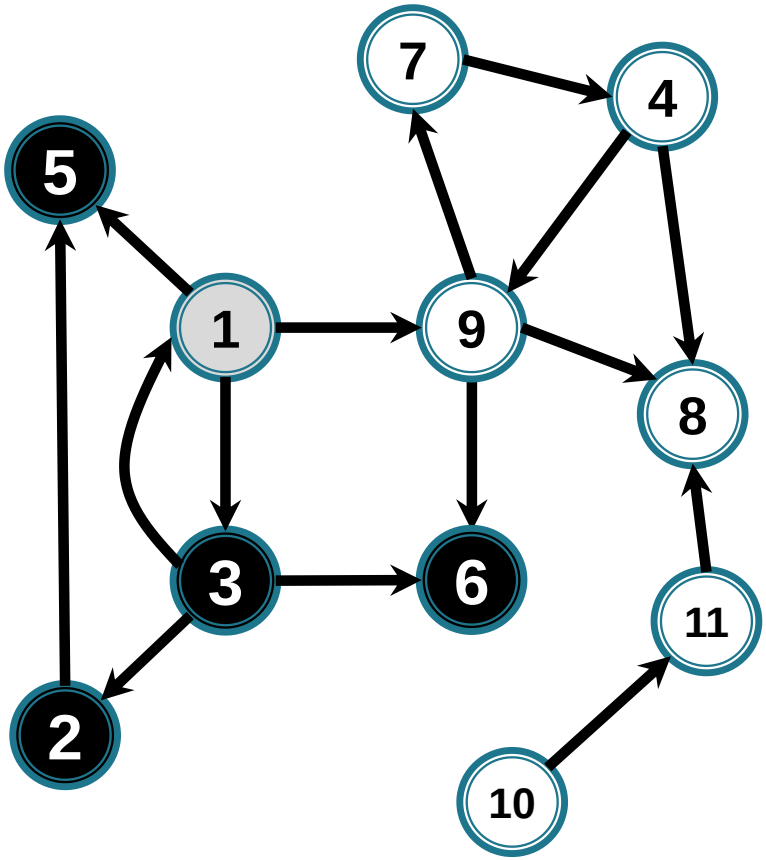
O muchie este detectată în timpul parcurgerii DF ca fiind de întoarcere dacă unește vârful curent cu un vârf gri (=vizitat+ascendent al său) care nu este tatăl lui

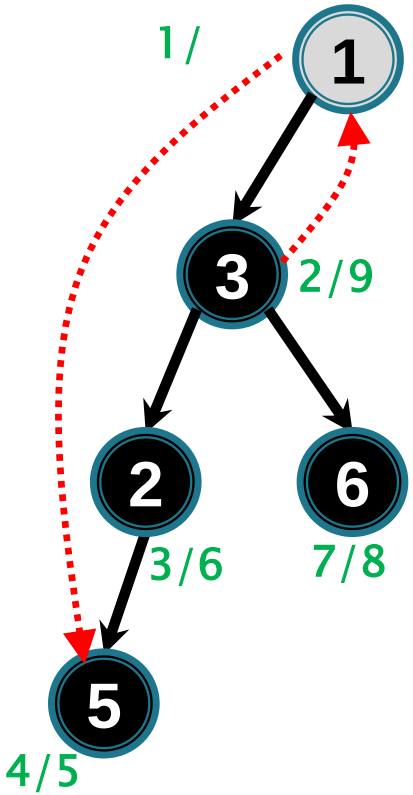
Un arc (u,v) este detectat ca fiind

- de avansare directă (de arbore): v este nevizitat (alb)
- **de avansare înainte:**

  `desc[u] < desc[v] < fin[v] < fin[u] și v nu e fiu ⇔`

  când este parcurs arcul uv, v este negru (finalizat) și este descendent al lui u, adică desc[u] < desc[v]

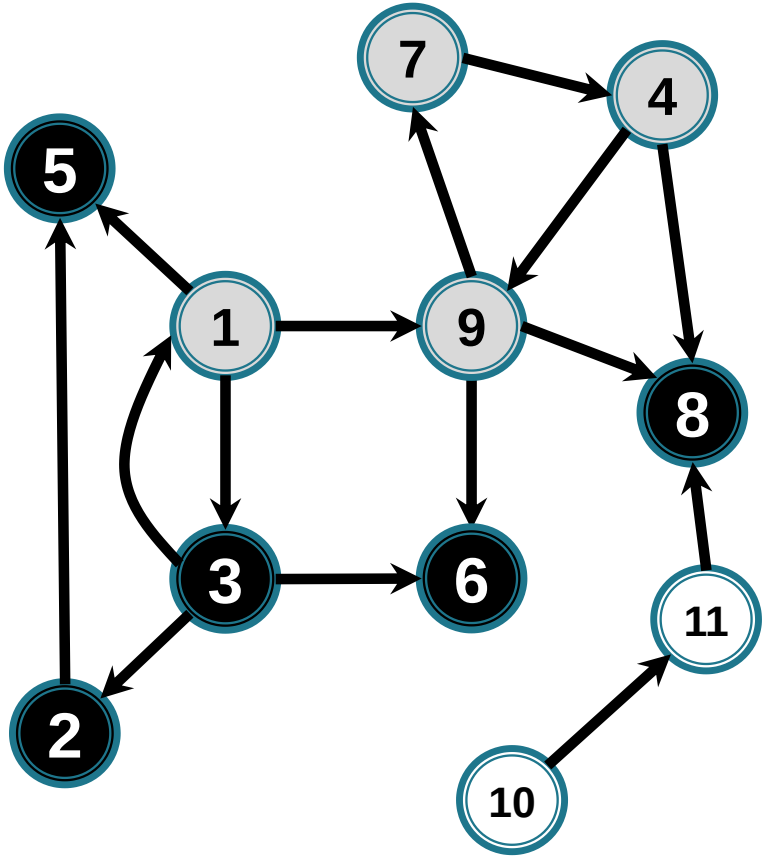


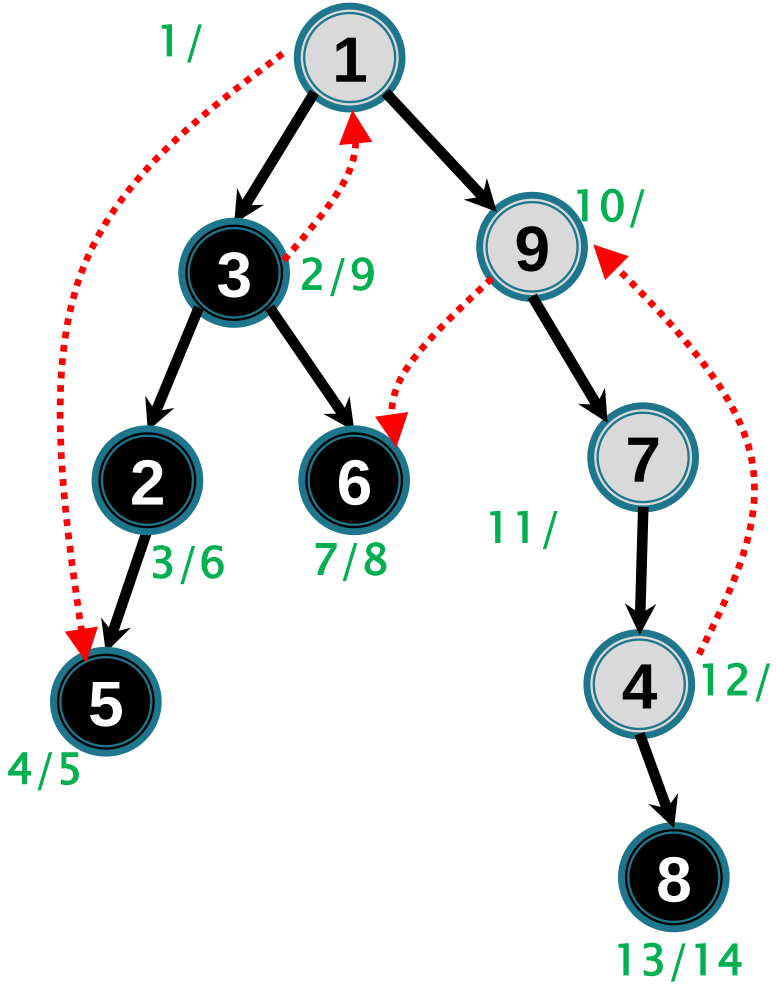


- **de întoarcere:**

`desc[v] < desc[u] < fin[u] < fin[v]` ⇔

când este parcurs arcul uv, v este încă gri (nefinalizat)

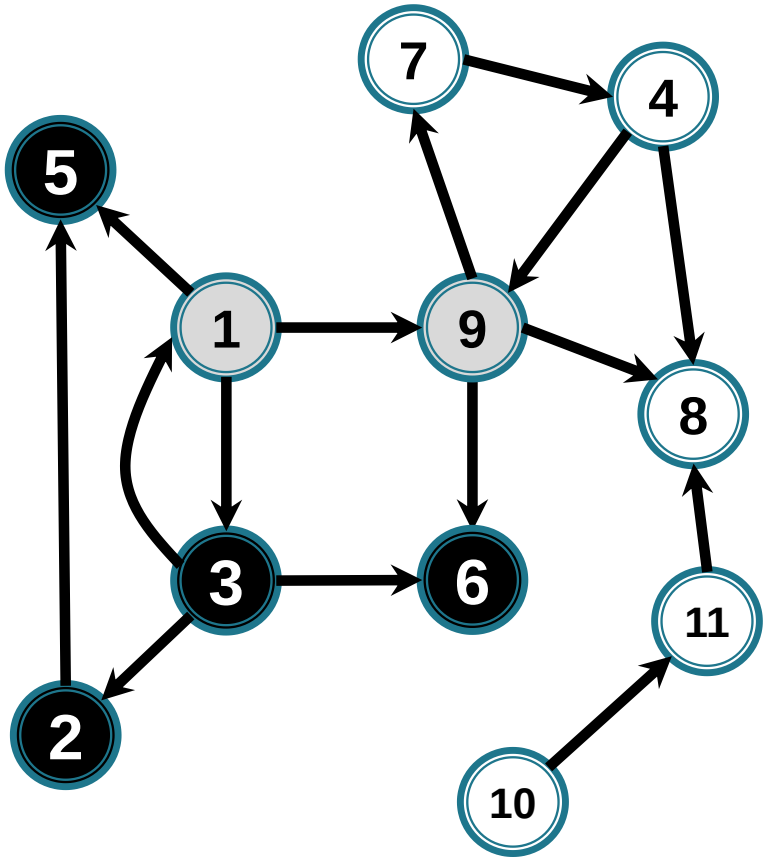


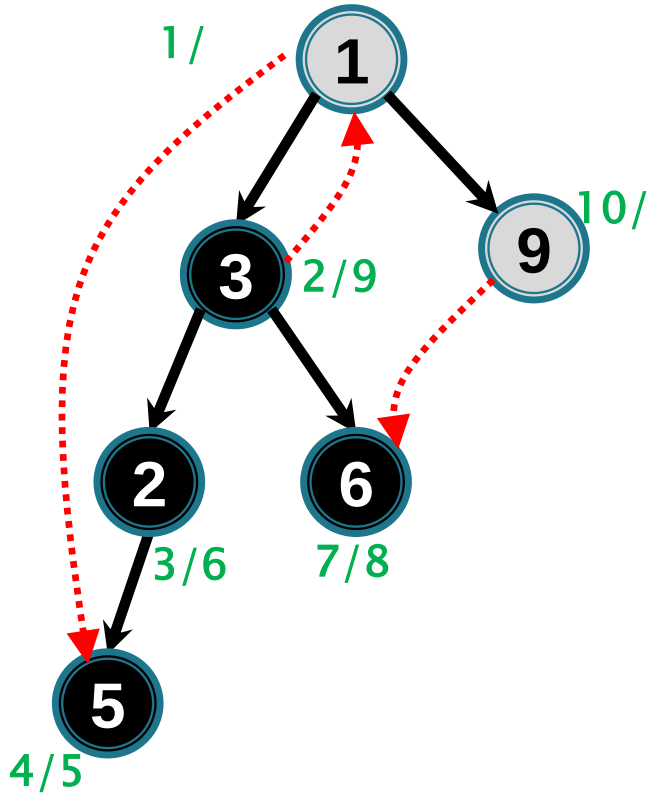


- **de traversare:**

`desc[v] < fin[v]  < desc[u] < fin[u]` ⇔

când este parcurs arcul uv, v este negru și nu este descendent al lui u, adică `desc[u] > desc[v]`

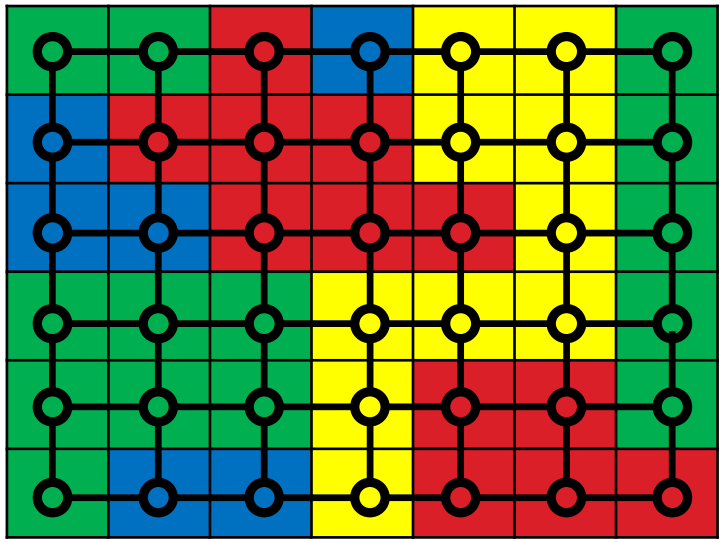




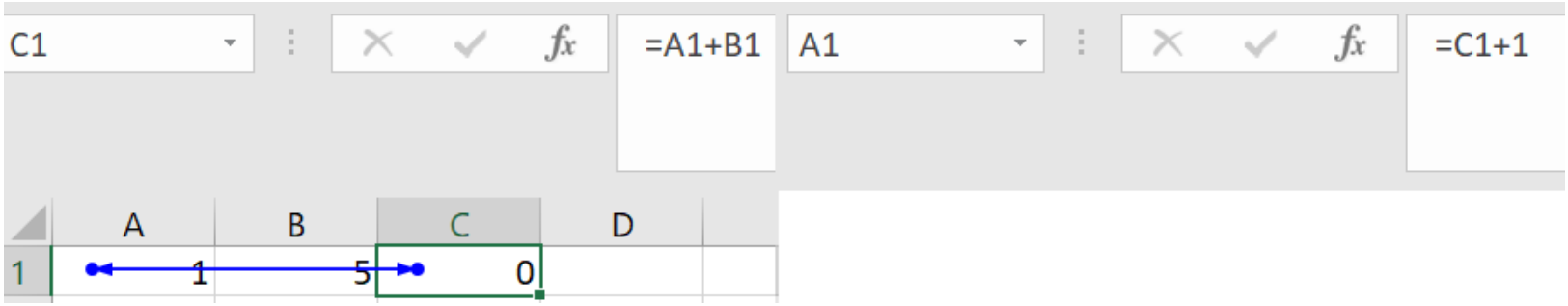
Parcurgerea în adâncime – Aplicații

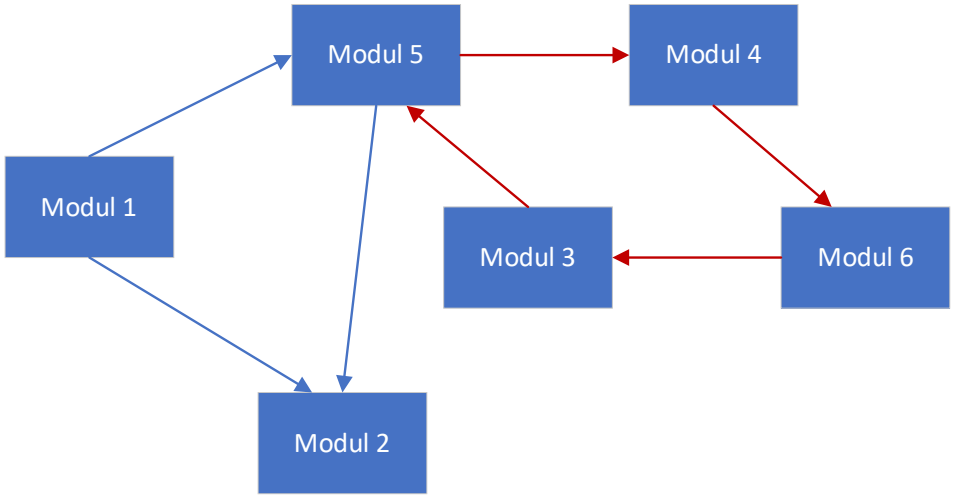
Determinarea componentelor conexe
Determinarea unui arbore parțial

- Ca și la parcurgerea în lățime
- Aplicații – algoritm de umplere (fill)



Determinarea de cicluri / circuite





Determinarea de cicluri / circuite

- **Ce fel de muchii/arce închid cicluri/circuite?**

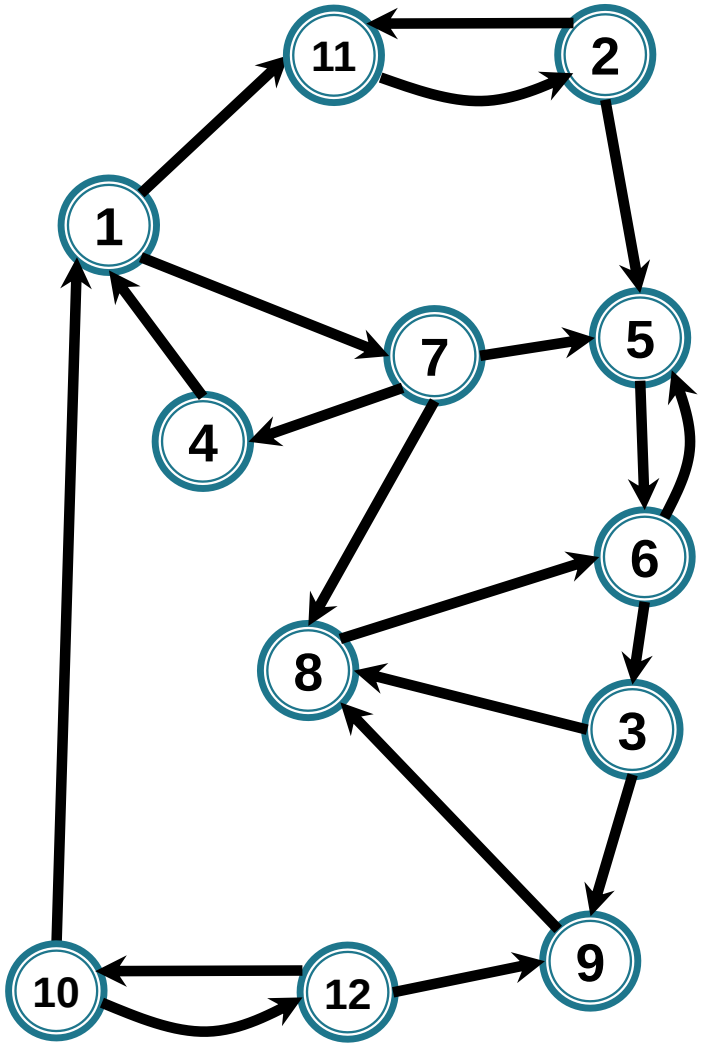
Determinarea de cicluri / circuite

- **Ciclu/circuit – închis doar de muchii/arce de întoarcere**

Un graf neorientat/orientat G are ciclu/circuit dacă și numai dacă există muchie/arc de întoarce uv în pădurea DFS

= de la un **vârf u la un vârf gri (nefinalizat)**

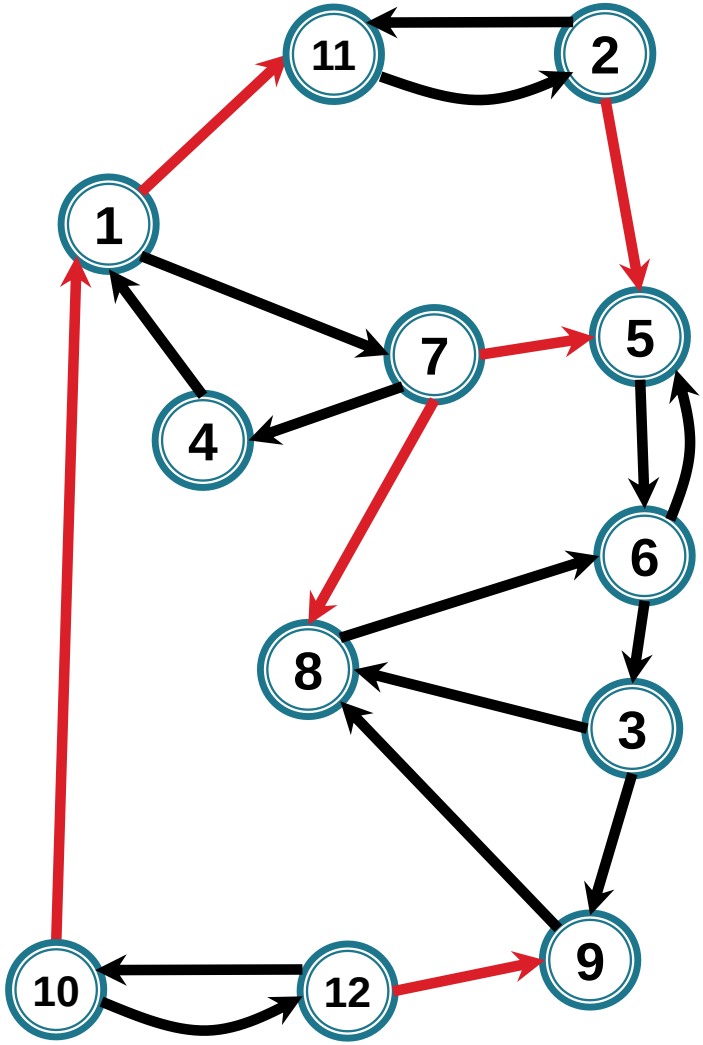
Determinarea componentelor tare conexe ale unui graf orientat

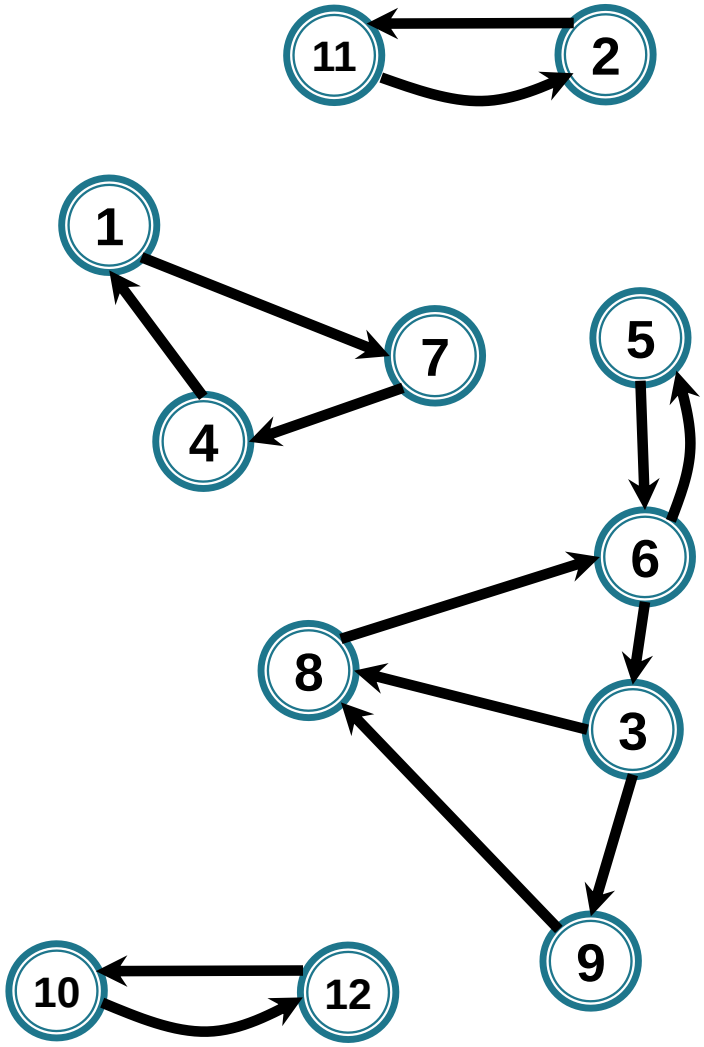


Fie G=(V,E) orientat

- G este **tare conex** dacă între oricare două vârfuri există un drum
- O **componentă tare conexă** a lui G = subgraf indus al lui G tare conex, maximal

Componente tare conexe

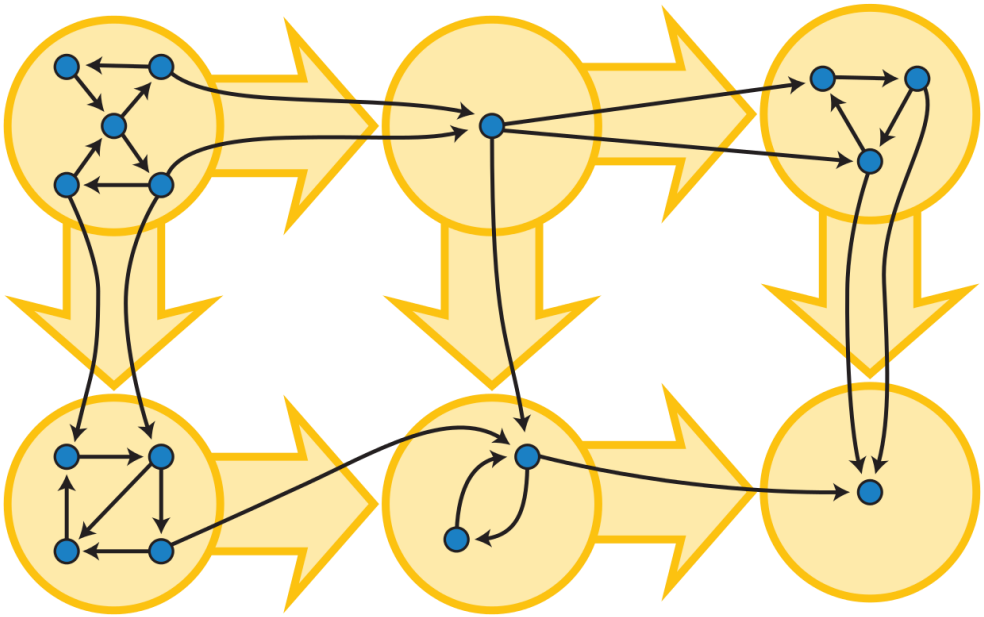




Componentele tare conexe

Componente tare conexe

- Detectarea de comunități în rețele (sociale, de colaborare/citări, economice)



- Etape în alți algoritmi, rezolvarea altor probleme, precum 2-SAT

Algoritmi componente tare conexe

- **Folosind mai multe parcurgeri?**

Posibilă idee:

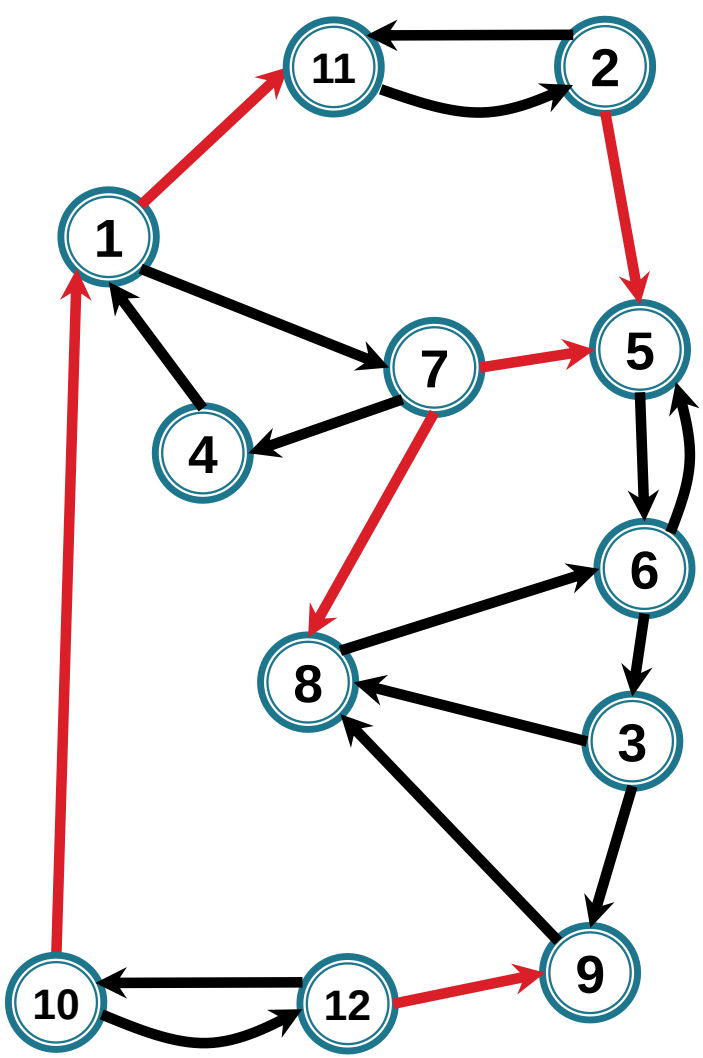
componenta(x) =

multimea vârfurilor accesibile din x în G ∩

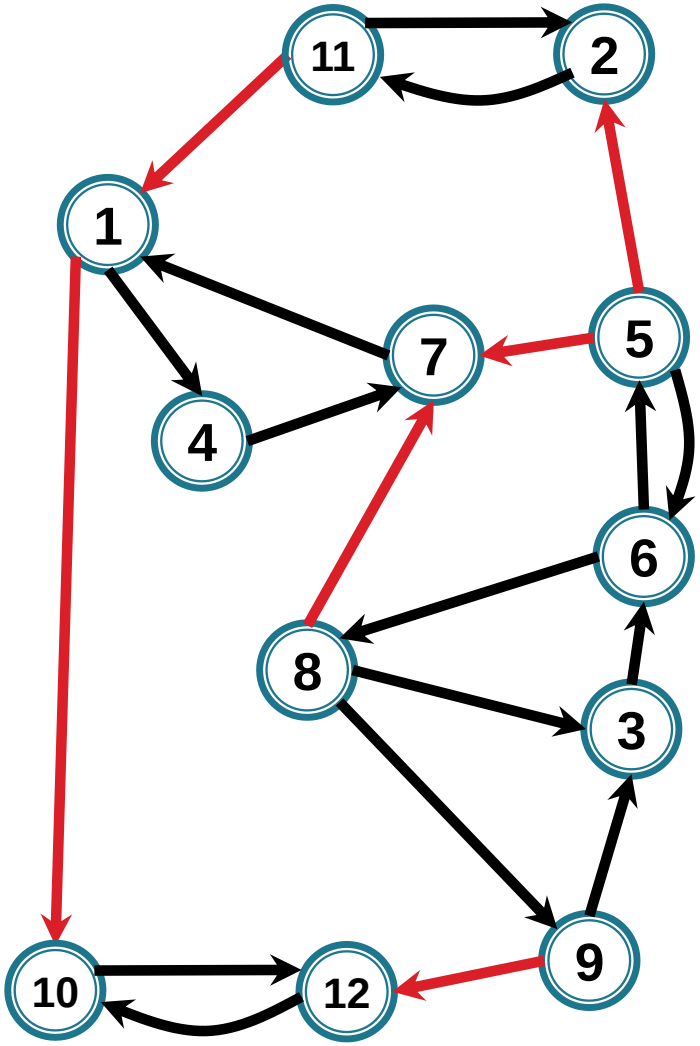
multimea vârfurilor accesibile din x în G^T

unde $G^T = (V, E^T)$, $E^T = \{yx \mid xy \in E\}$

Algoritmi componente tare conexe



G



G^T

Algoritmi componente tare conexe

Componenta tare conexă a vârfului 1 =

mulțimea vârfurilor accesibile din 1 în G (vizitate în DFS(1,G))

$\cap$ intersectată cu

mulțimea vârfurilor accesibile din 1 în G^T (vizitate în DFS(1,G^T))

Algoritmi componente tare conexe

- **Observații**

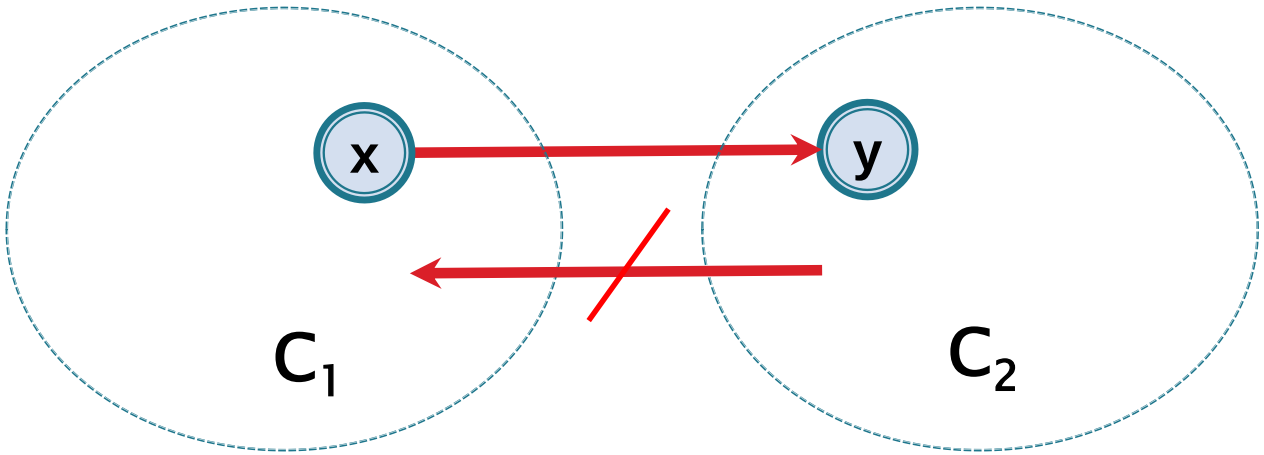
componente tare conexe din G =

componente tare conexe din G^T

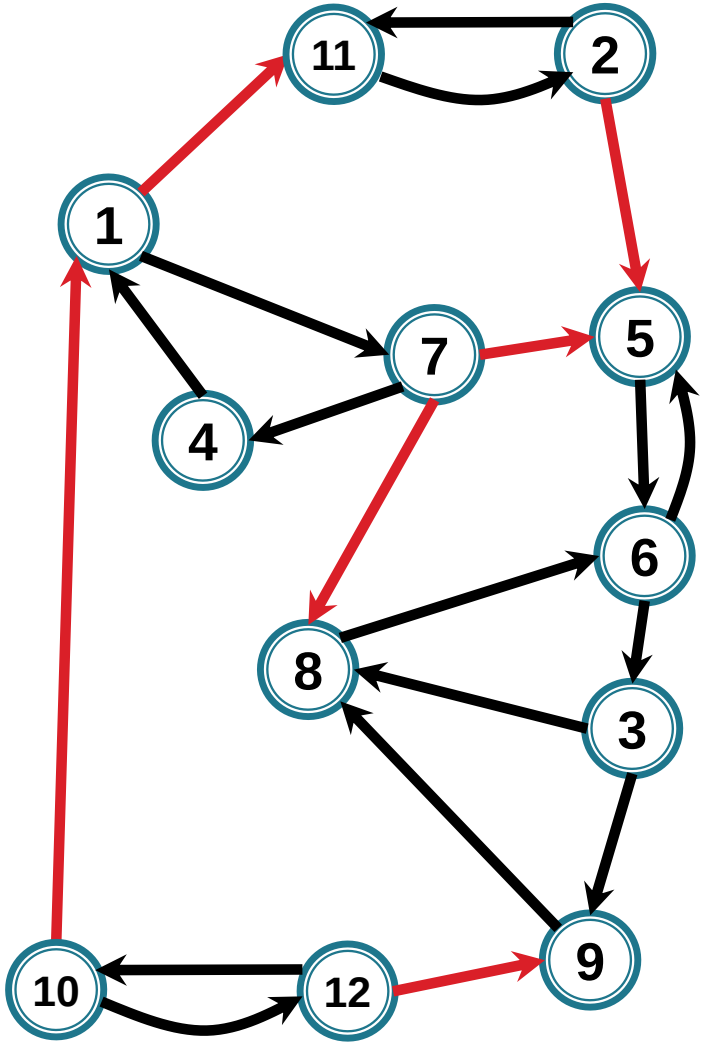
Algoritmi componente tare conexe

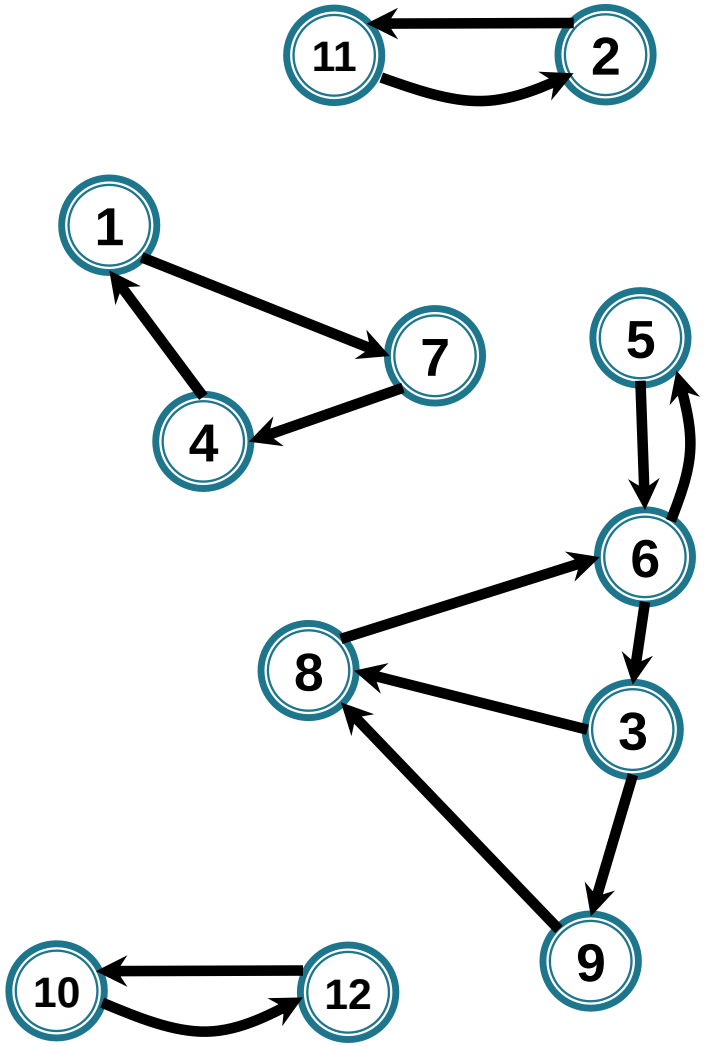
- **Observații**

Dacă C_1 și C_2 sunt componente tare conexe aî există arc de la C_1 la C_2, atunci nu există arc/drum de la C_2 la C_1



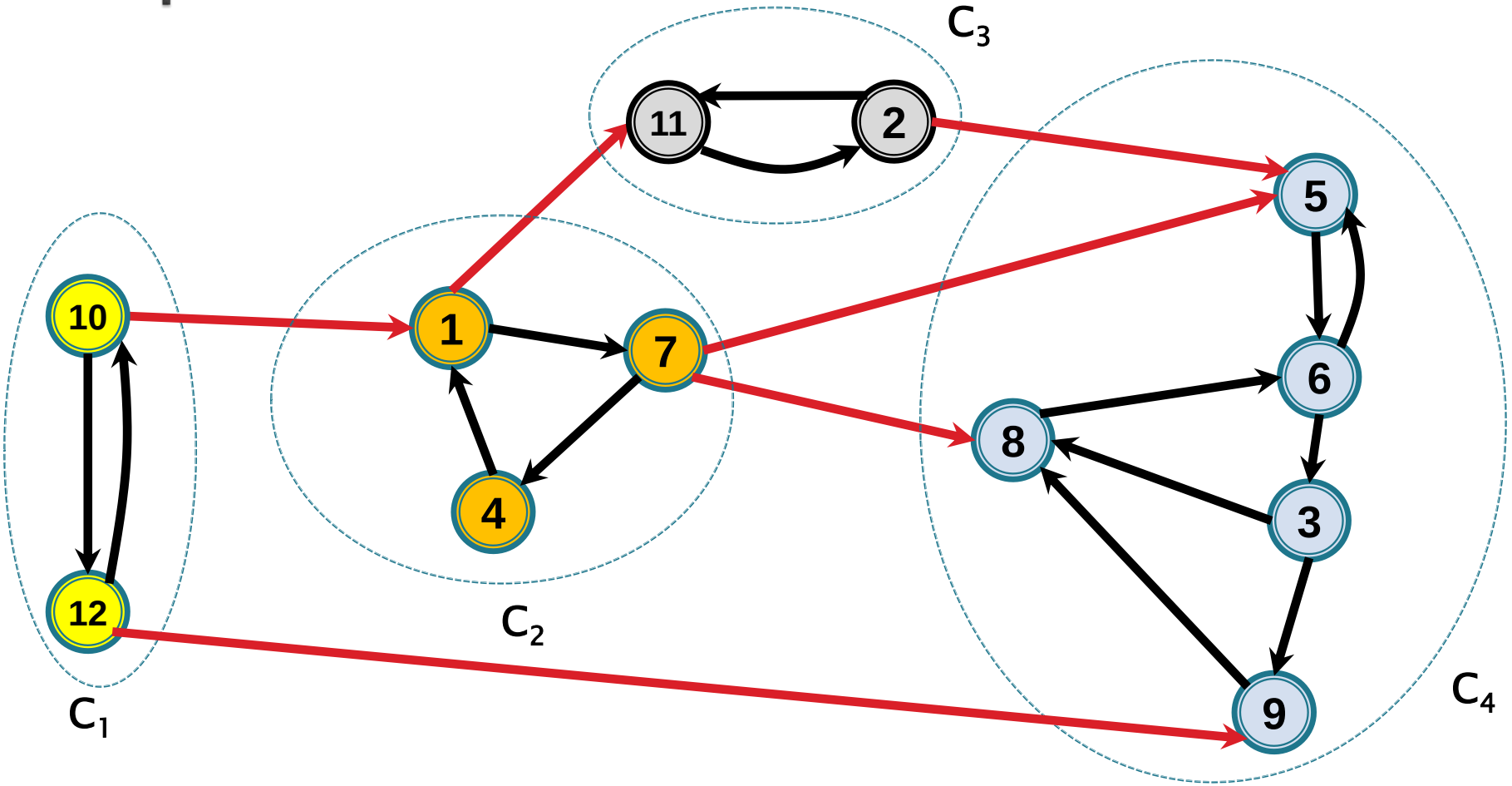
Componente tare conexe



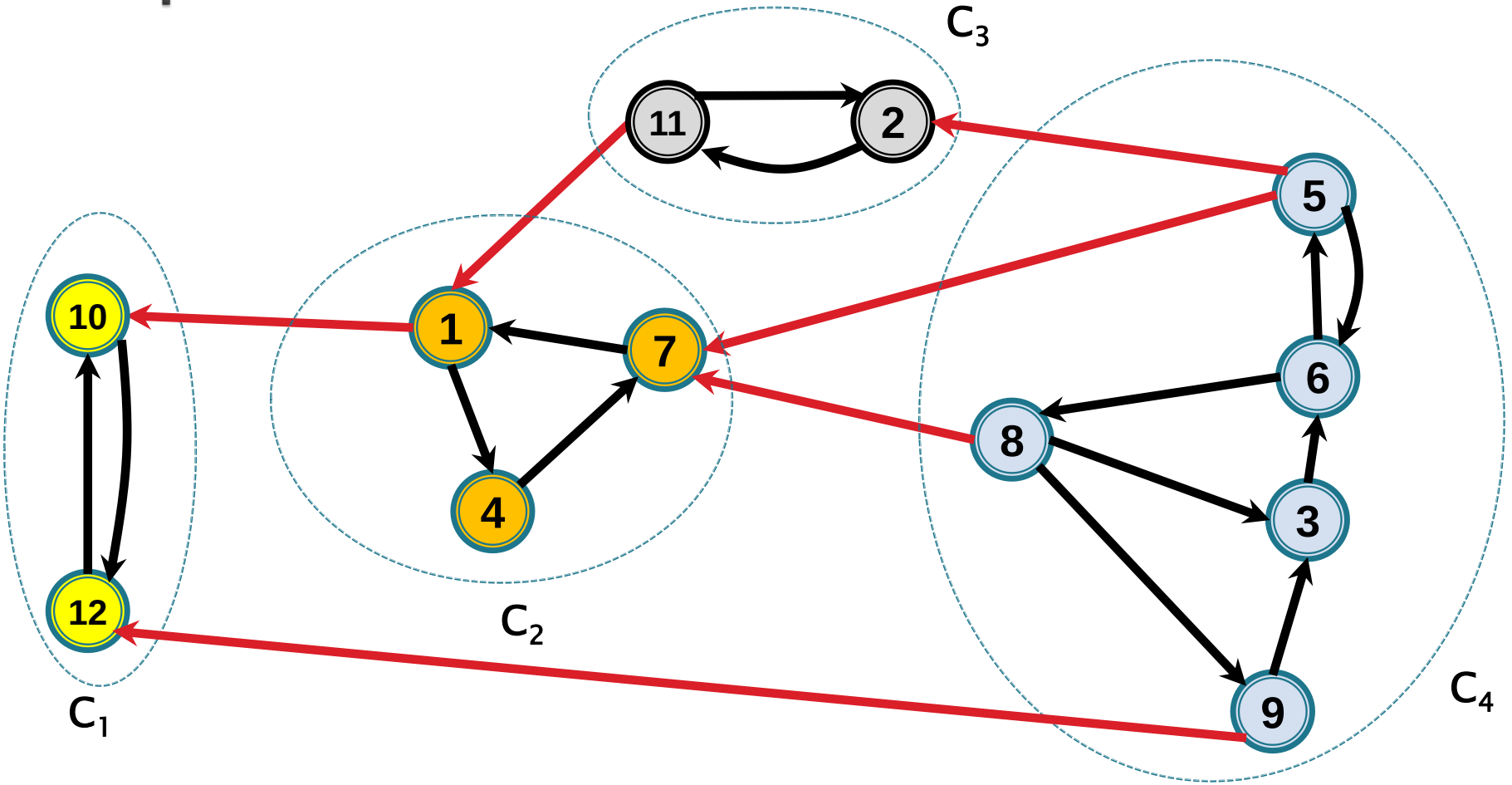


Componentele tare conexe

Componente tare conexe



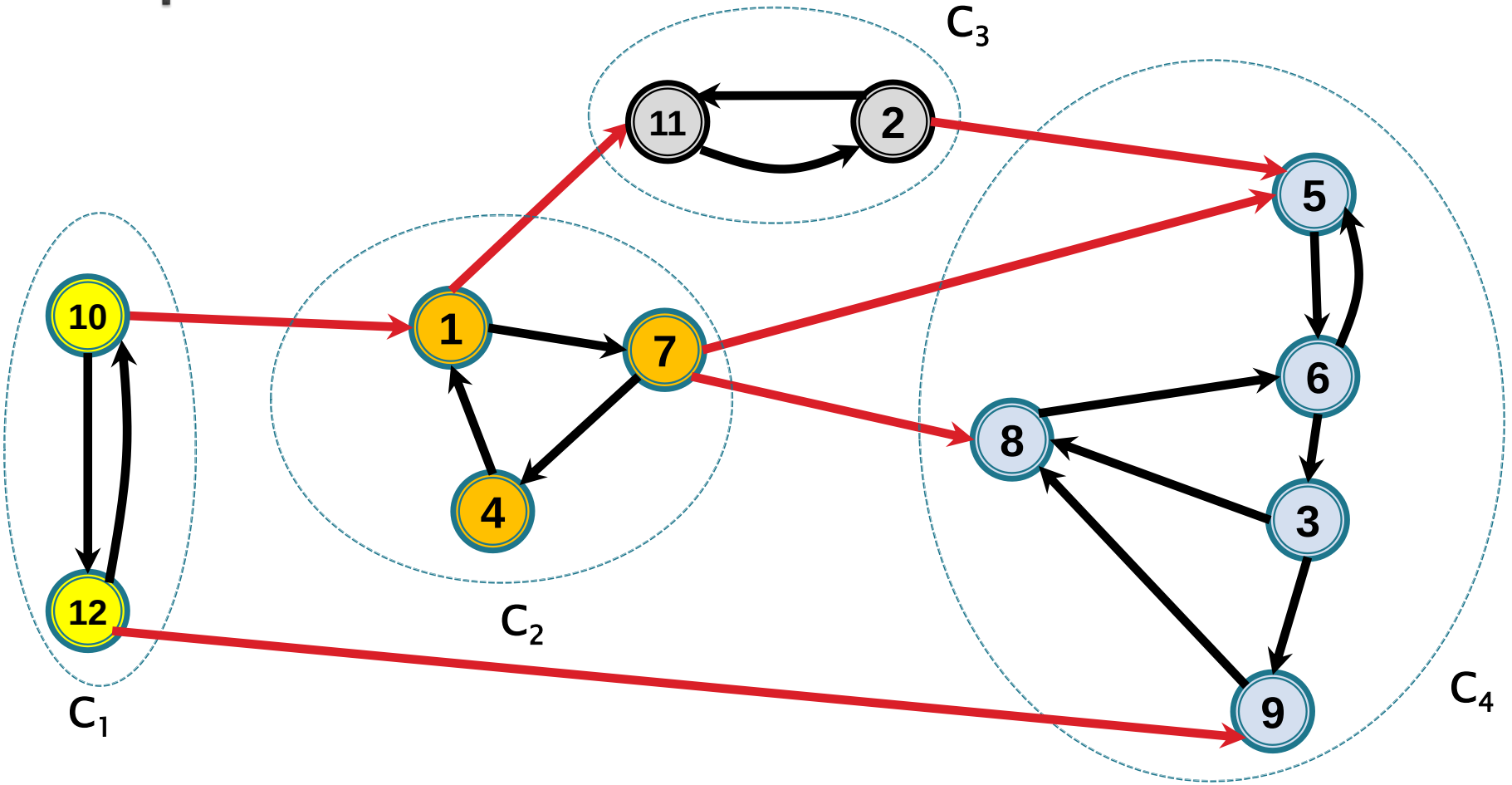
Componente tare conexe



G^T – ar fi bine sa determinăm întâi componenta lui 10: DF(G^T,10)

(să nu se "amestece" componentele)

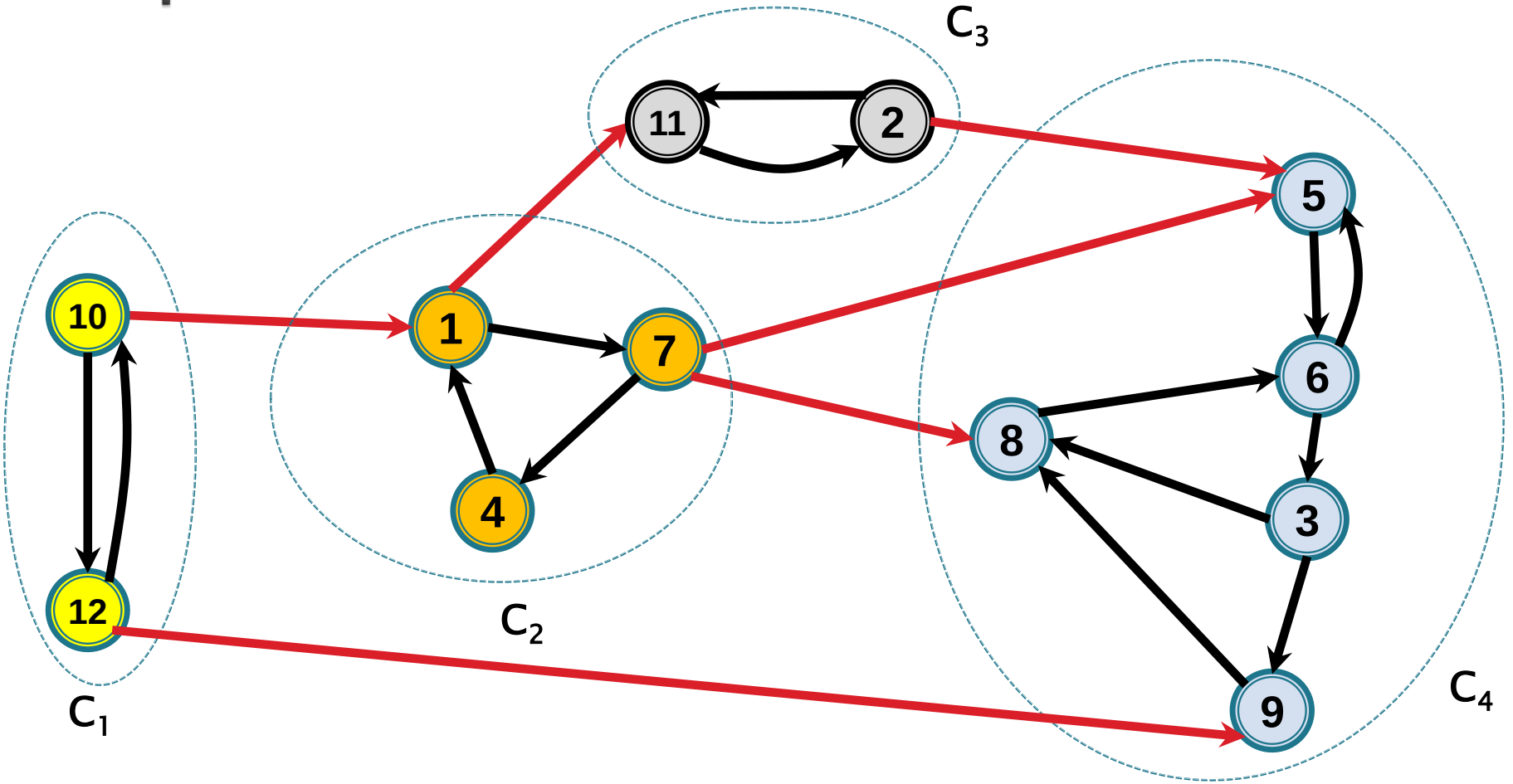
Componente tare conexe



Ar fi bine sa determinăm întâi componenta lui 10 (“de la margine”)

Ce proprietate are vârful 10?

Componente tare conexe



Ar fi bine sa determinăm întâi componenta lui 10 (“de la margine”)

Ce proprietate are vârful 10? => Este ultimul finalizat în DF pentru G

Algoritmi componente tare conexe

- Folosind doar două parcurgeri, una în G și una în G^T?

  DA, dar a doua într-o ordine particulară a vârfurilor (în funcție de ordinea în care au fost finalizate în DF)

  $\Rightarrow$ Algoritmul lui Kosaraju

Algoritmi componente tare conexe

- Dar folosind o singură parcurgere?

  DA, folosind o idee similară cu cea de la componente biconexe (vom discuta)

  $\Rightarrow$ Algoritmul lui Tarjan (SUPLIMENTAR)

Algoritmul lui Kosaraju

Algoritmul lui Kosaraju

Pasul 1. DFS(G,x) pentru fiecare vârf x nevizitat + **o stivă S în care se introduc vârfurile când sunt finalizate**

Pasul 2. DFS(G^T,x) pentru x (nevizitat) în ordinea în care sunt scoase din S (=**descrescător în raport timpul de finalizare** – similar cu sortarea topologică)

Avem

vârfuri vizitate în DFS(G^T,x) = componenta tare conexă a lui x

Algoritmul lui Kosaraju

Complexitate:

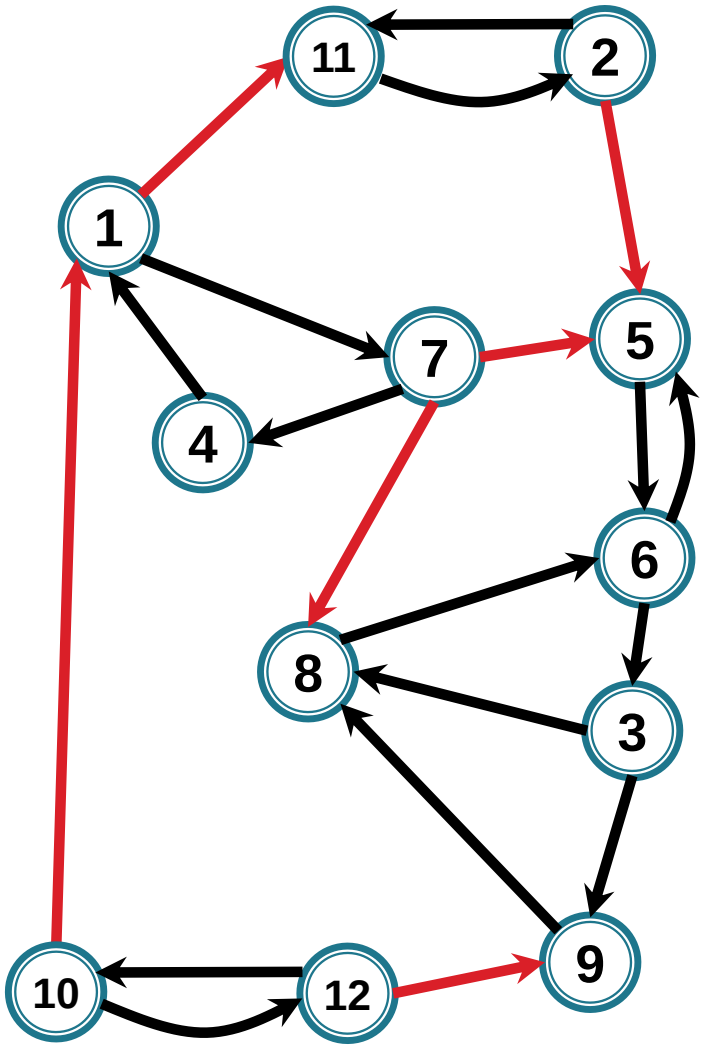
2 parcurgeri + construcția lui G^T => O(n+m)

Algoritmul lui Kosaraju

Timp de finalizare

Pasul 1.

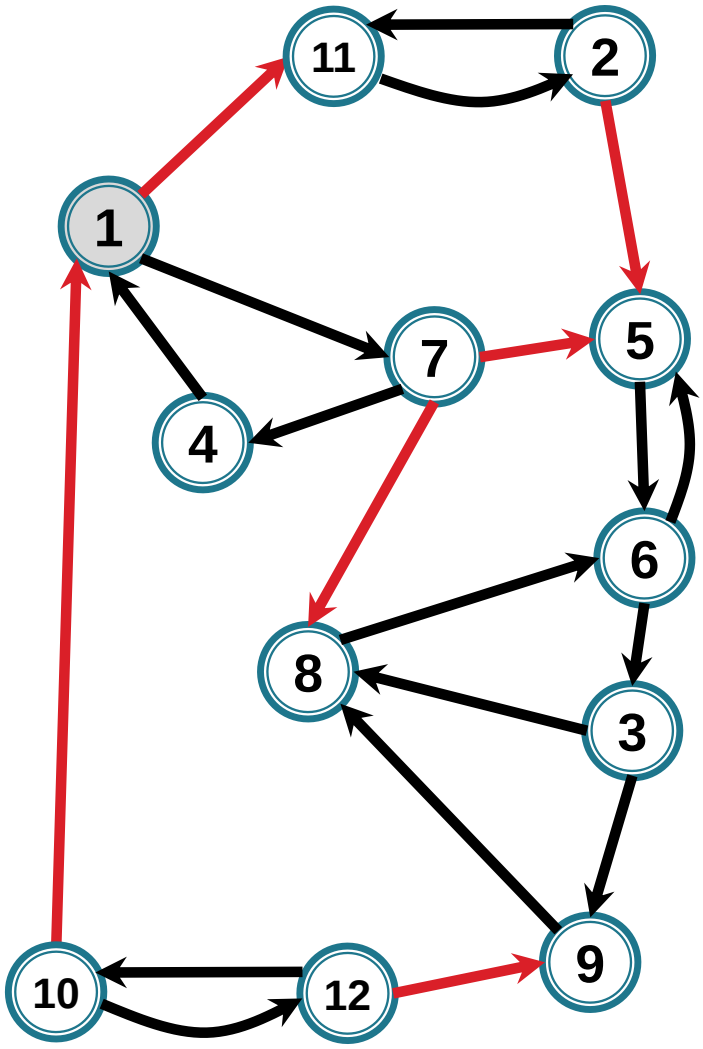
DFS(1)



Ordinea descrescătoare finalizare:

Algoritmul lui Kosaraju

Pasul 1.



Timp de finalizare

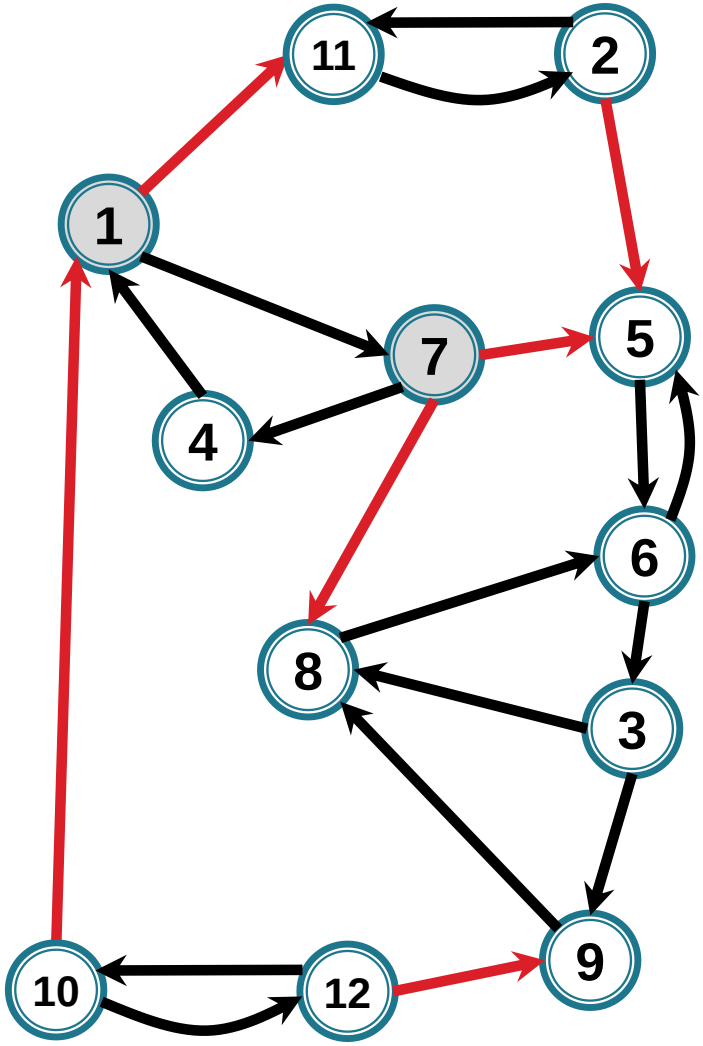
1

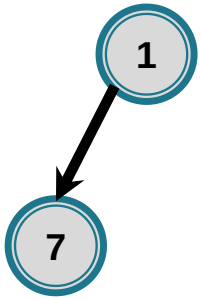
Ordinea descrescătoare finalizare:

Algoritmul lui Kosaraju

Timp de finalizare

Pasul 1.



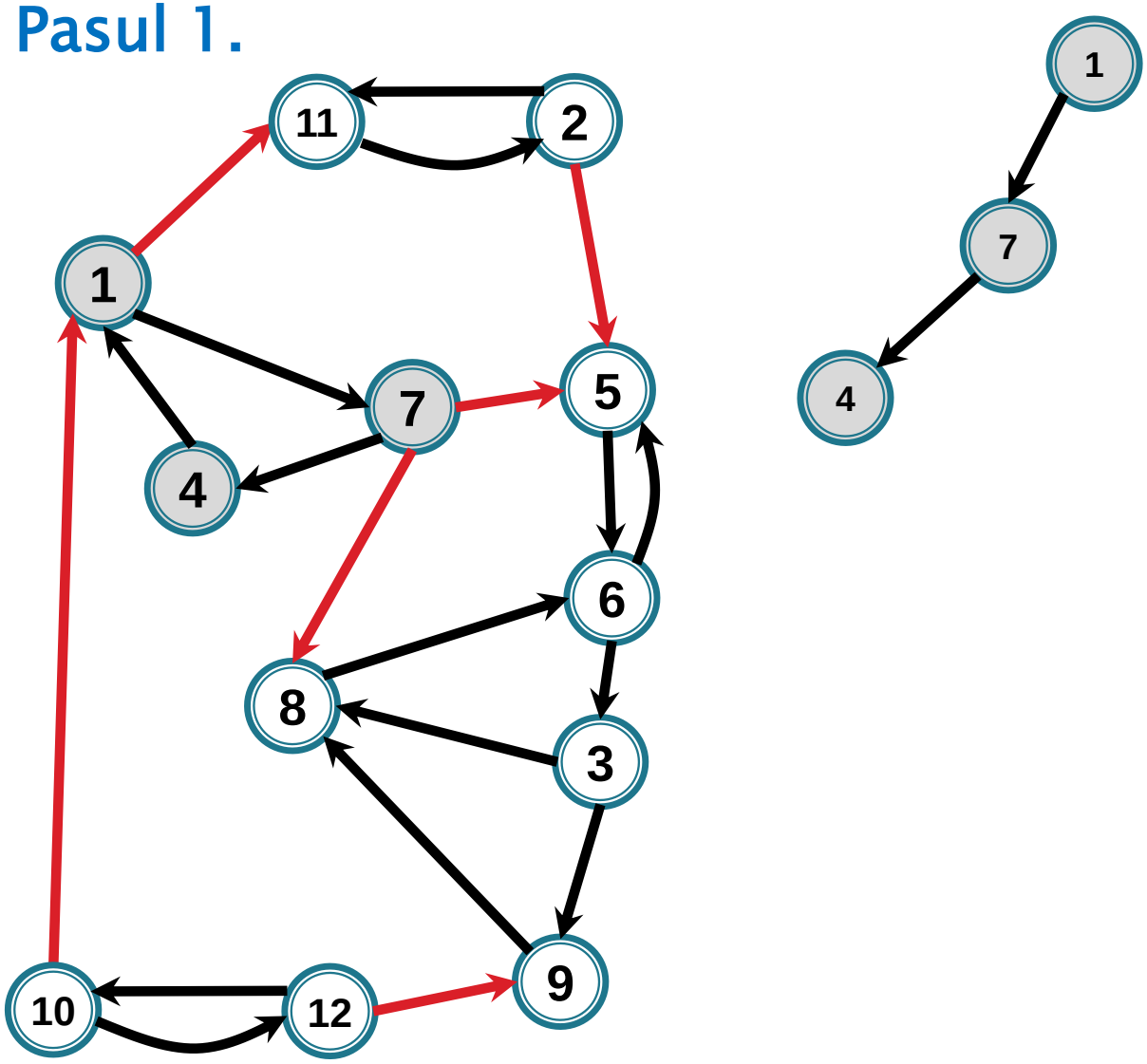


Ordinea descrescătoare finalizare:

Algoritmul lui Kosaraju

Timp de finalizare

Pasul 1.

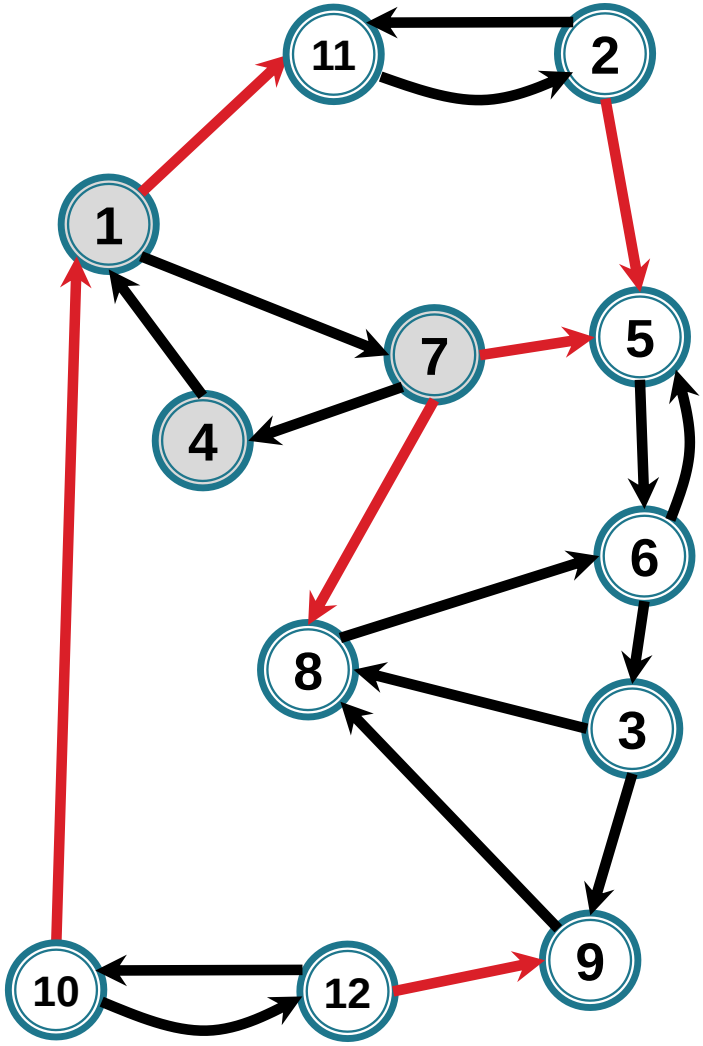


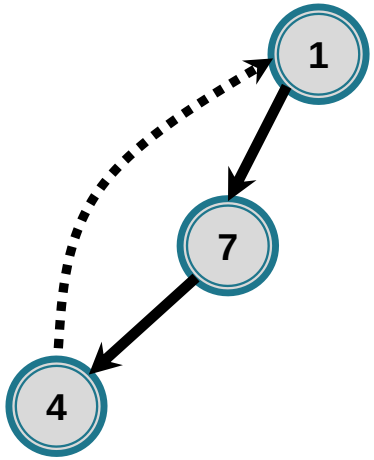
Ordinea descrescătoare finalizare:

Algoritmul lui Kosaraju

Timp de finalizare

Pasul 1.





Ordinea descrescătoare finalizare:

Algoritmul lui Kosaraju

Timp de finalizare

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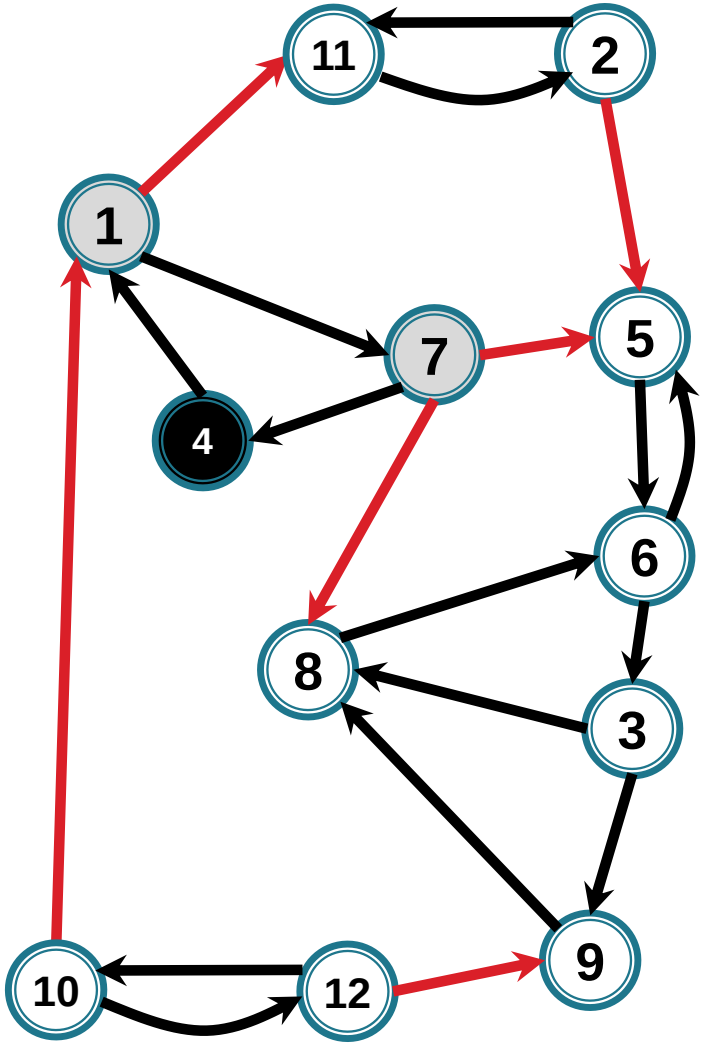

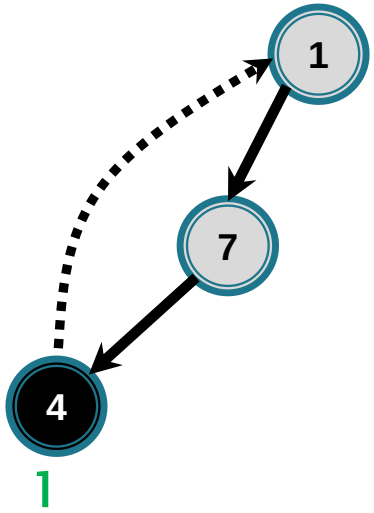

Ordinea descrescătoare finalizare:

4

Algoritmul lui Kosaraju

Timp de finalizare

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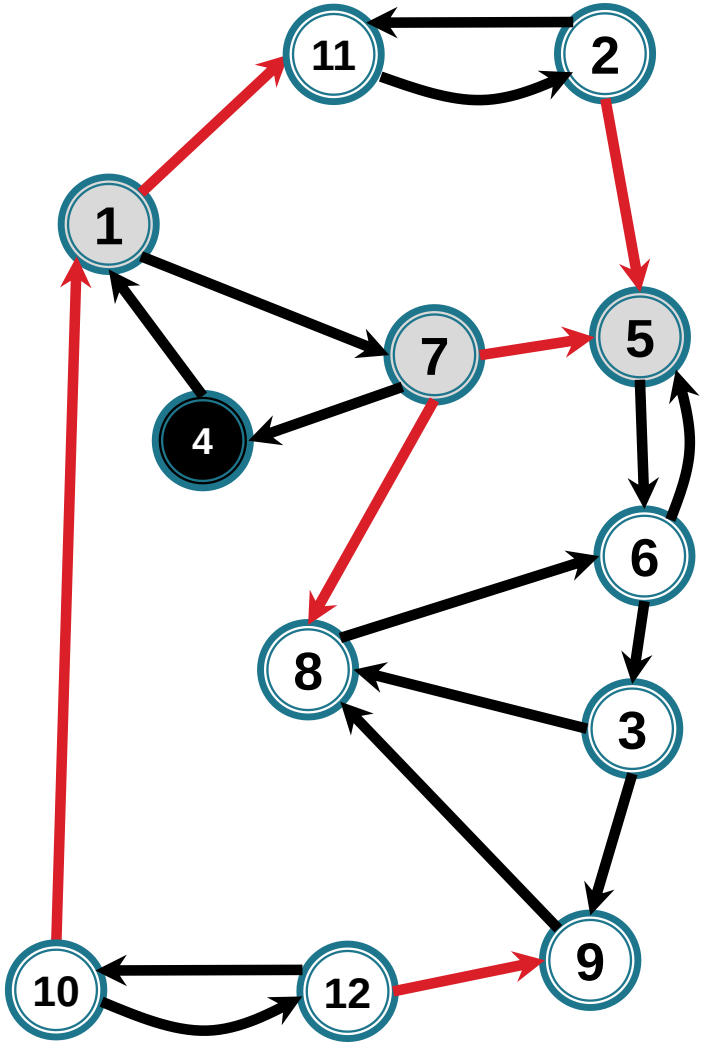

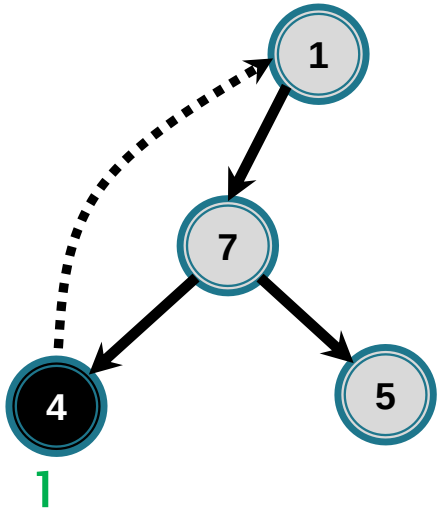

Ordinea descrescătoare finalizare:

4

Algoritmul lui Kosaraju

Timp de finalizare

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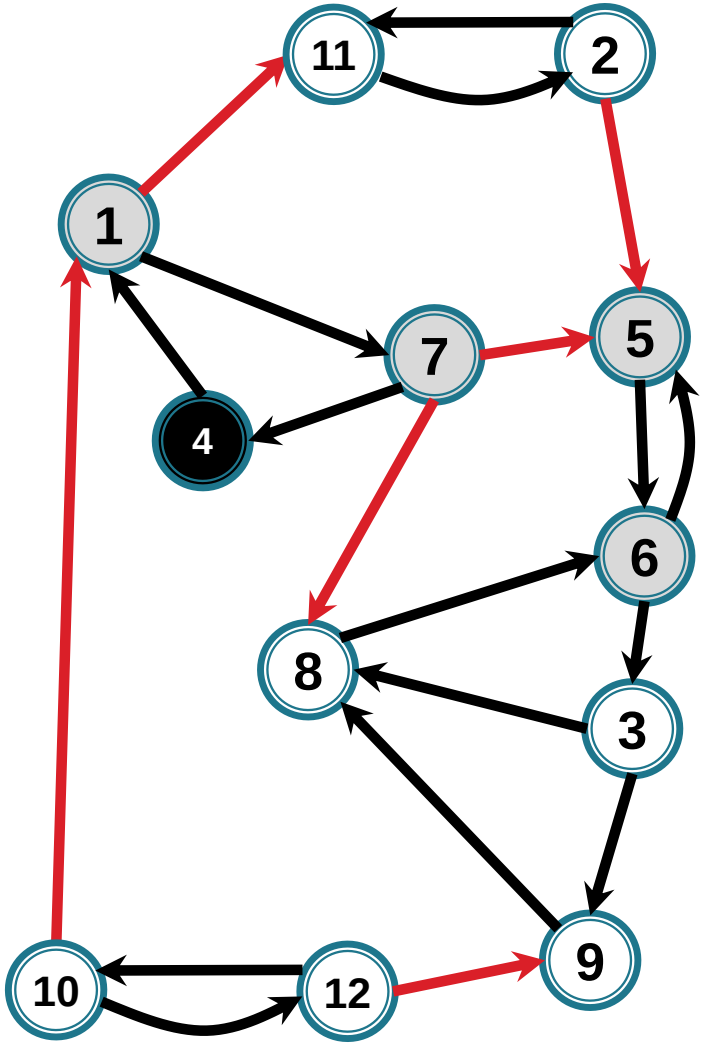

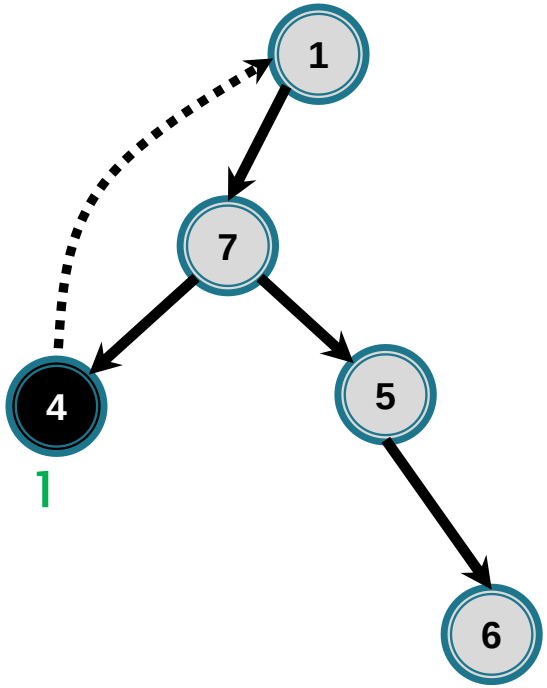

Ordinea descrescătoare finalizare:

4

Algoritmul lui Kosaraju

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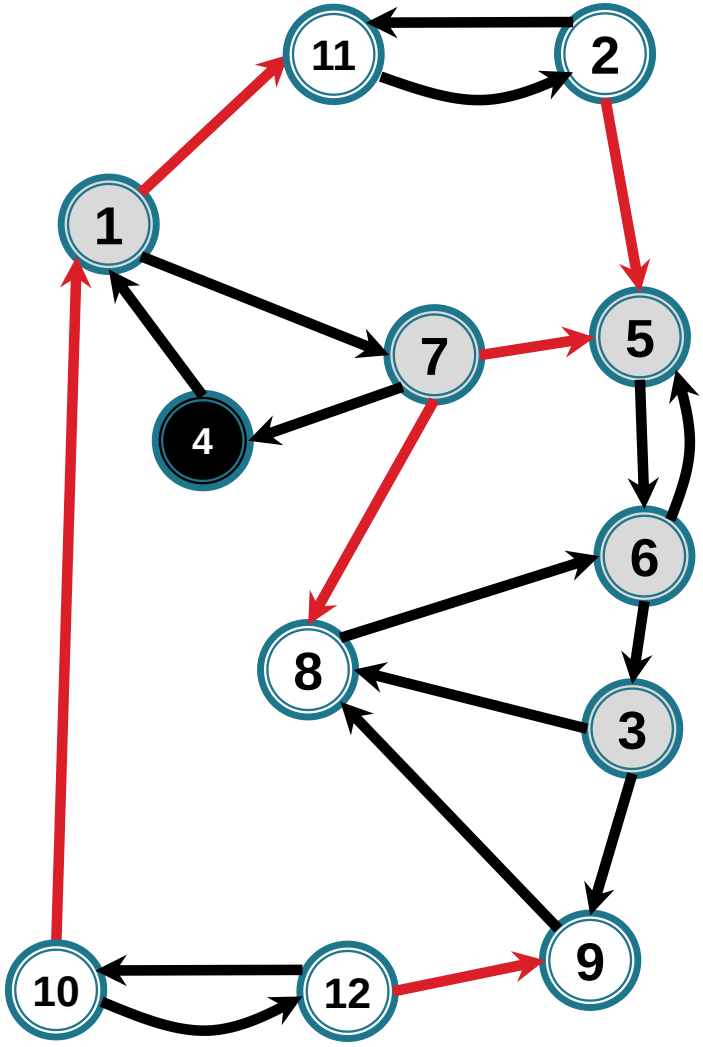

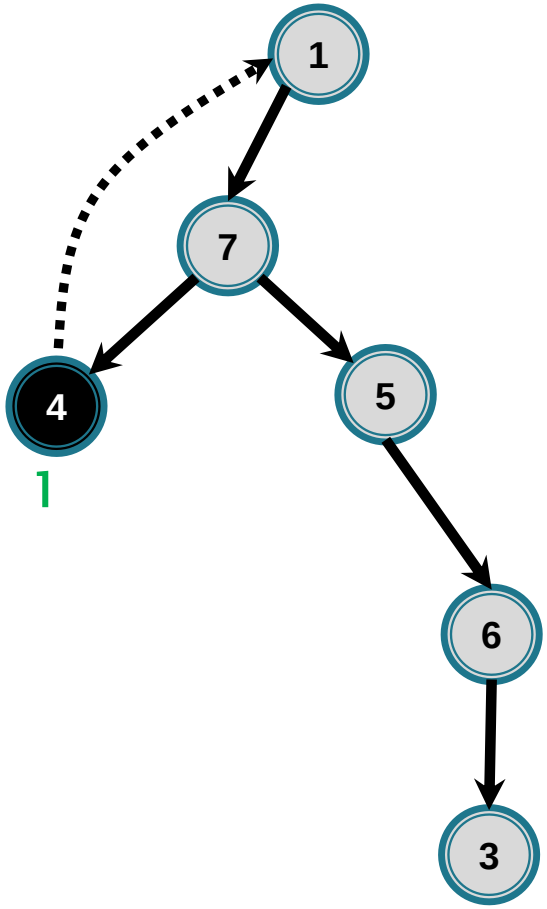

Ordinea descrescătoare finalizare:

4

Algoritmul lui Kosaraju

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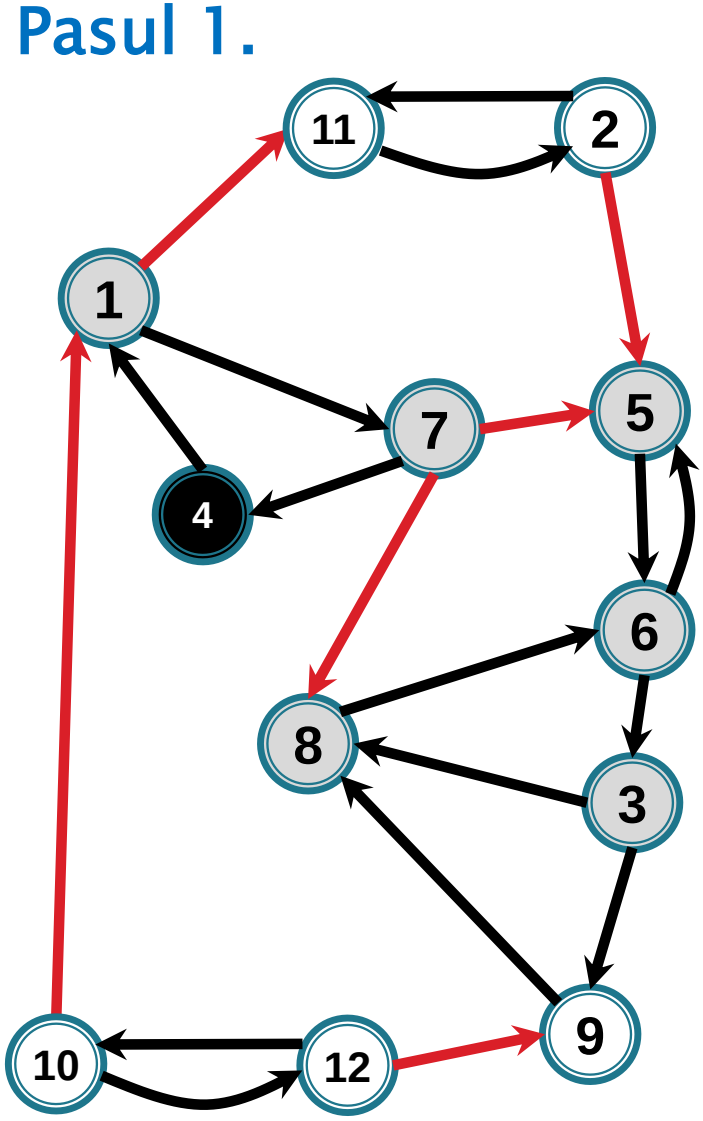

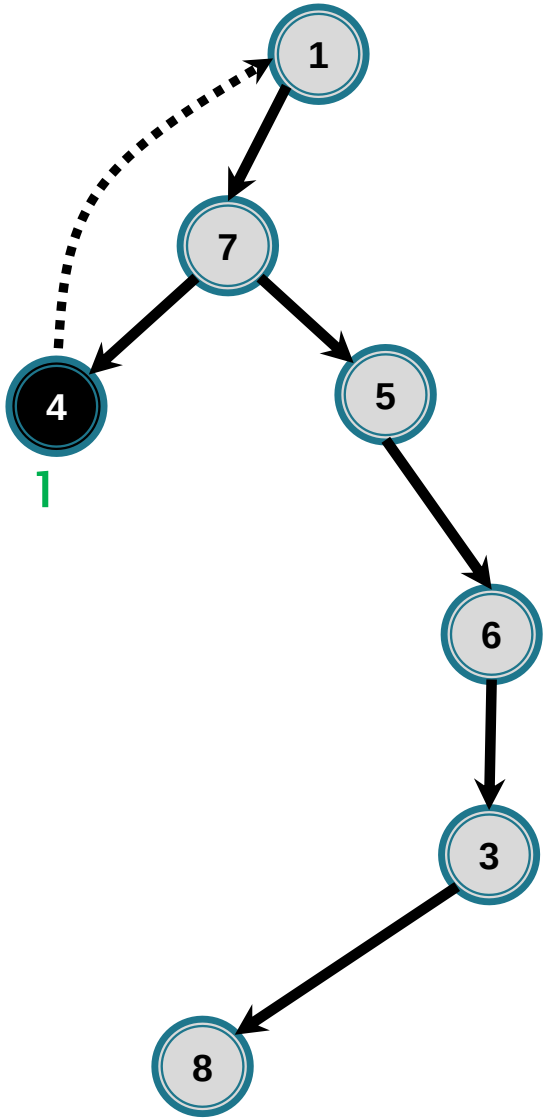

Ordinea descrescătoare finalizare:

4

Algoritmul lui Kosaraju

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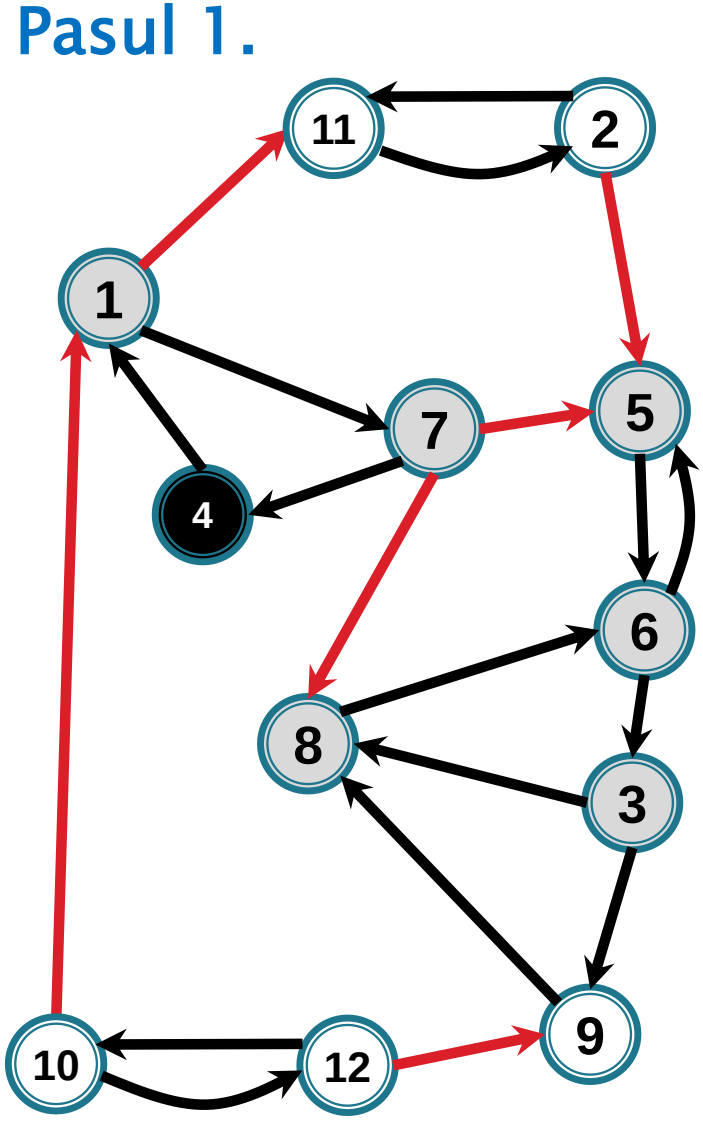

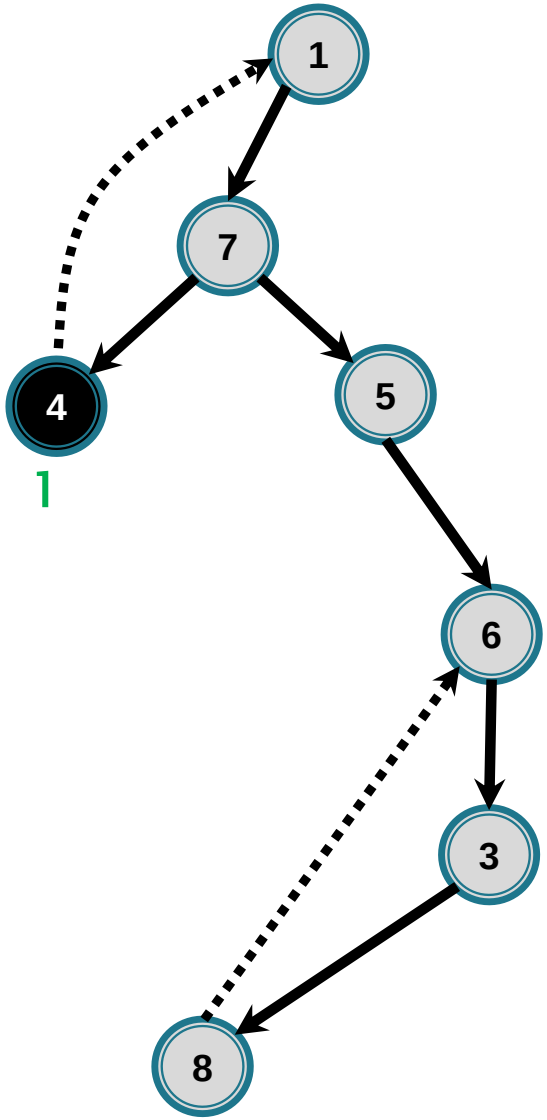

Ordinea descrescătoare finalizare:

4

Algoritmul lui Kosaraju

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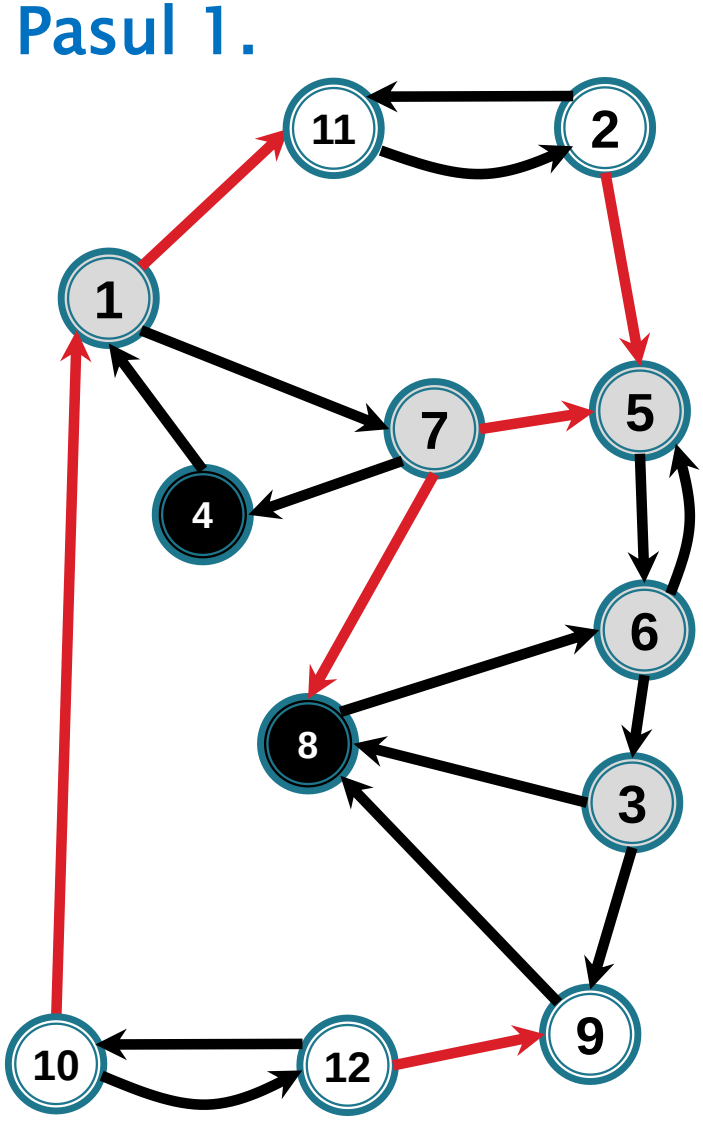

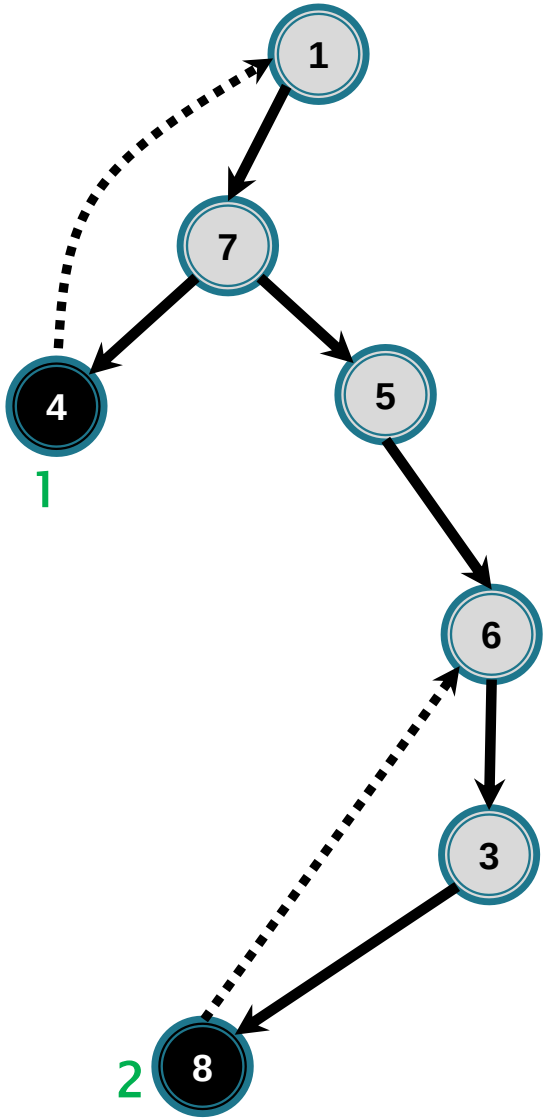

Ordinea descrescătoare finalizare:

8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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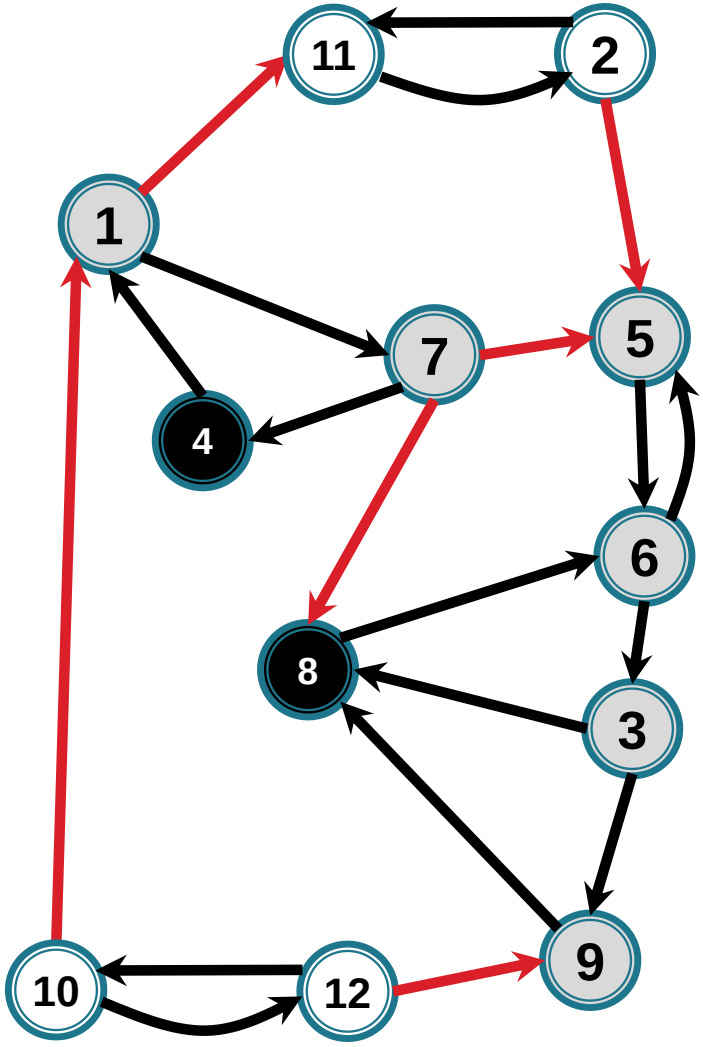

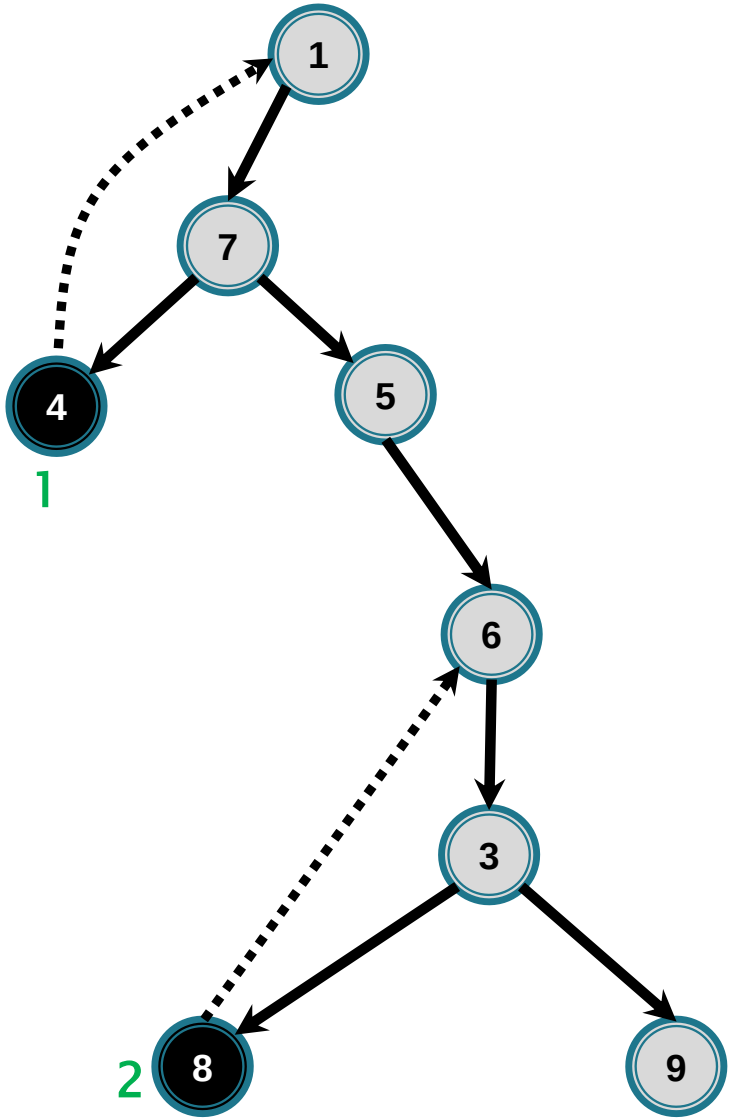

Ordinea descrescătoare finalizare:

8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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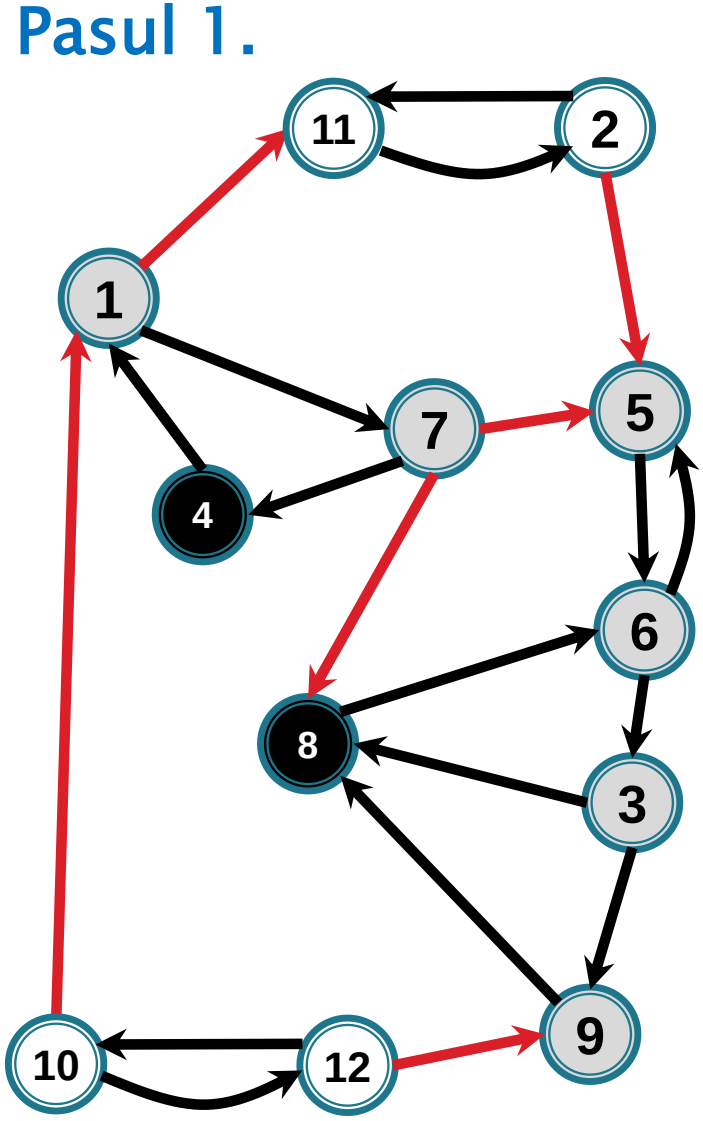

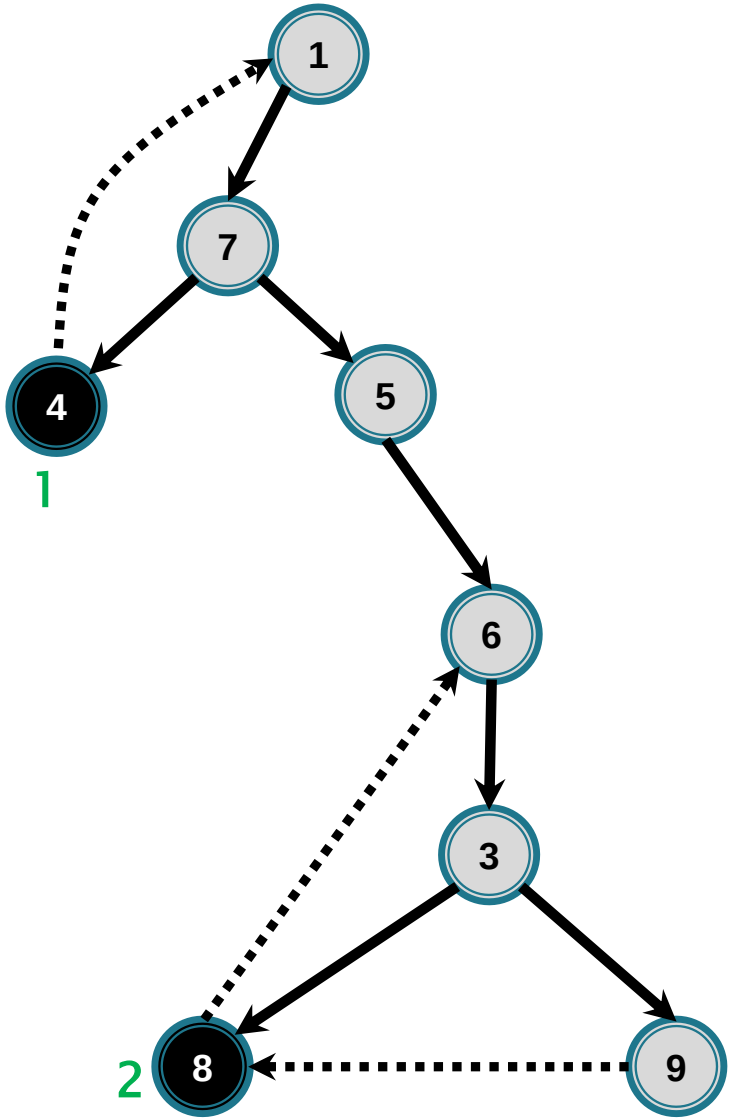

Ordinea descrescătoare finalizare:

8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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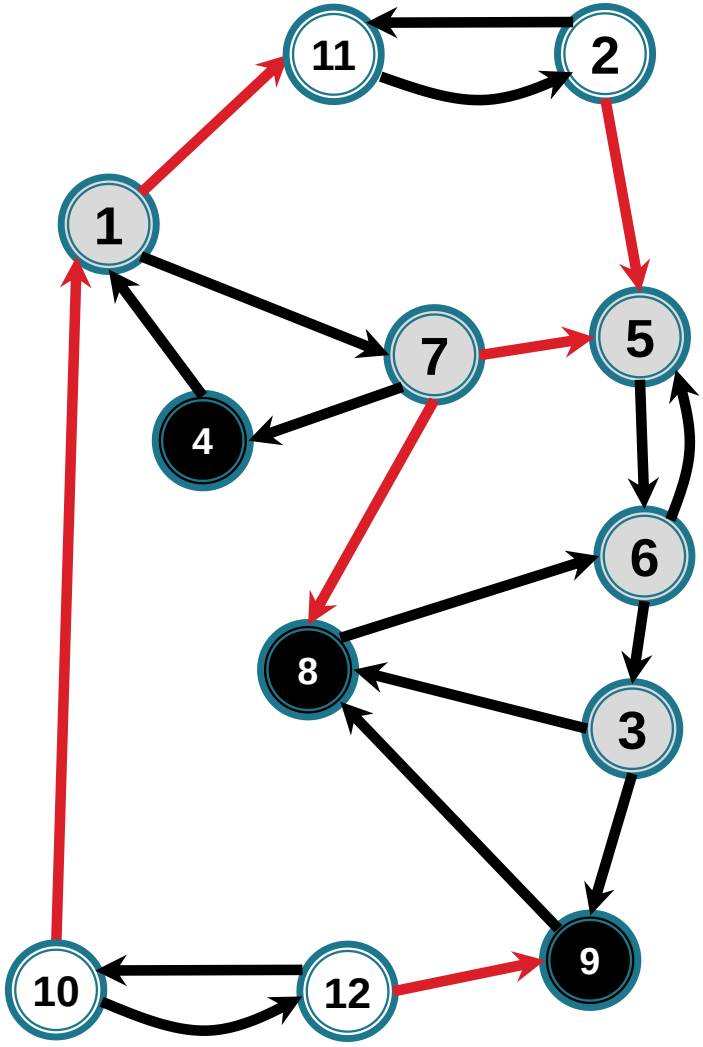

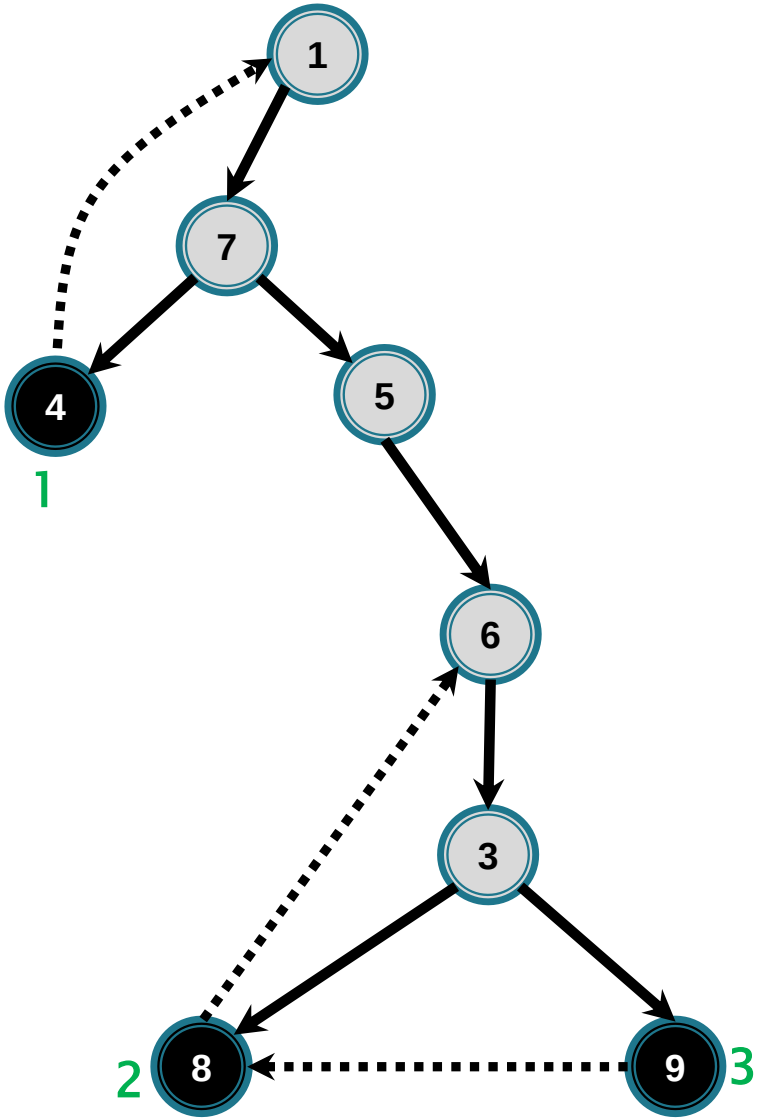

Ordinea descrescătoare finalizare:

9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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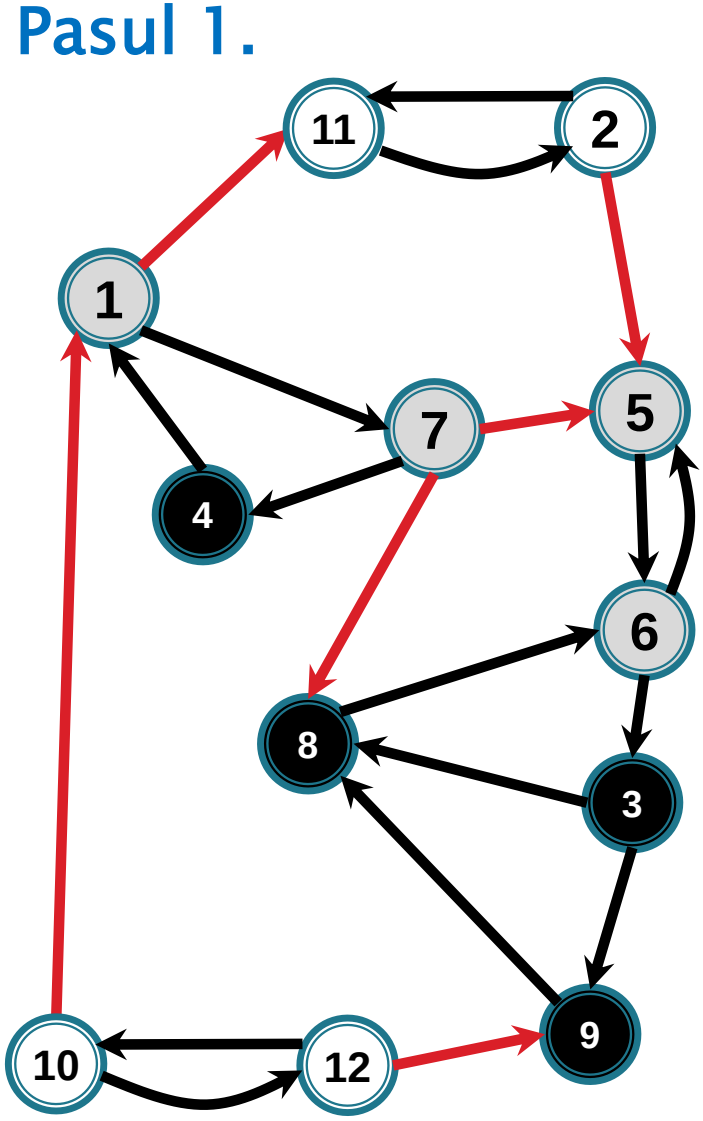

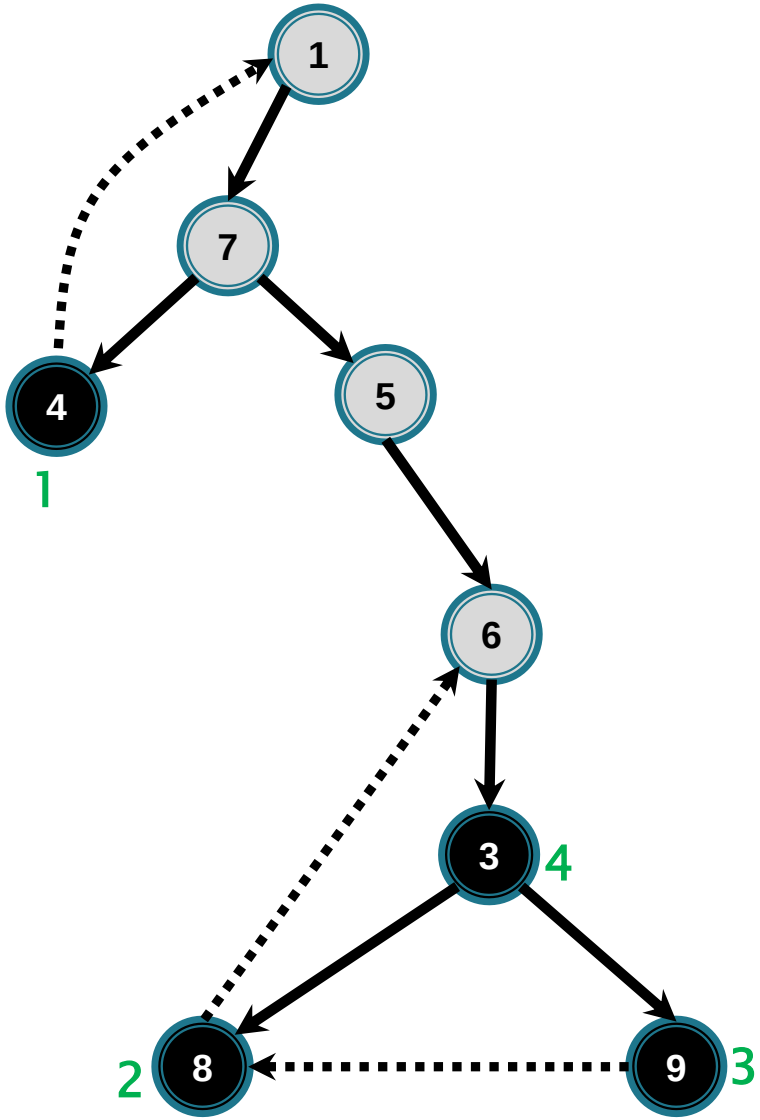

Ordinea descrescătoare finalizare:

3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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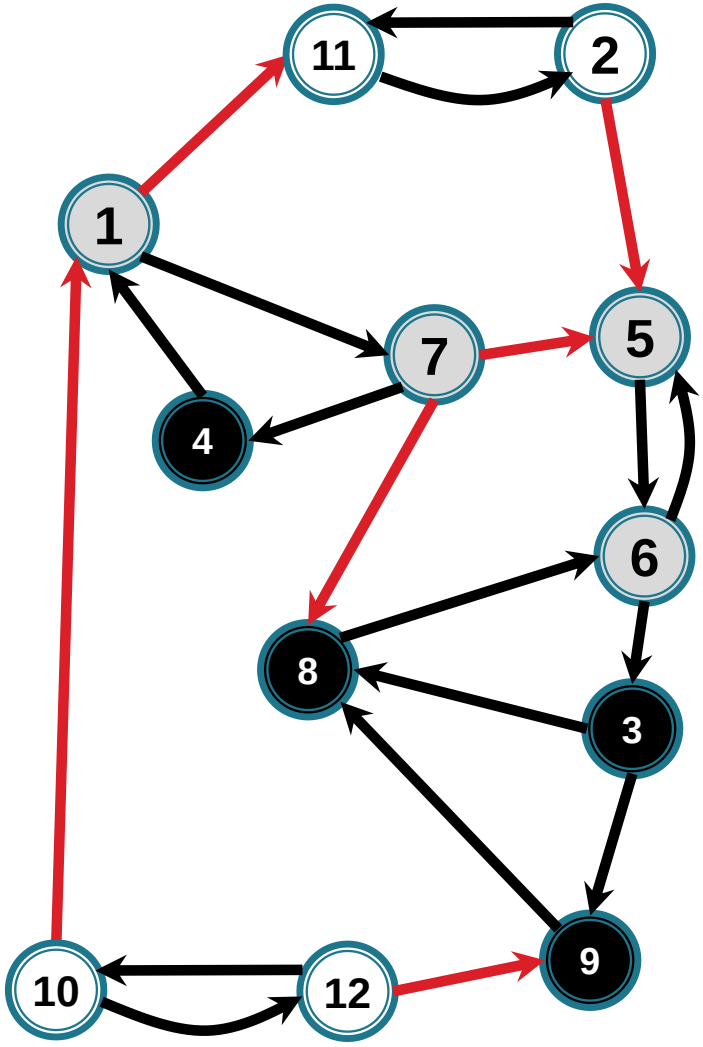
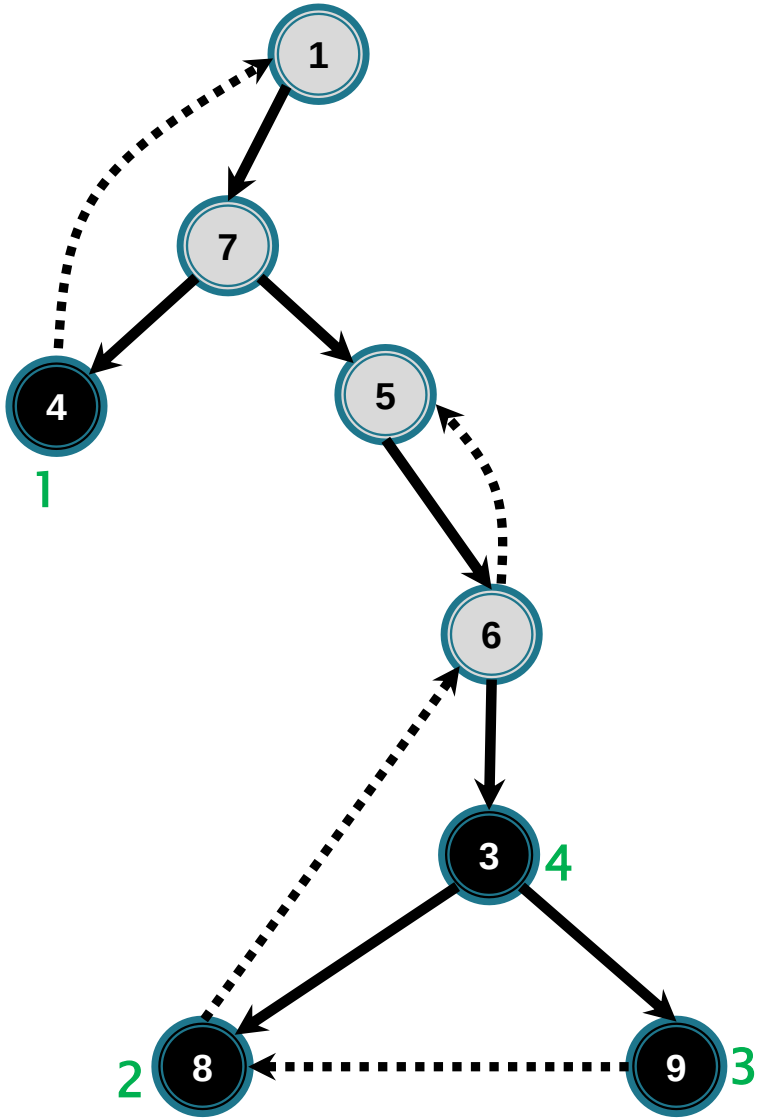




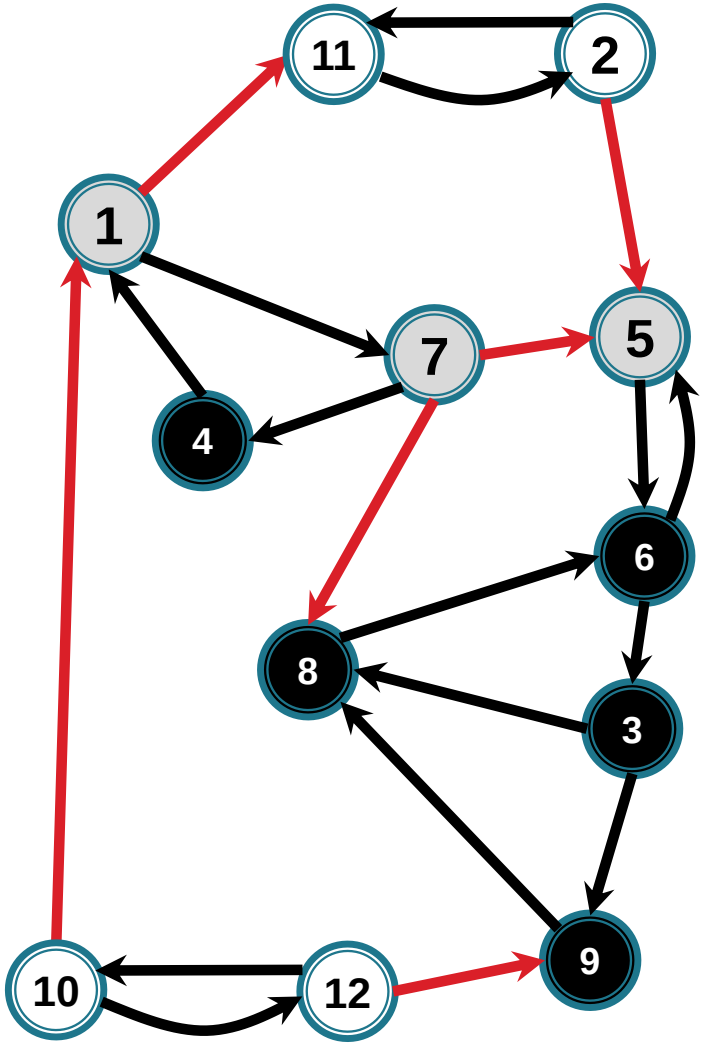
Ordinea descrescătoare finalizare:

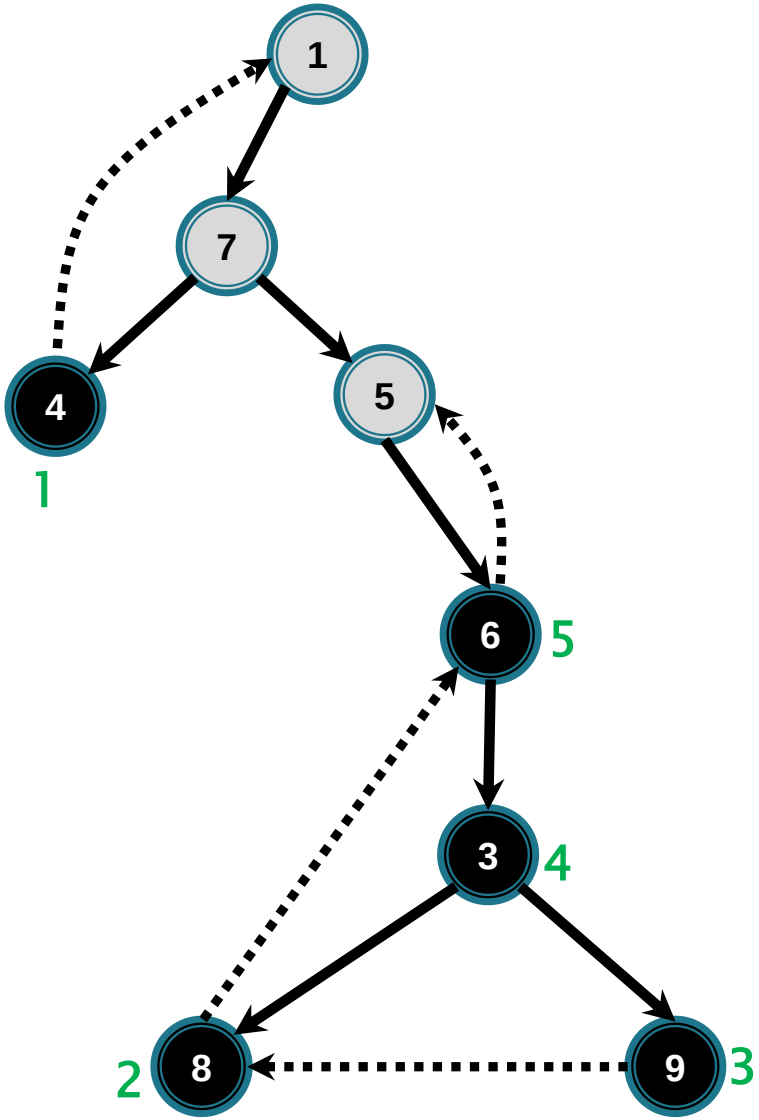
3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

Pasul 1.





Ordinea descrescătoare finalizare:

6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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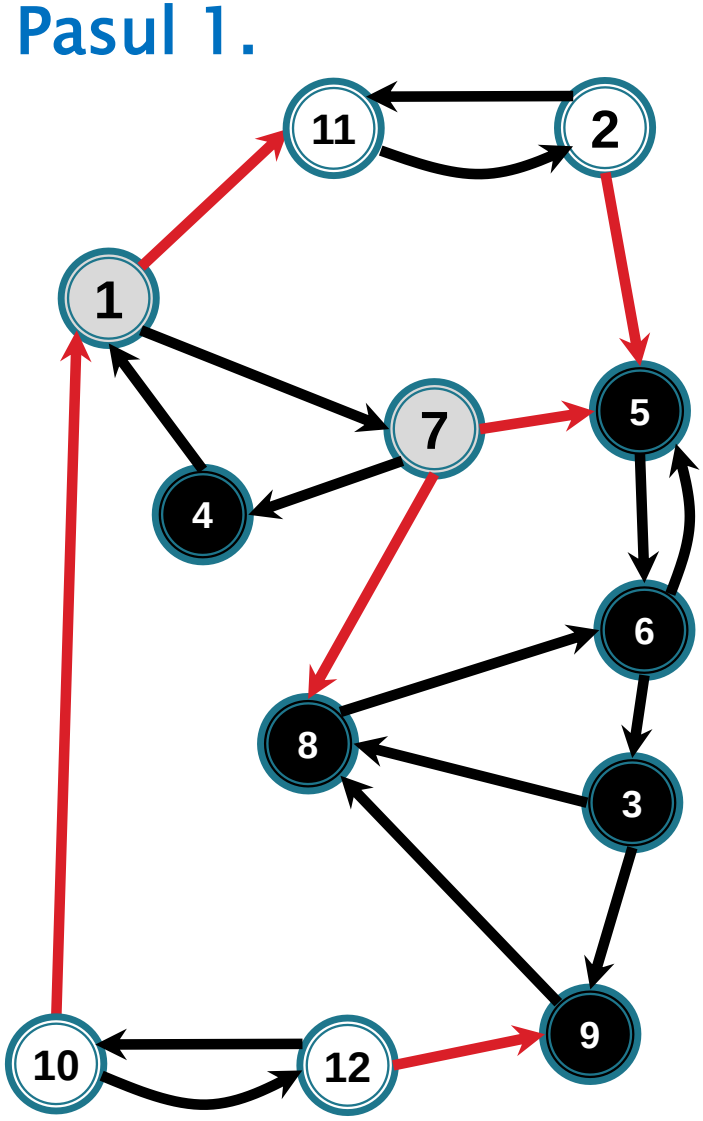

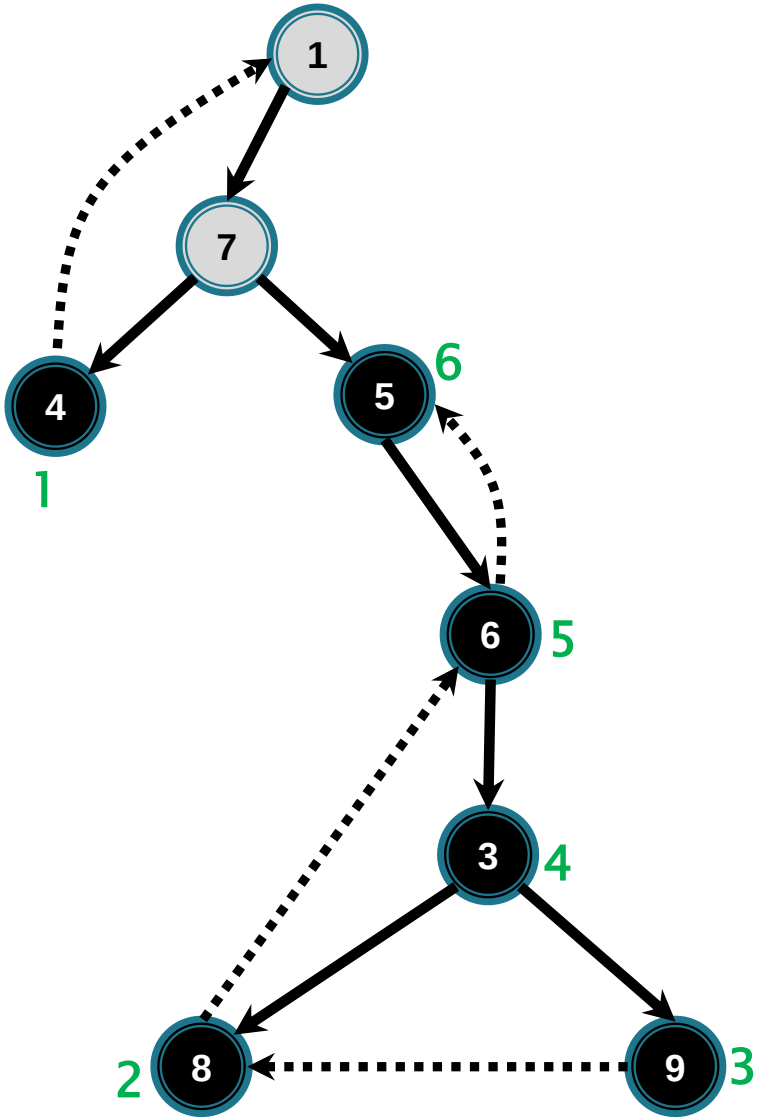

Ordinea descrescătoare finalizare: 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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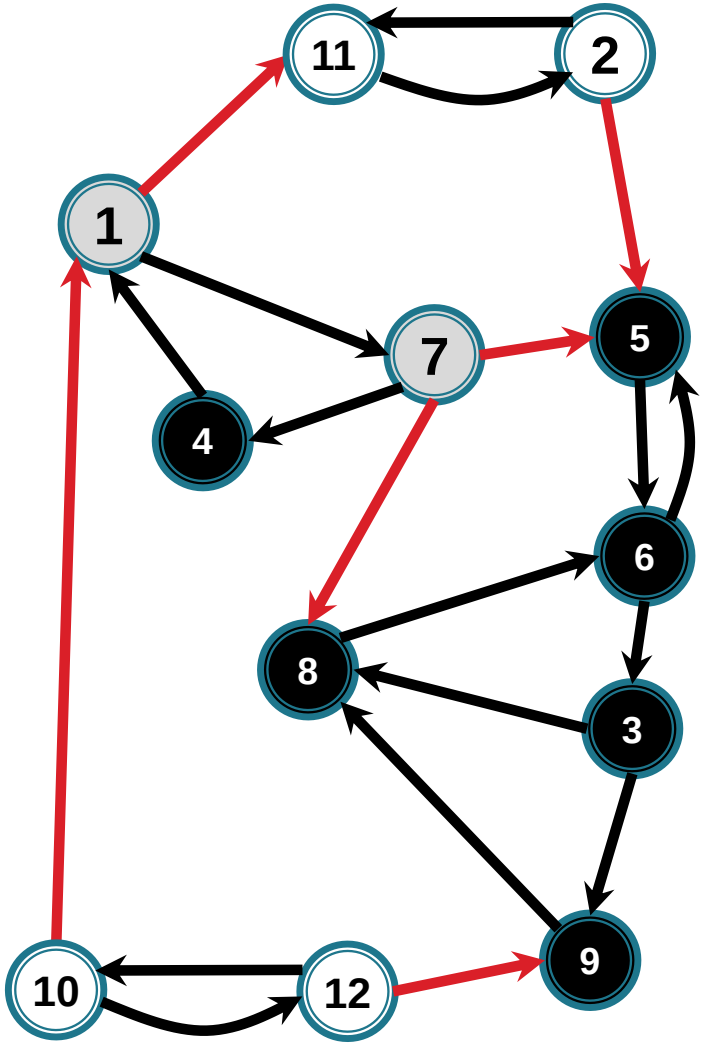
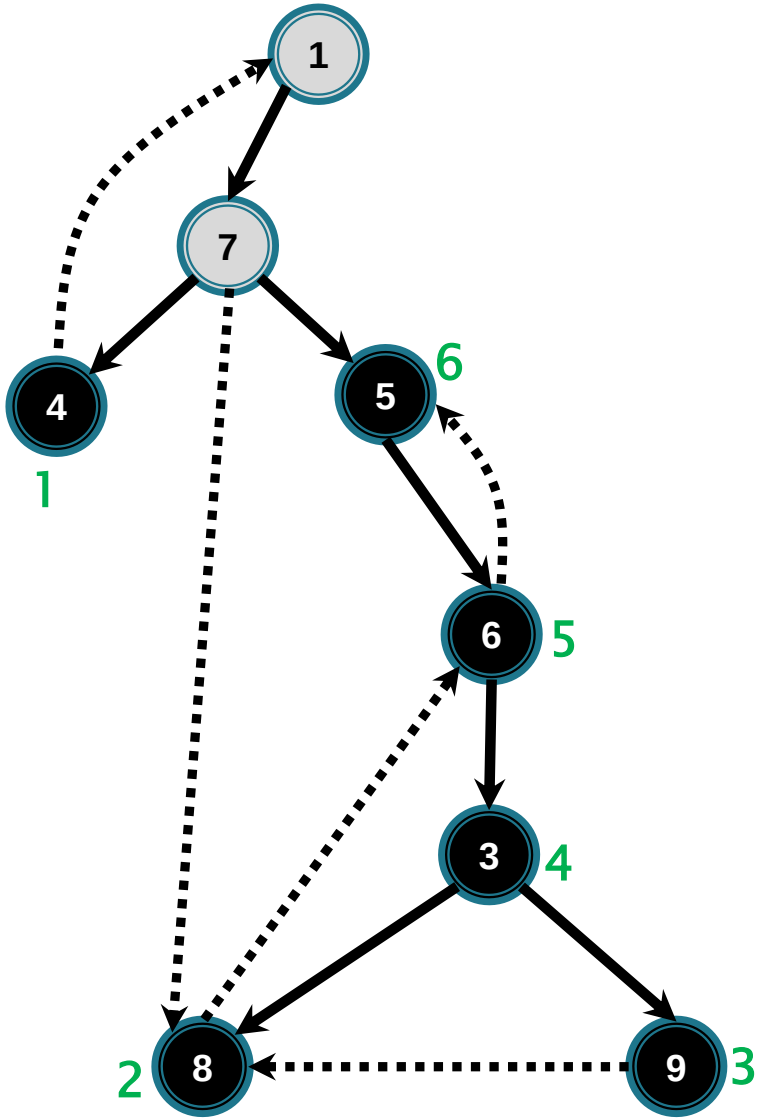


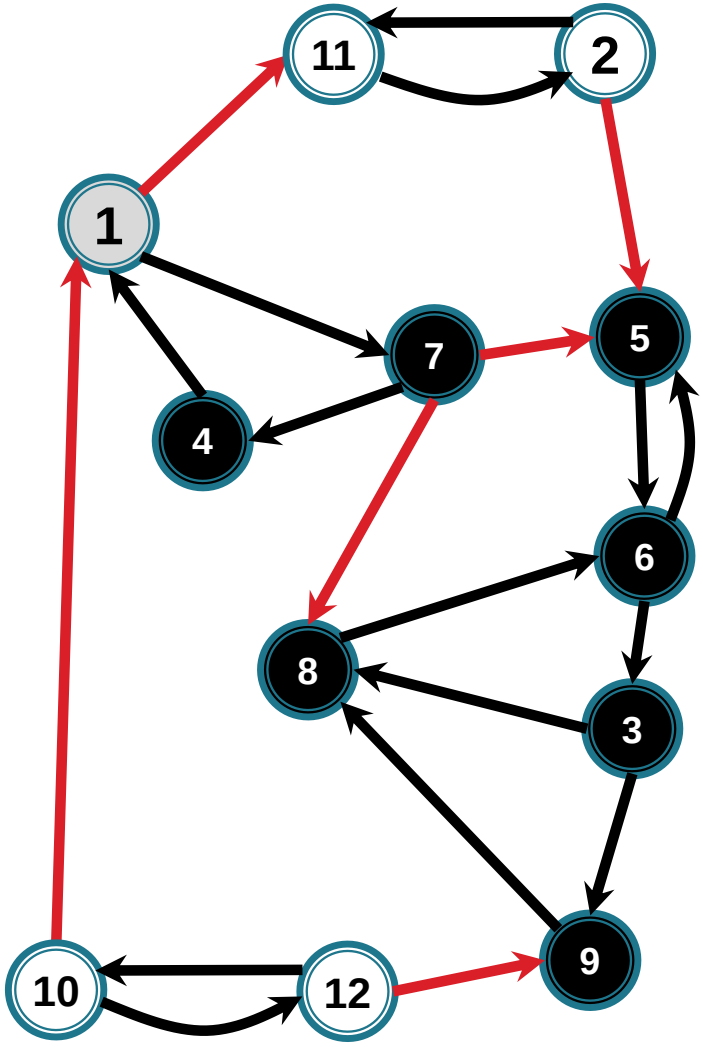


Ordinea descrescătoare finalizare:

5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



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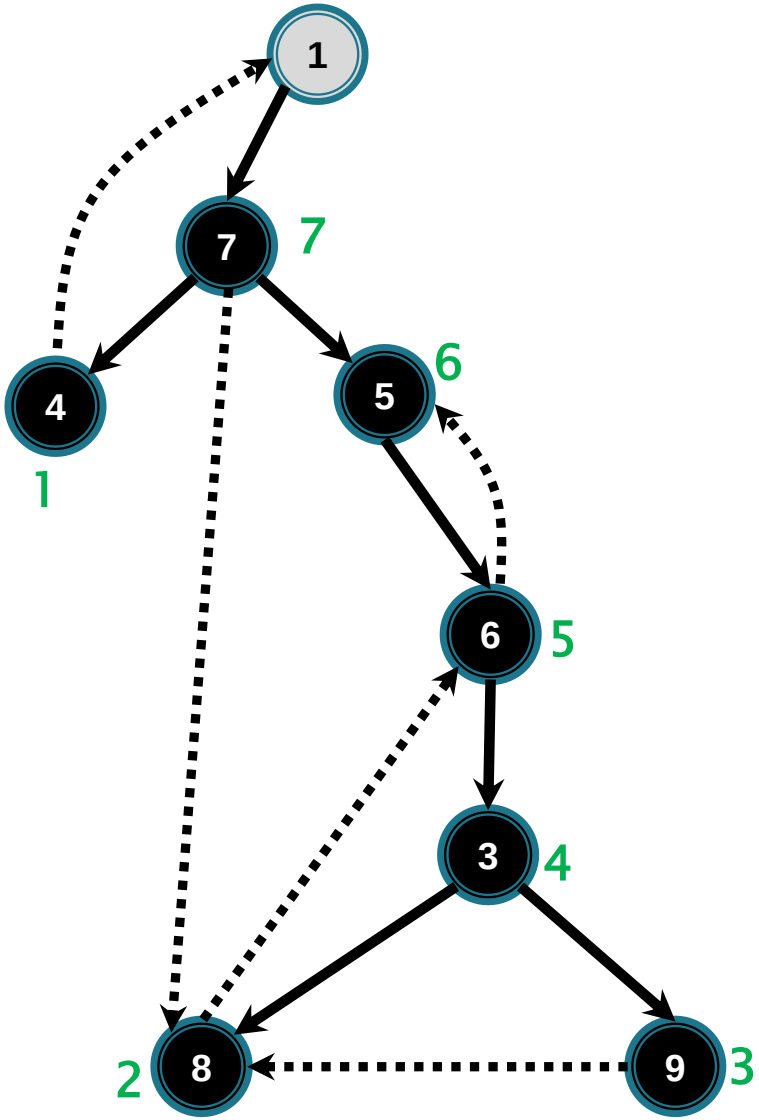

Ordinea descrescătoare finalizare: 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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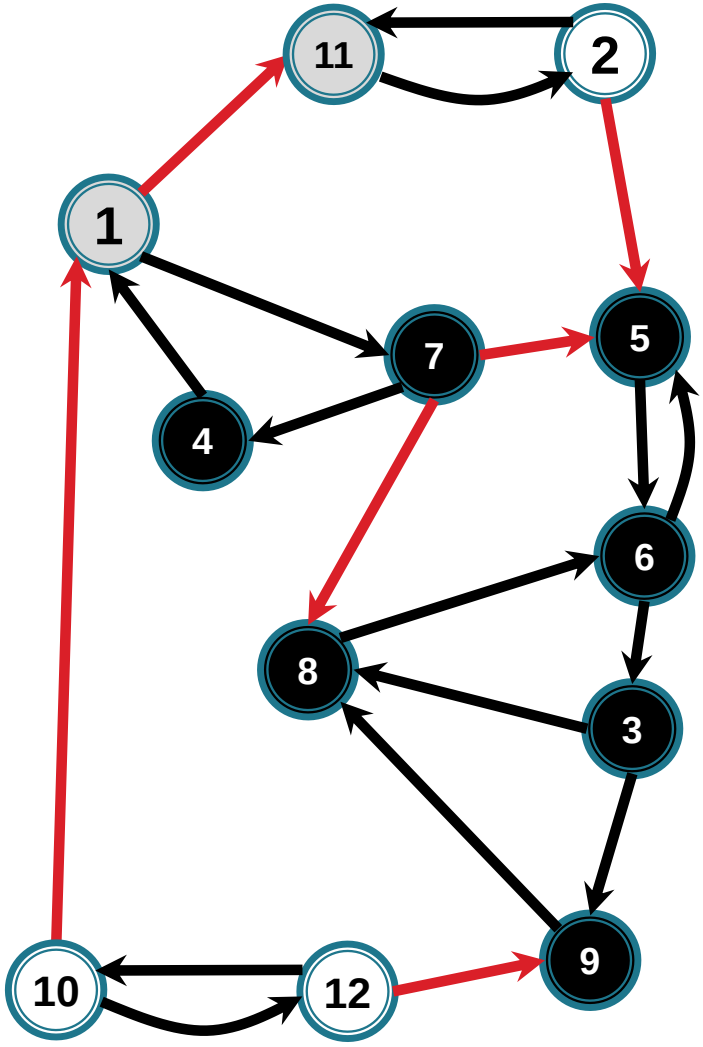

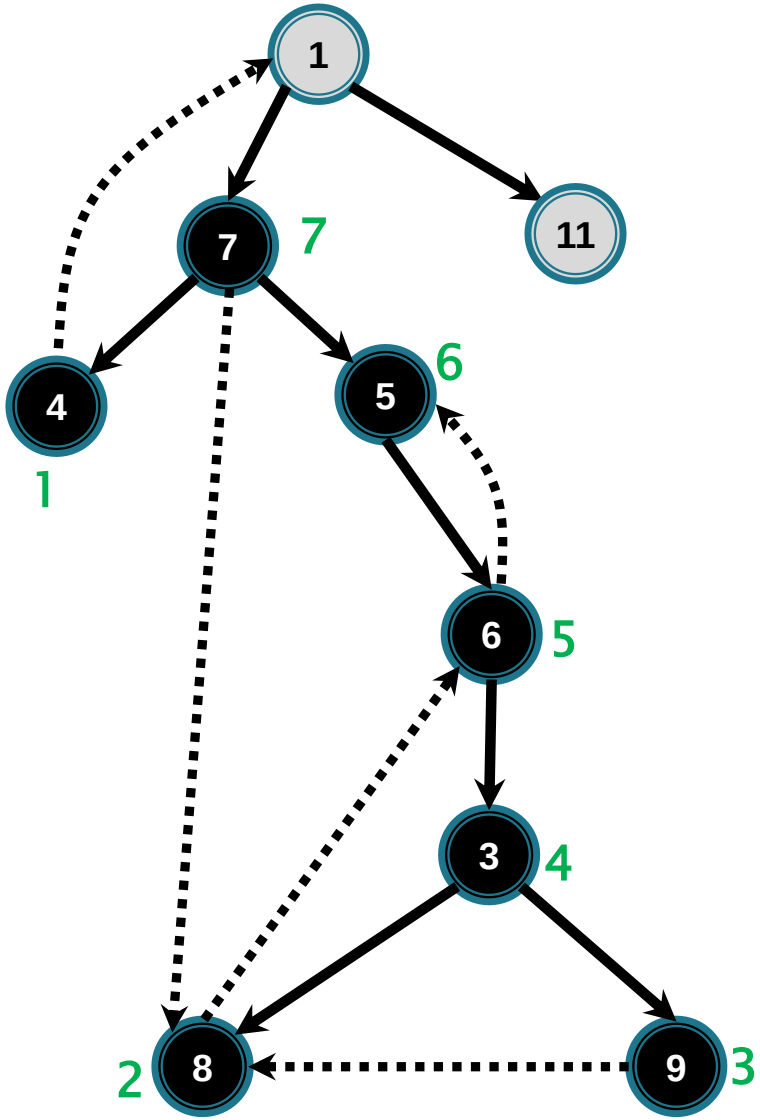

Ordinea descrescătoare finalizare: 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

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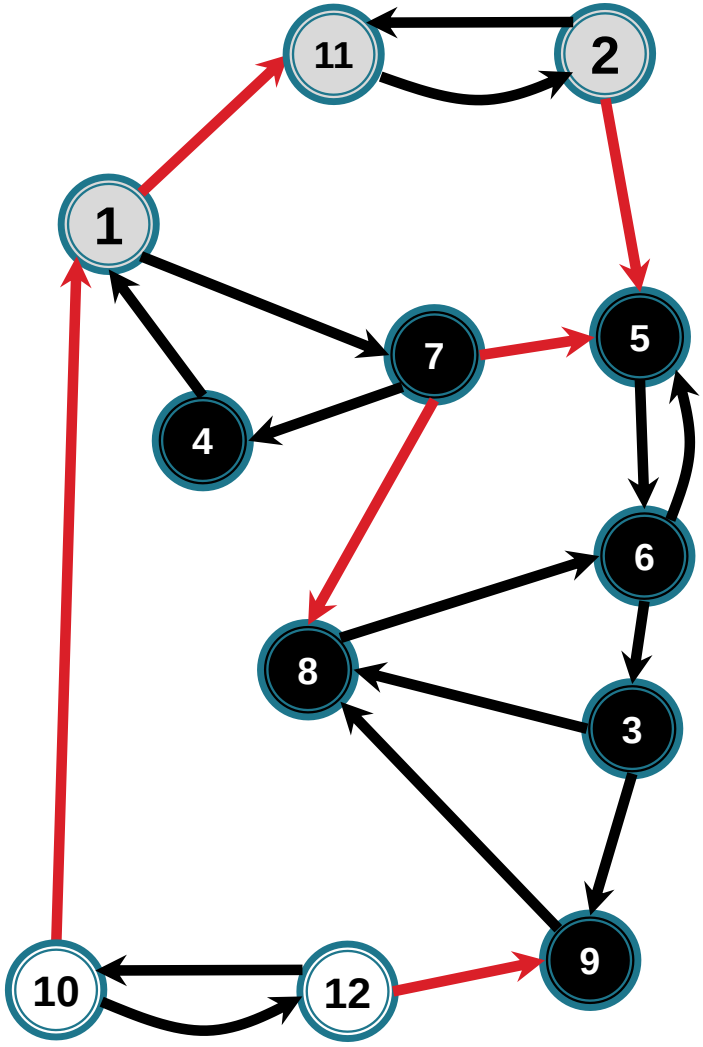

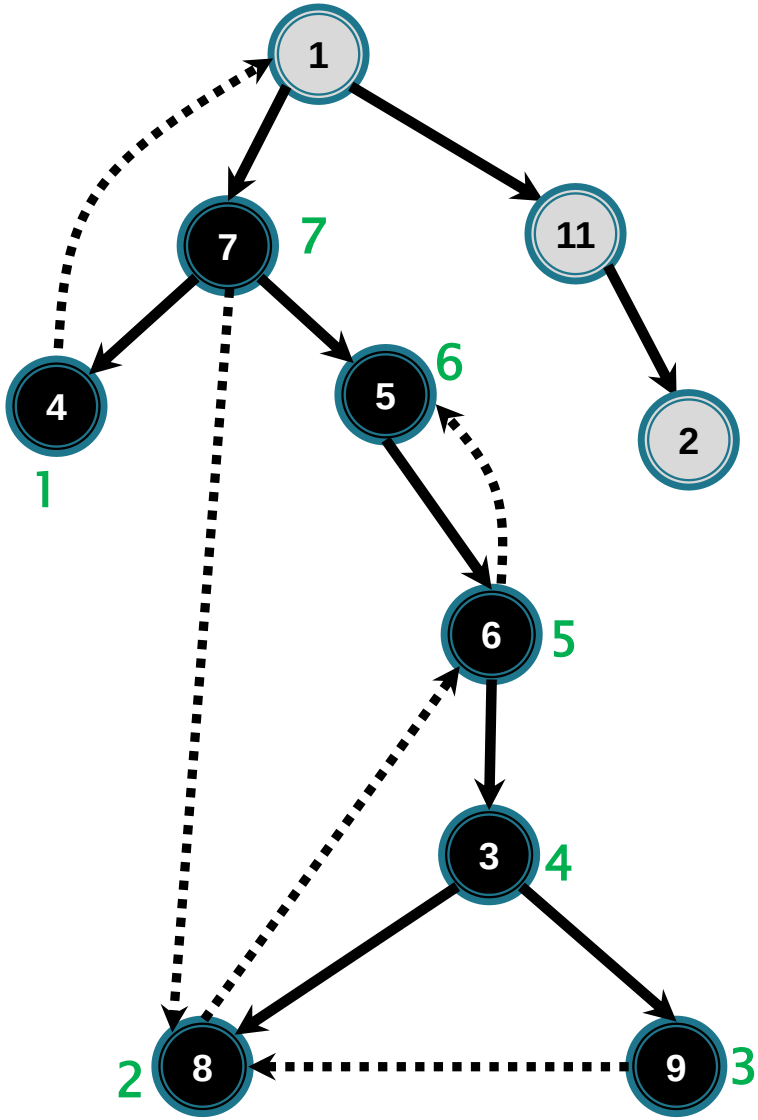

Ordinea descrescătoare finalizare: 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

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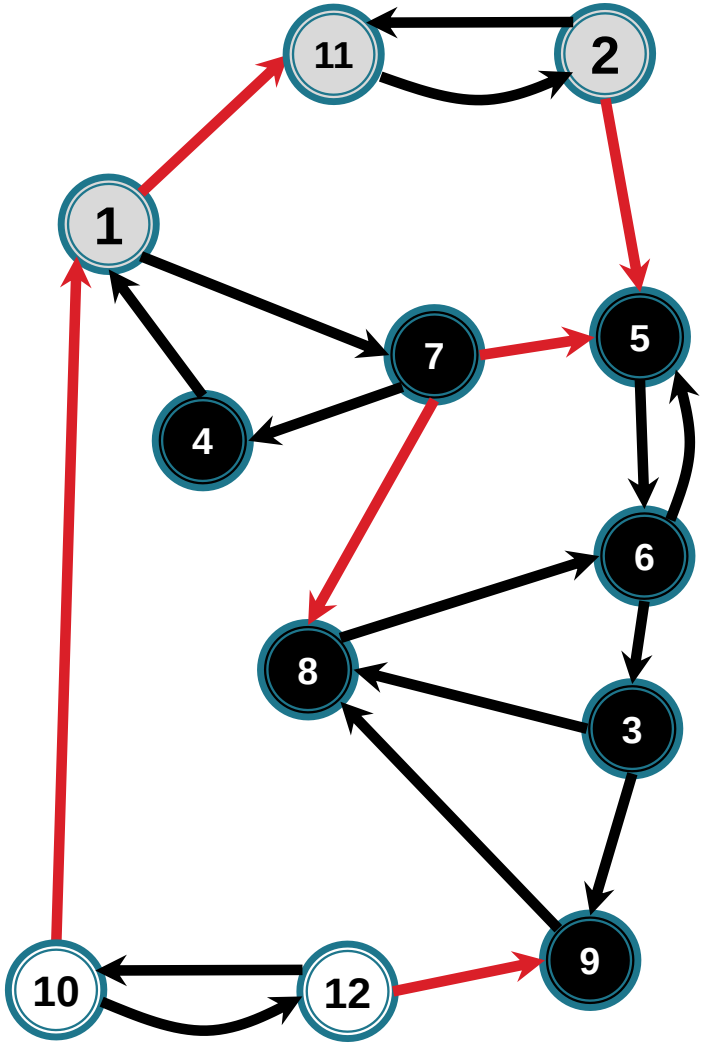

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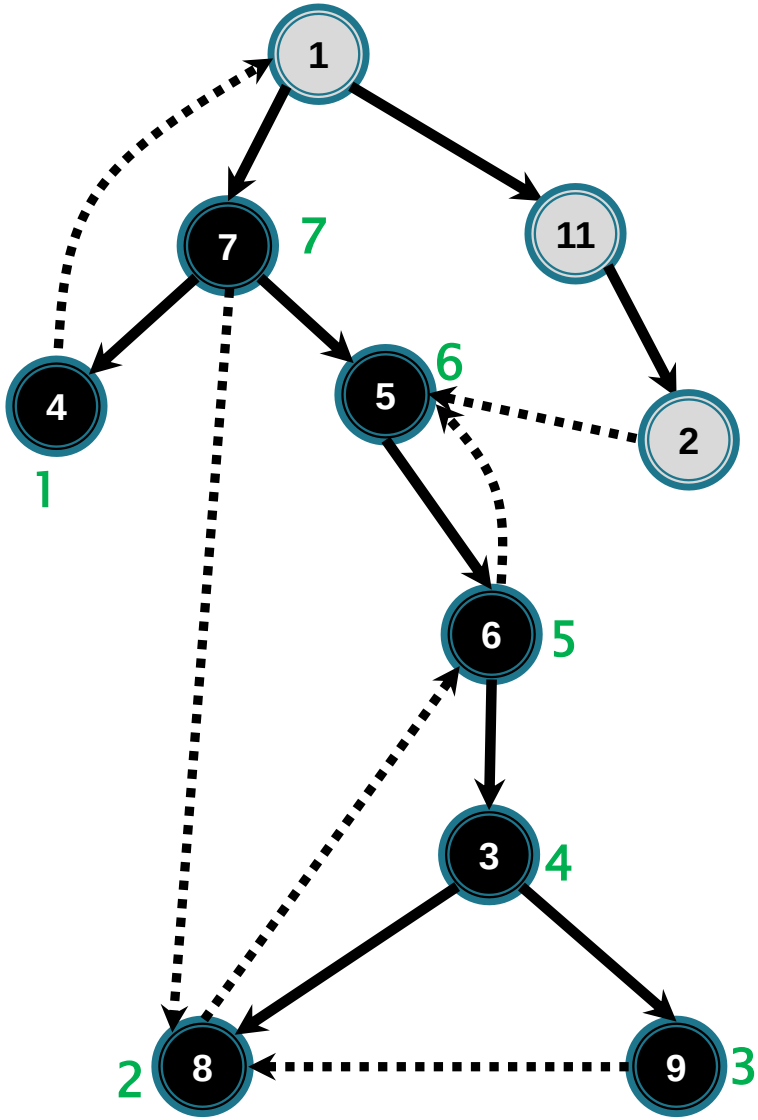
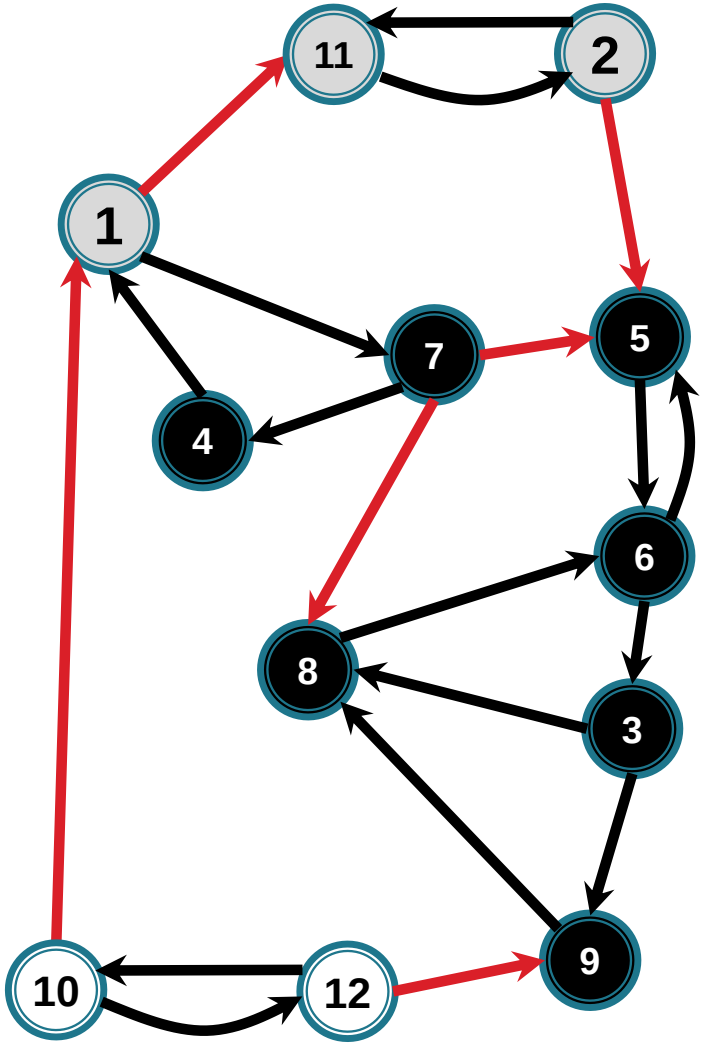


Ordinea descrescătoare finalizare: 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



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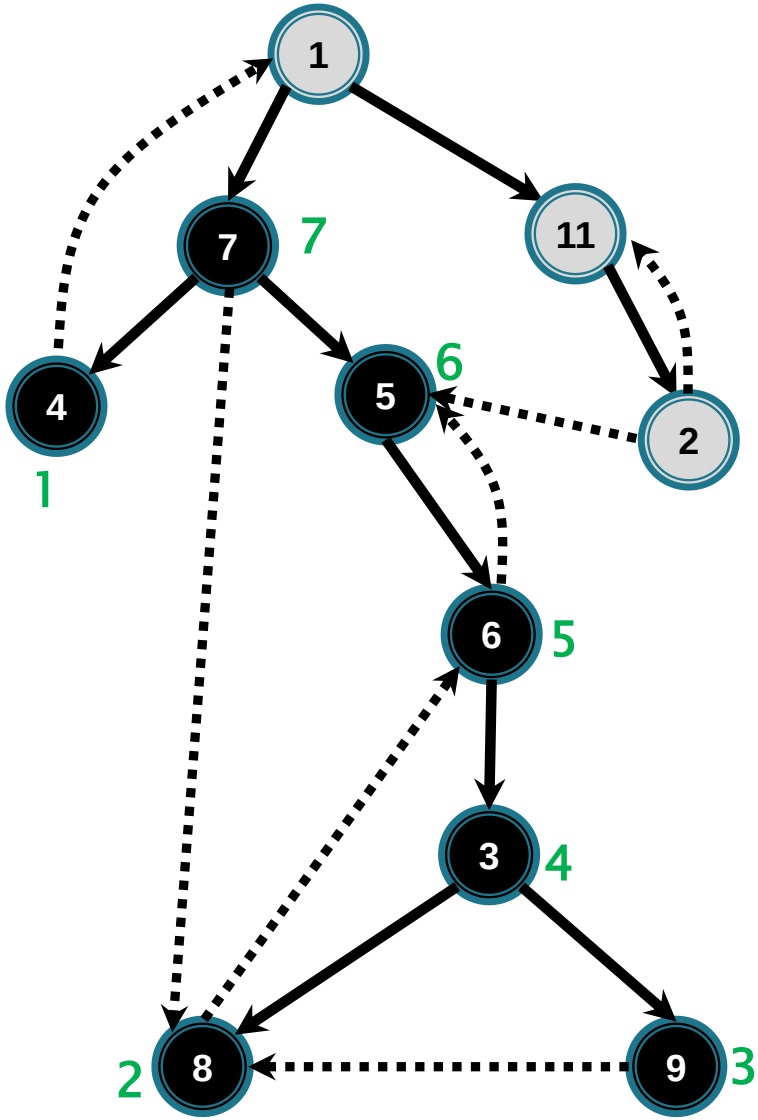
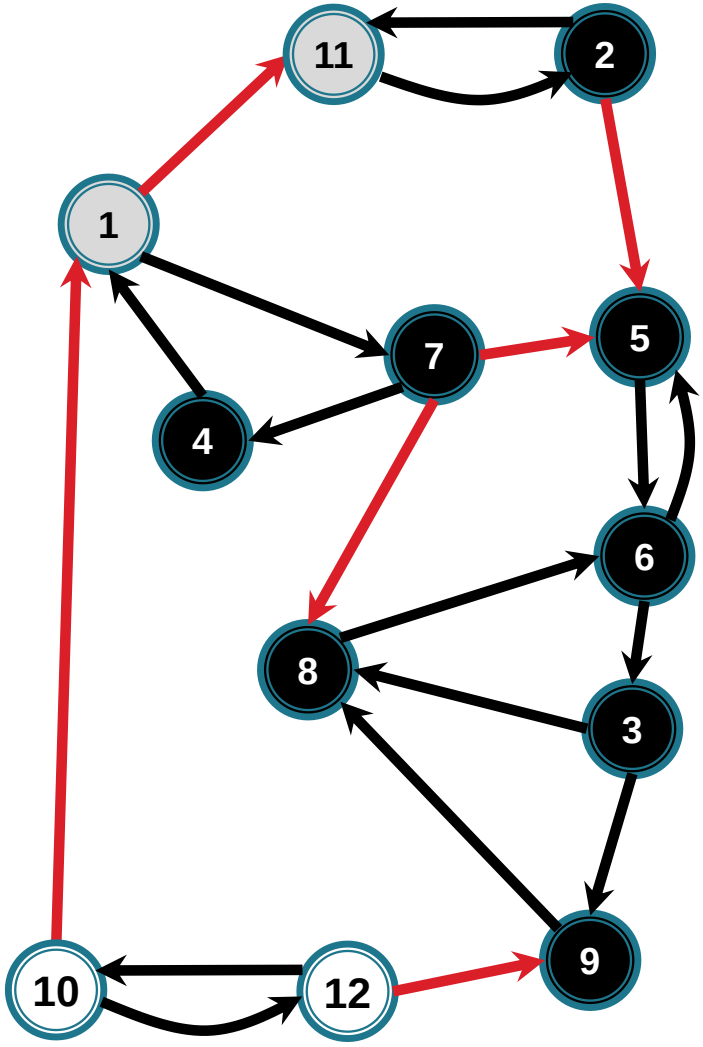


Ordinea descrescătoare finalizare: 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



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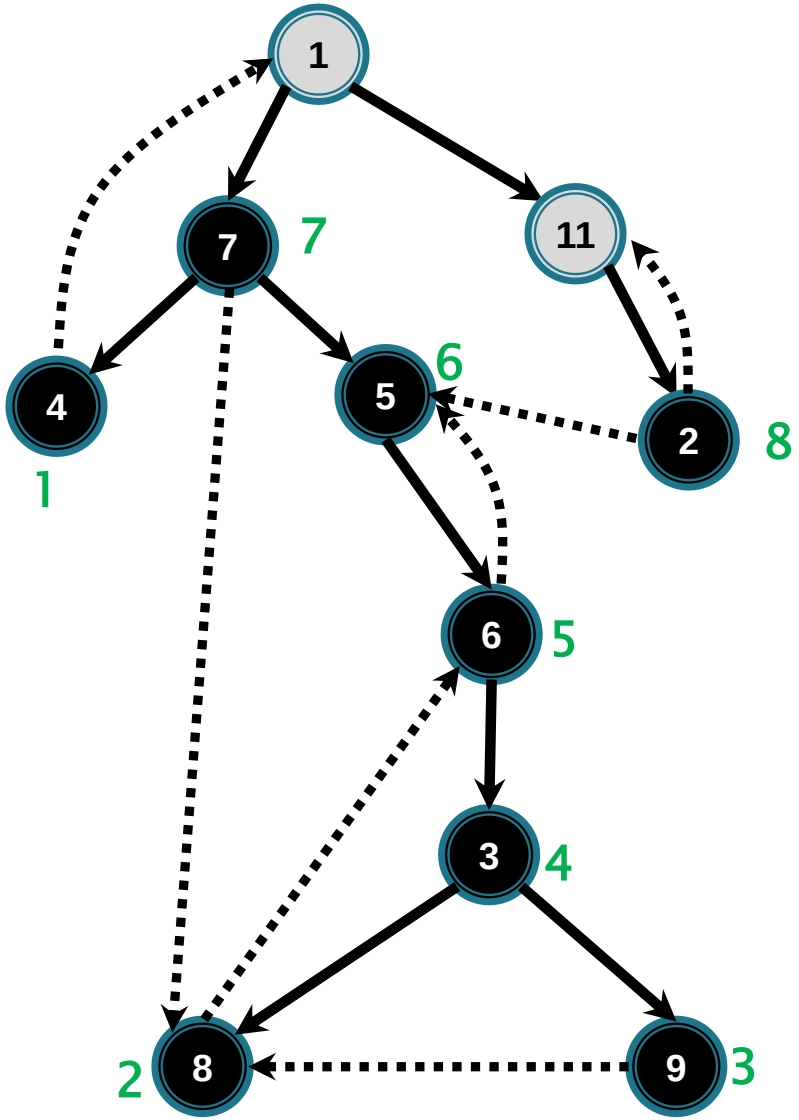
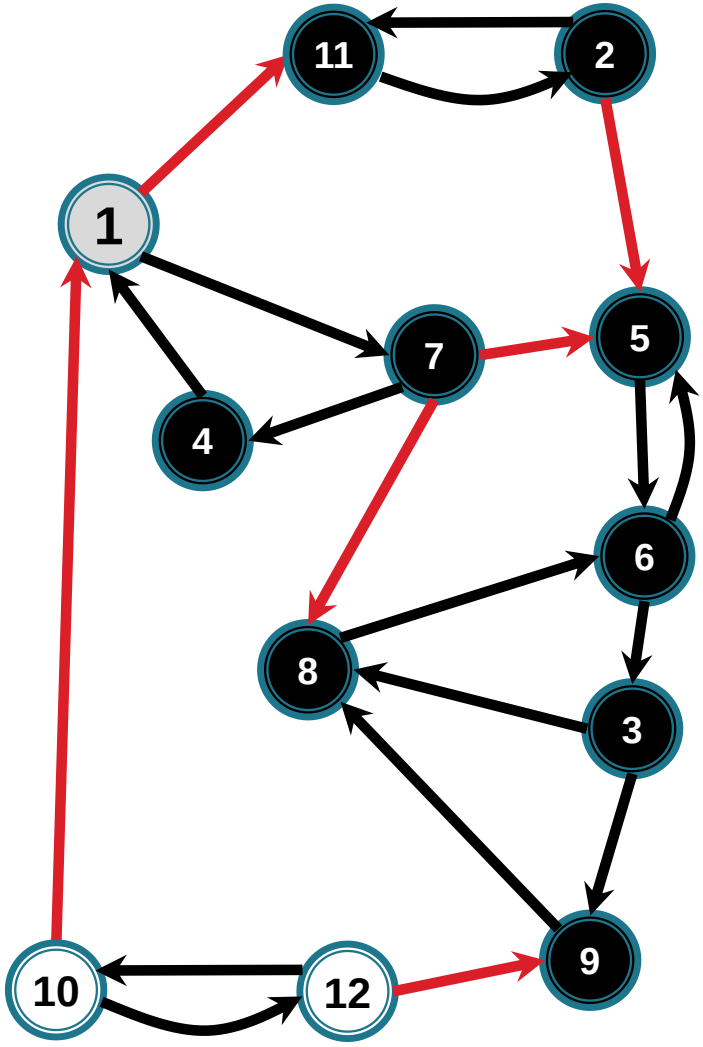


Ordinea descrescătoare finalizare: 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



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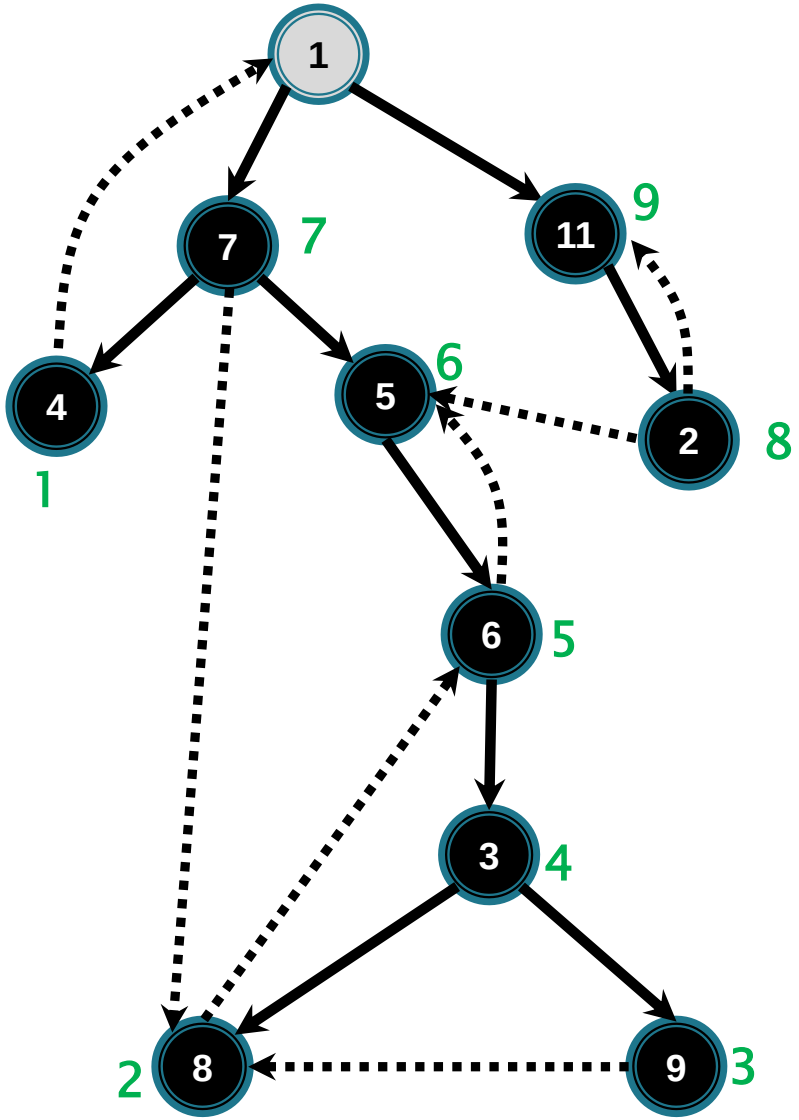
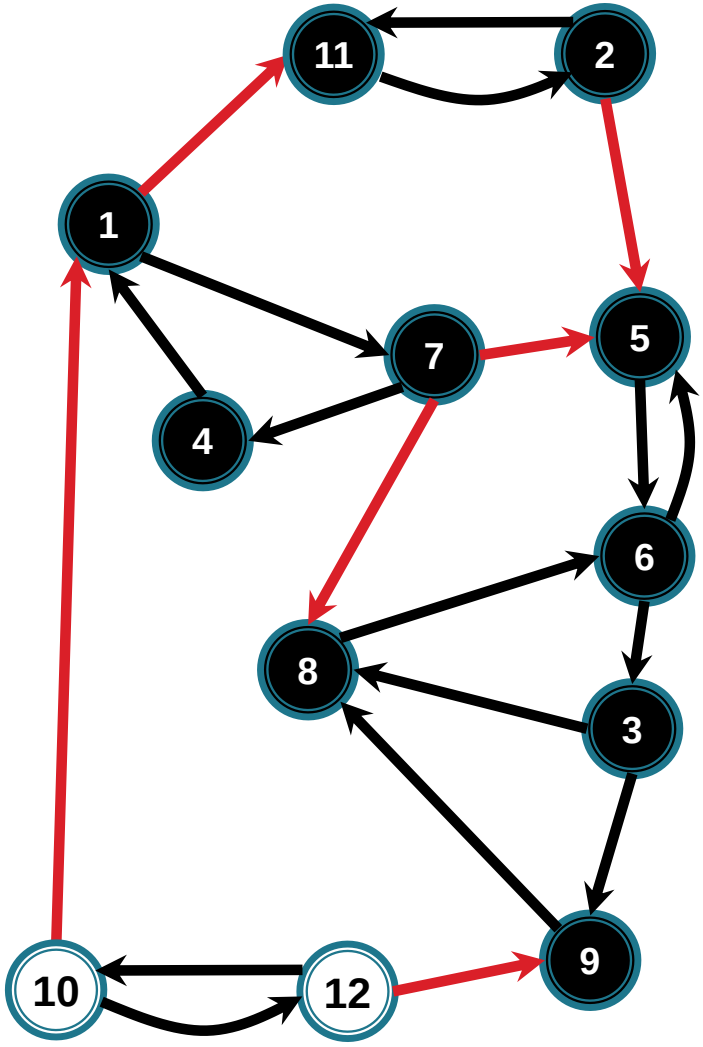


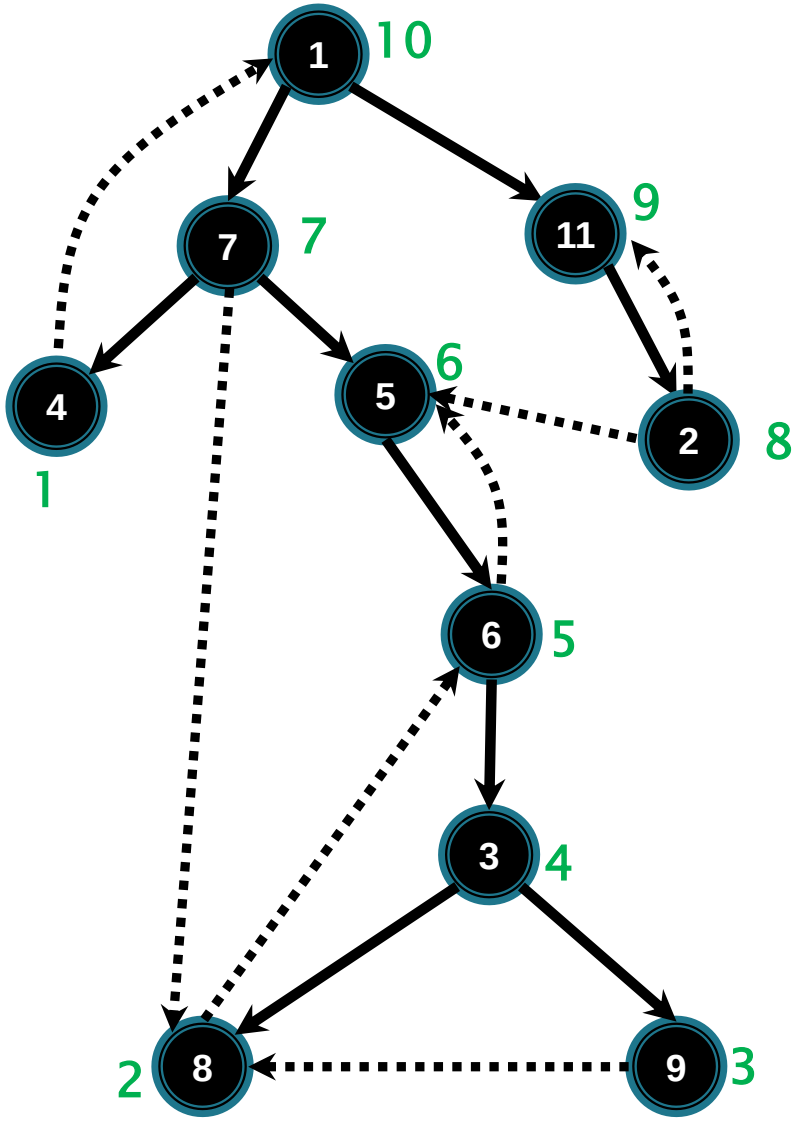
Ordinea descrescătoare finalizare: 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Timp de finalizare

Pasul 1.

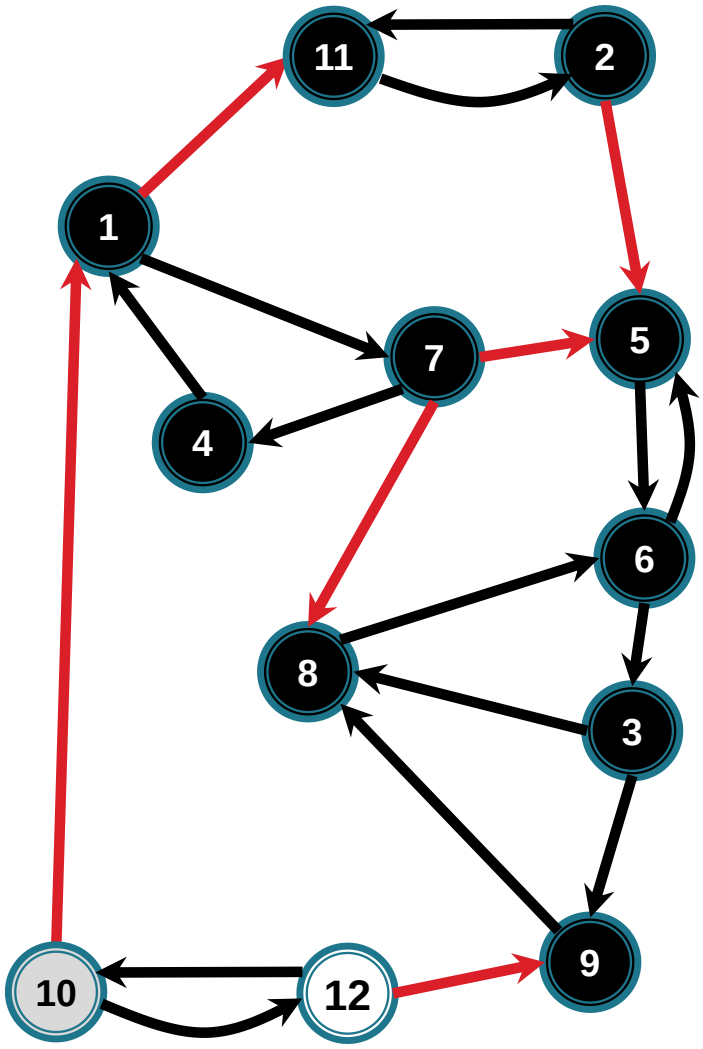




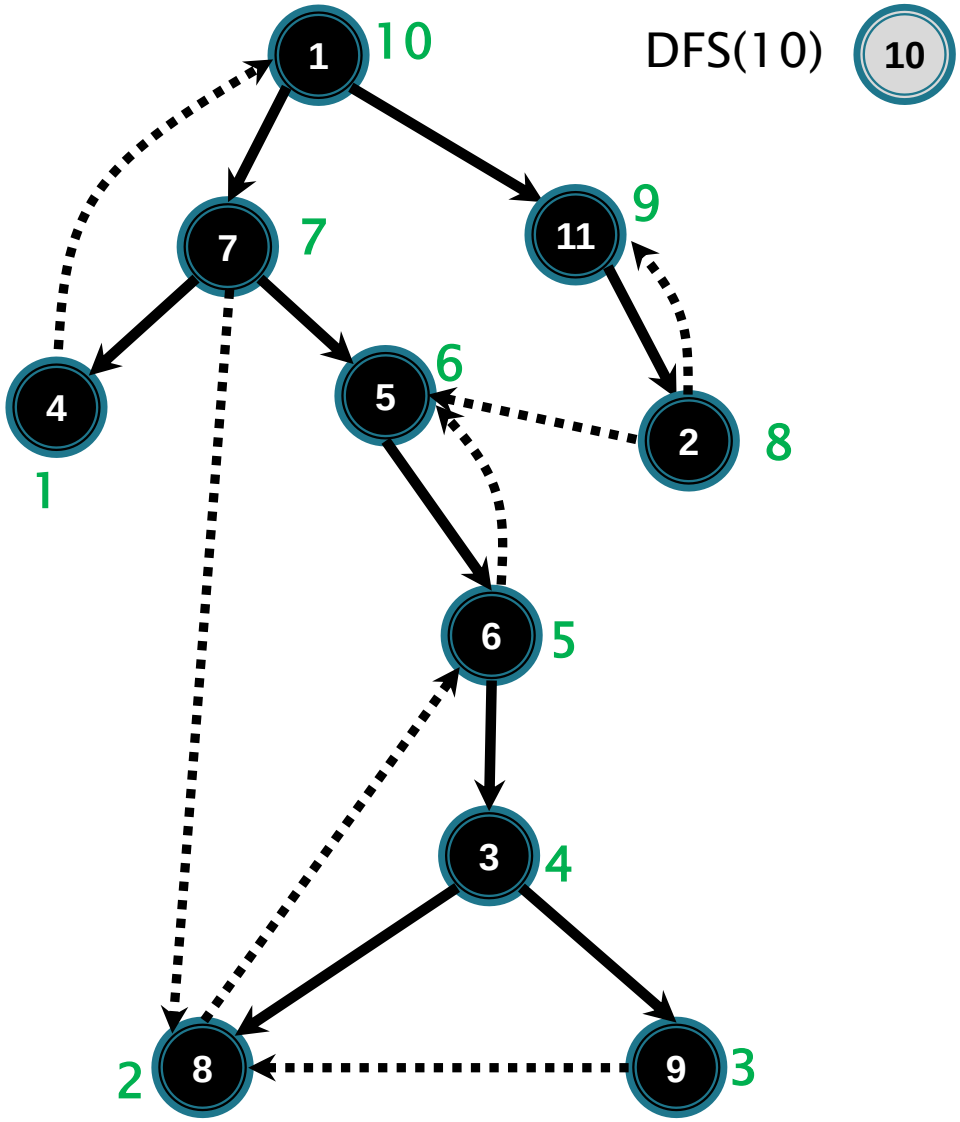
Ordinea descrescătoare finalizare: 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



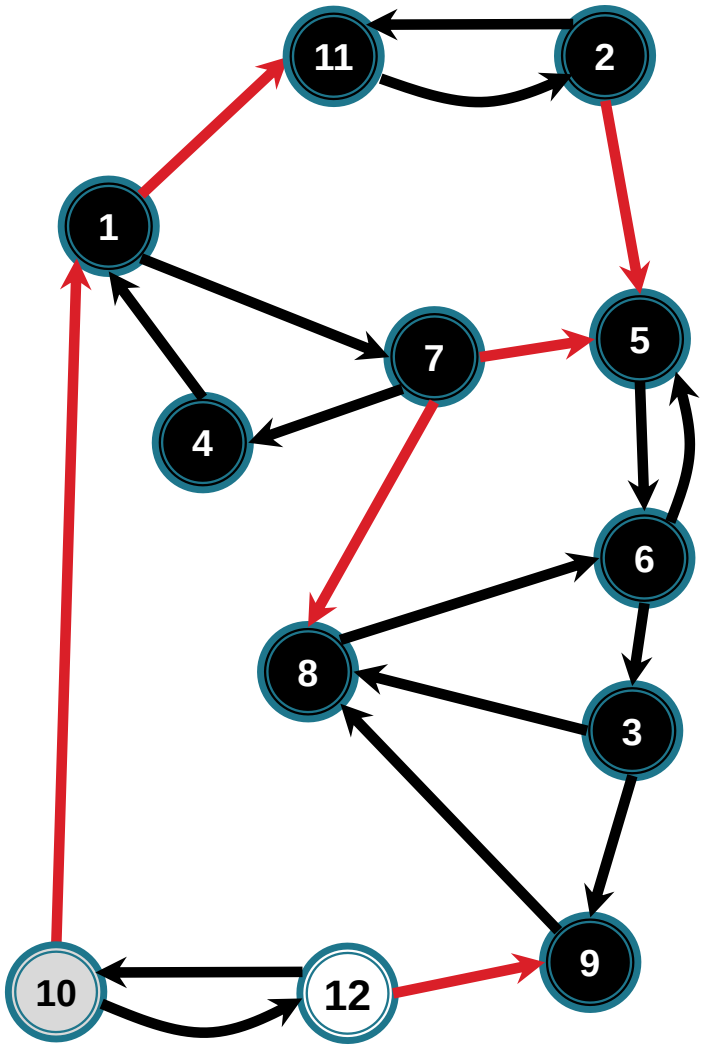
Timp de finalizare



Ordinea descrescătoare finalizare: 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



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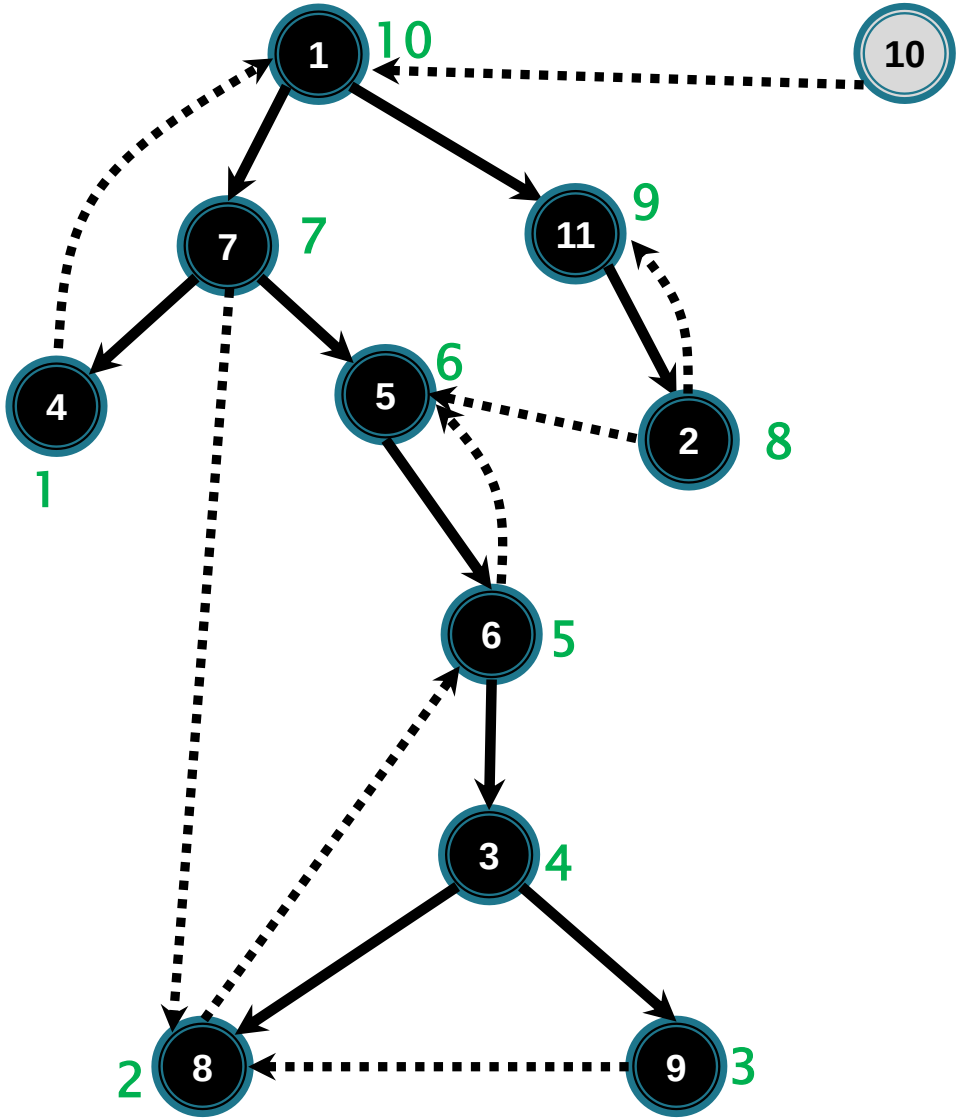
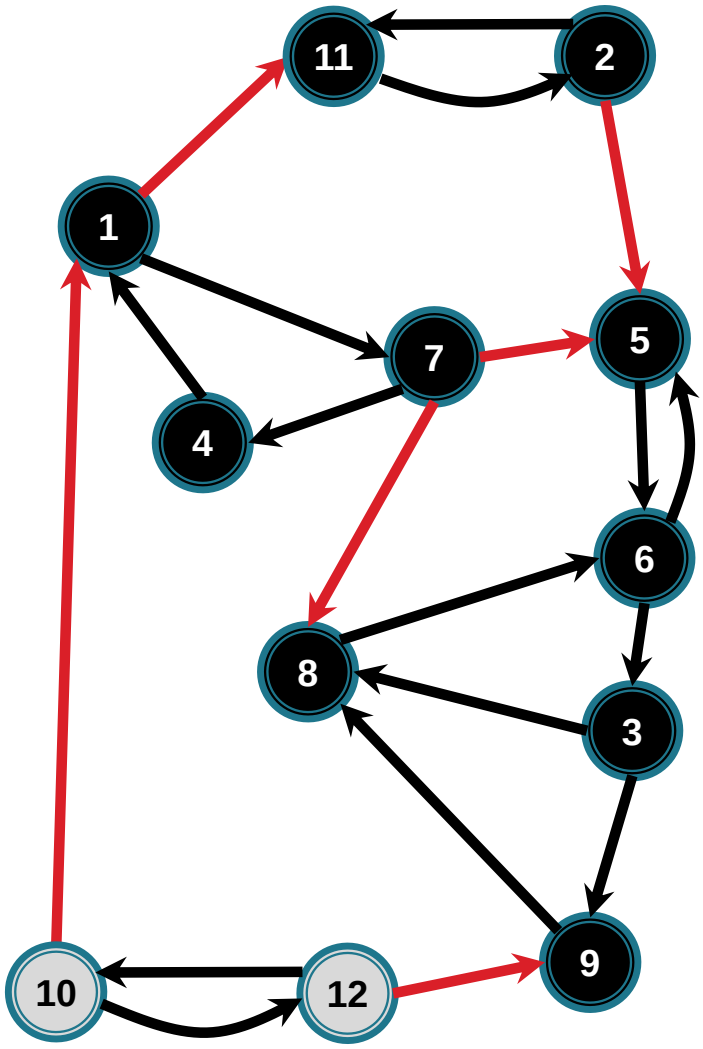


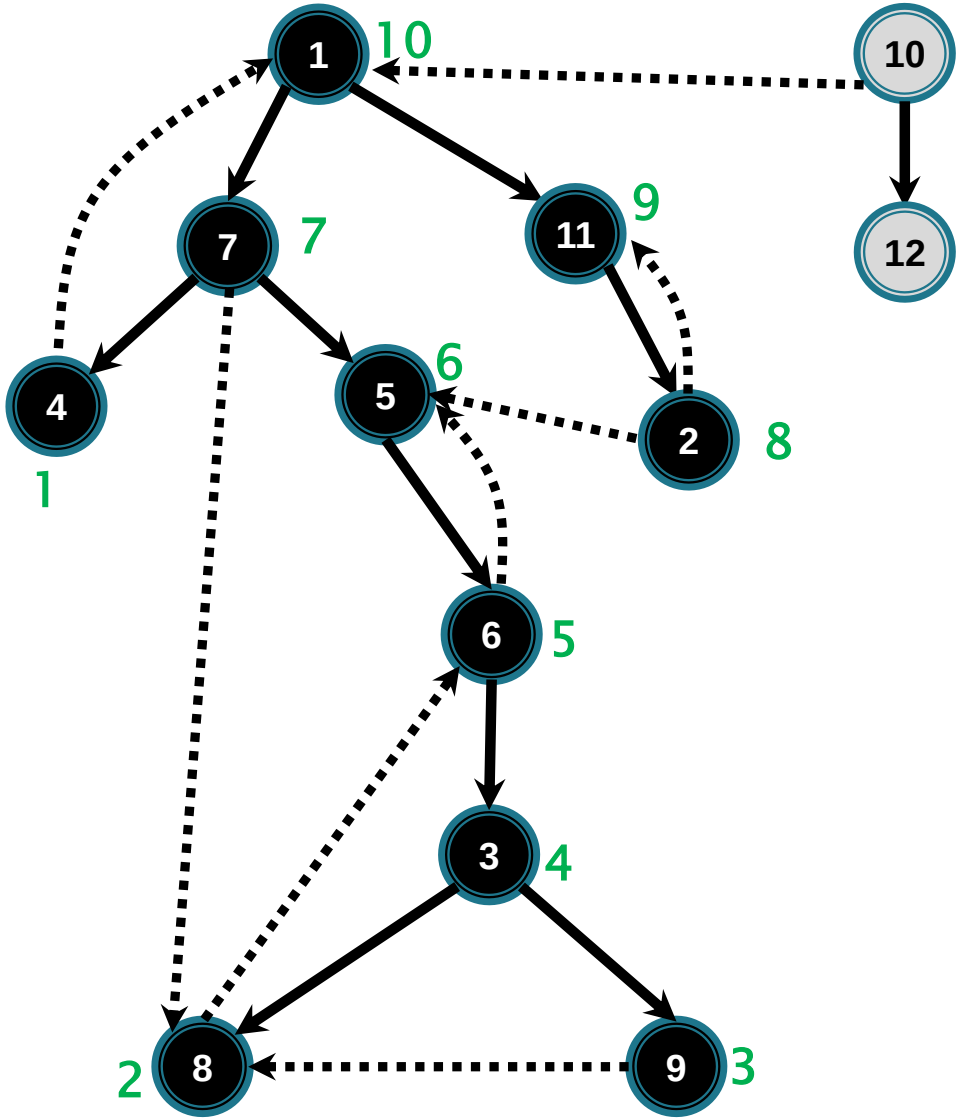
Ordinea descrescătoare finalizare: 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



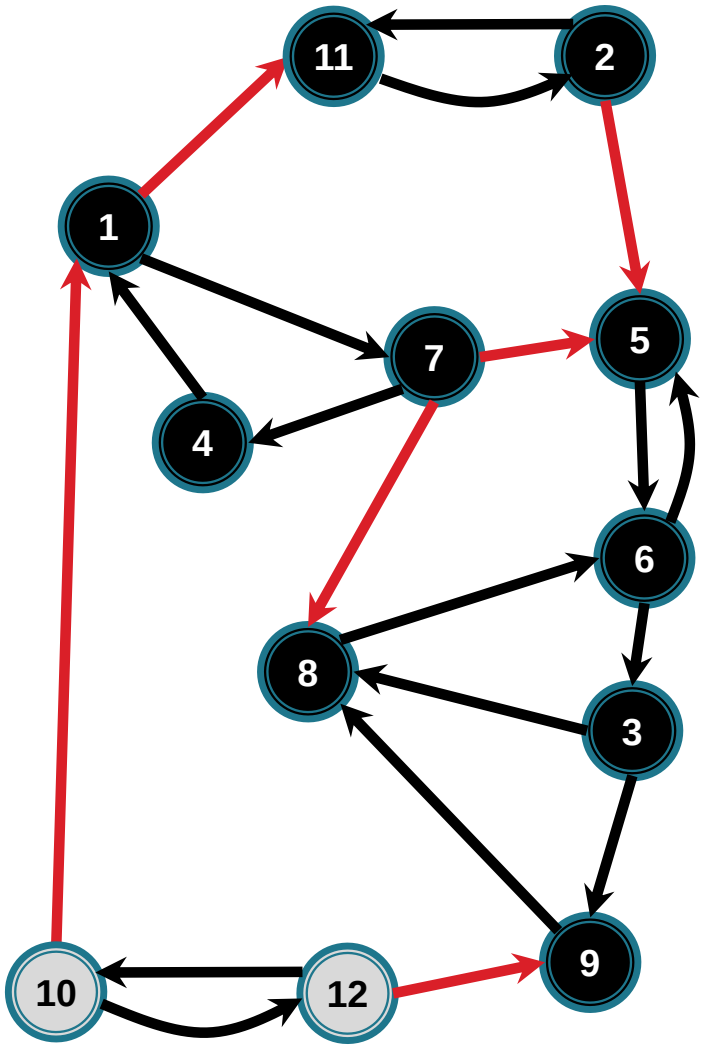
Timp de finalizare



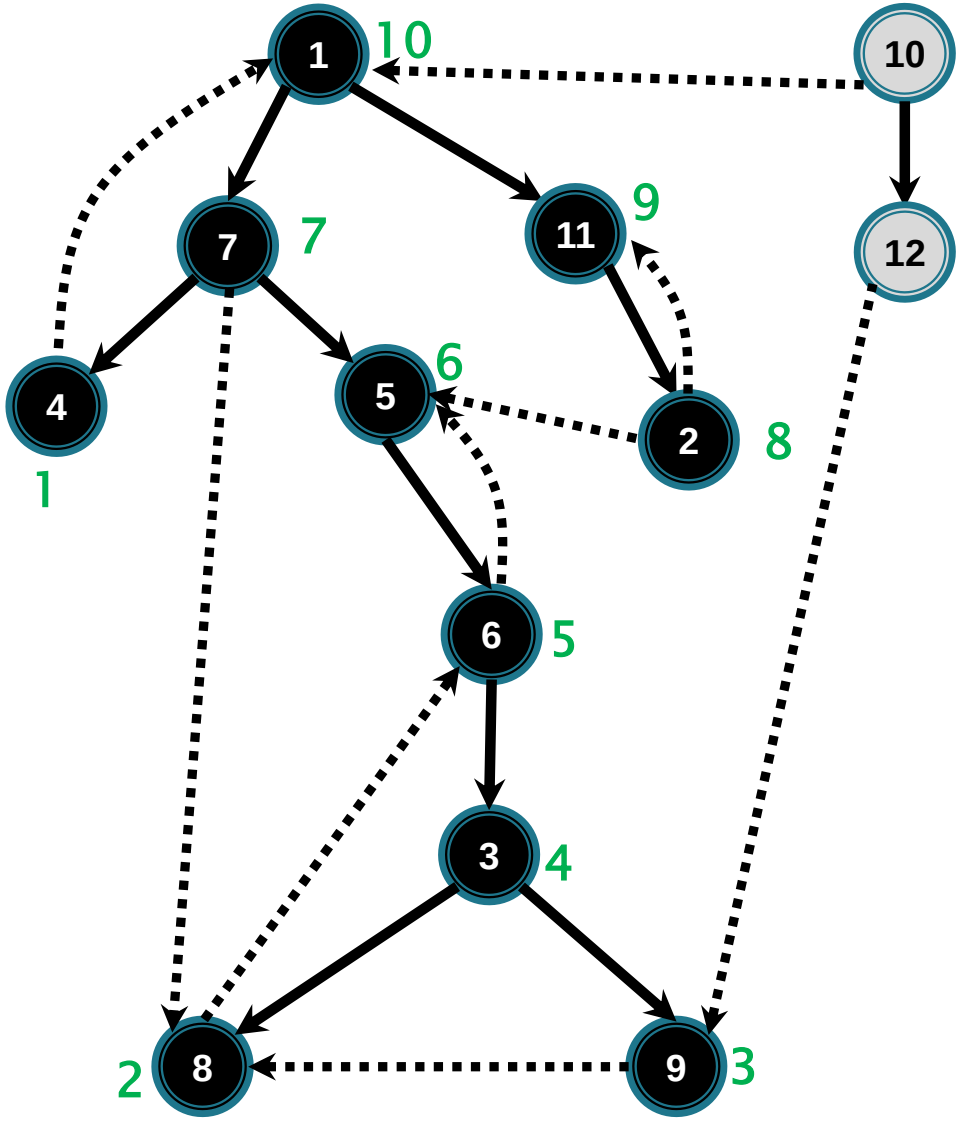
Ordinea descrescătoare finalizare: 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



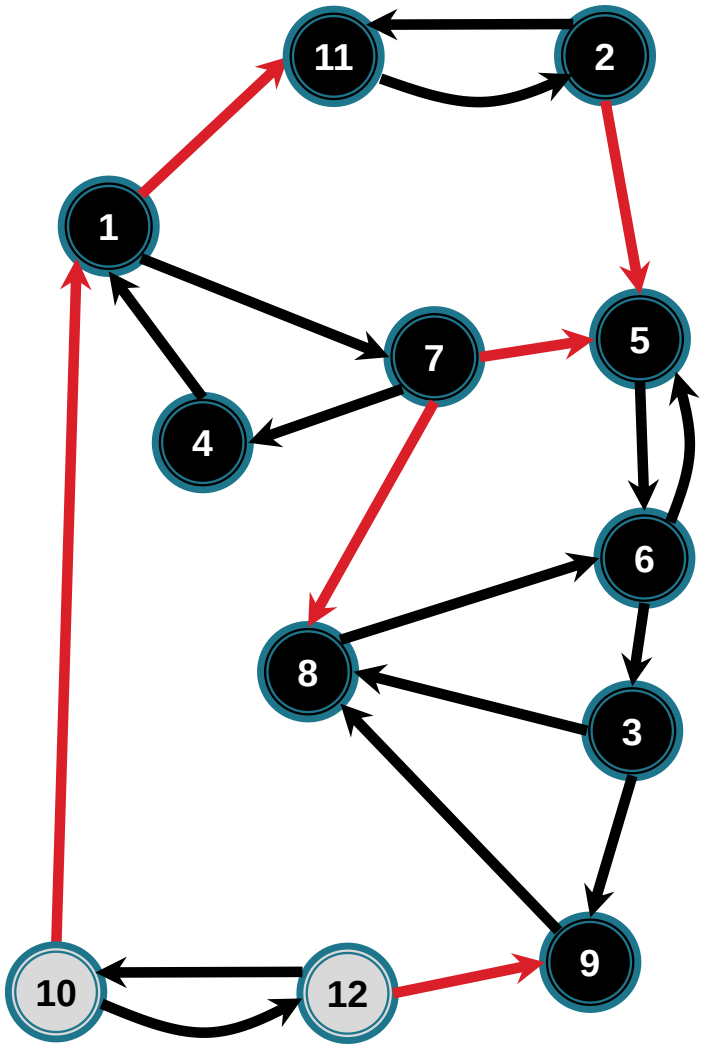
Timp de finalizare



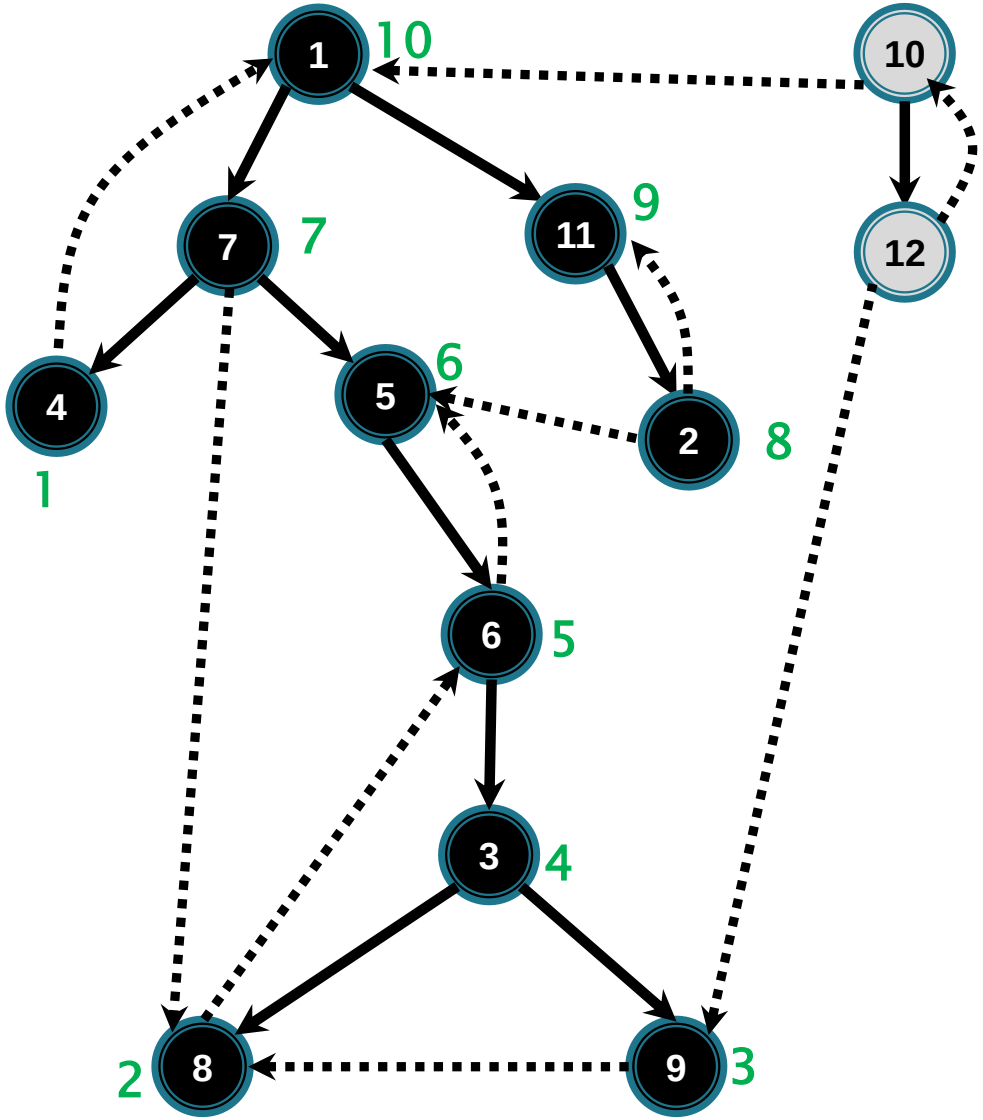
Ordinea descrescătoare finalizare: 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



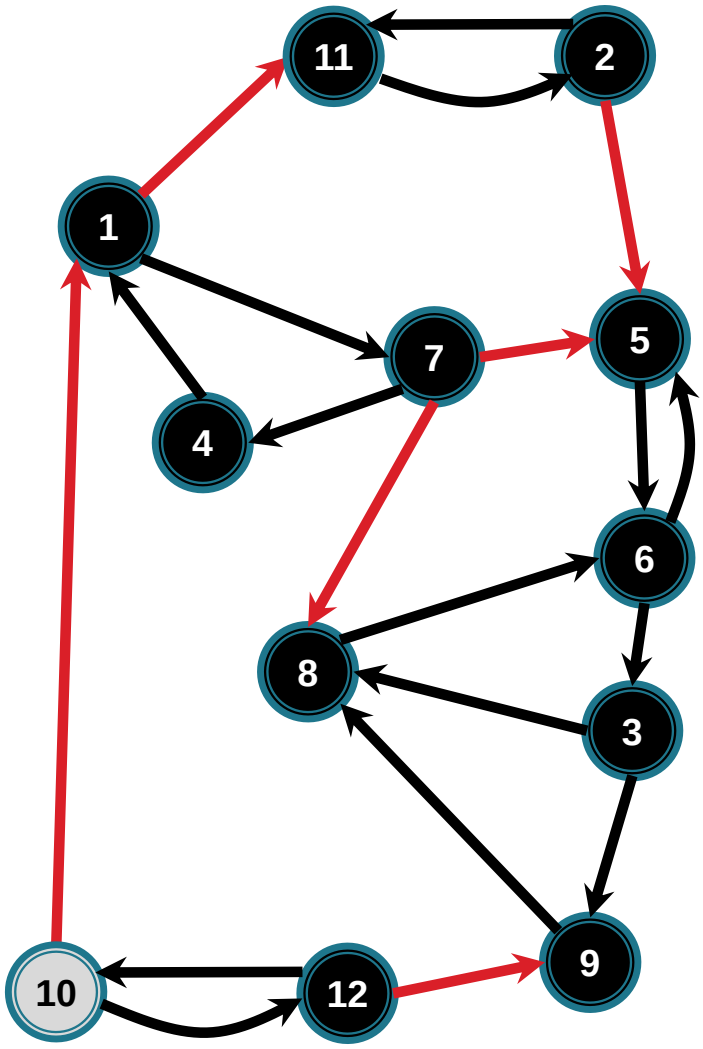
Timp de finalizare



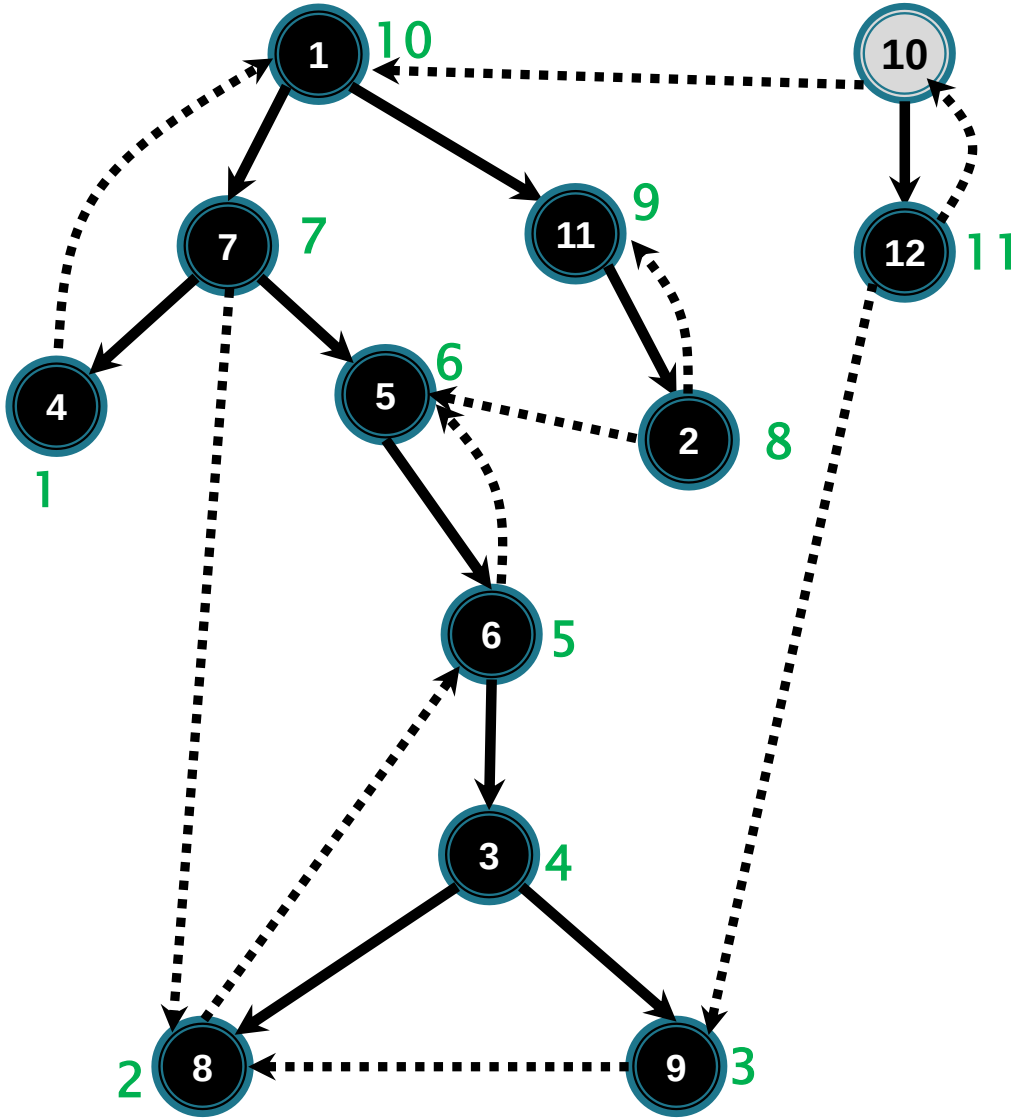
Ordinea descrescătoare finalizare: 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.



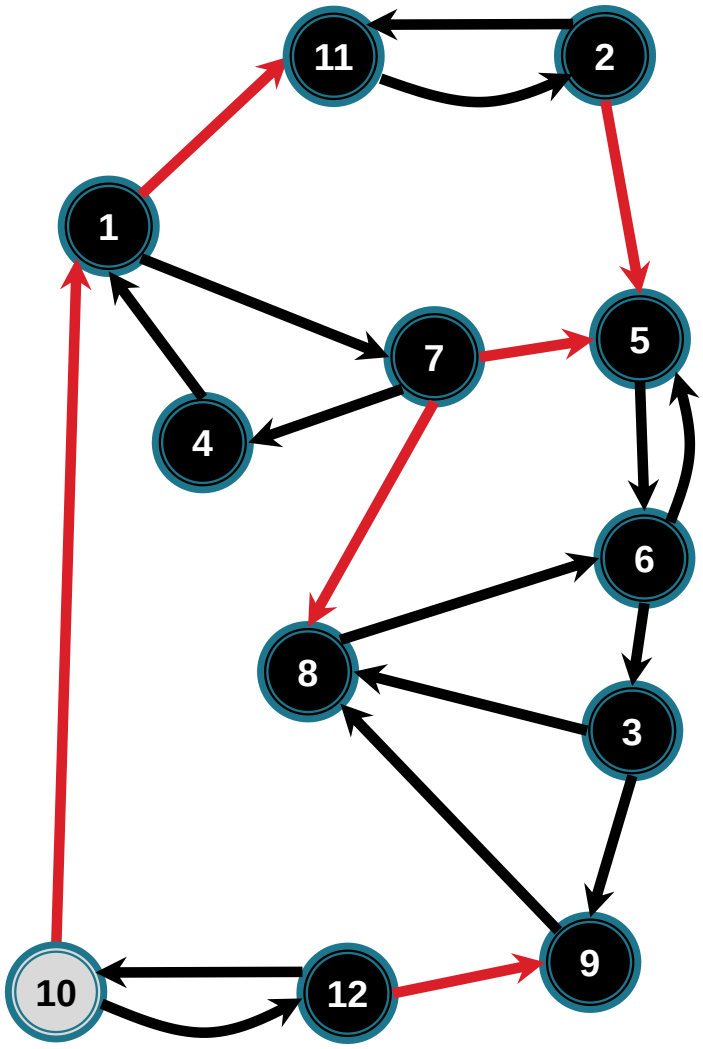
Timp de finalizare



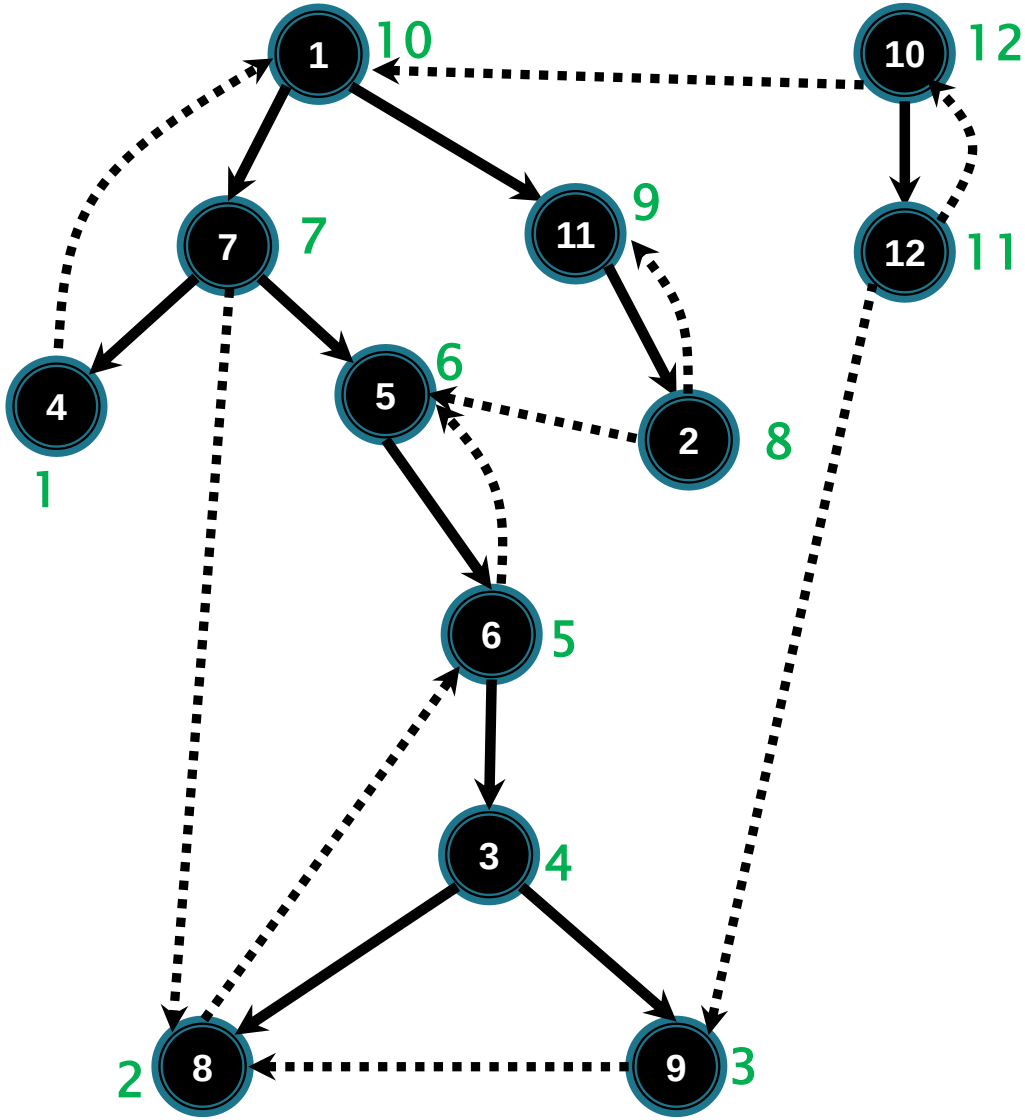
Ordinea descrescătoare finalizare: 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 1.

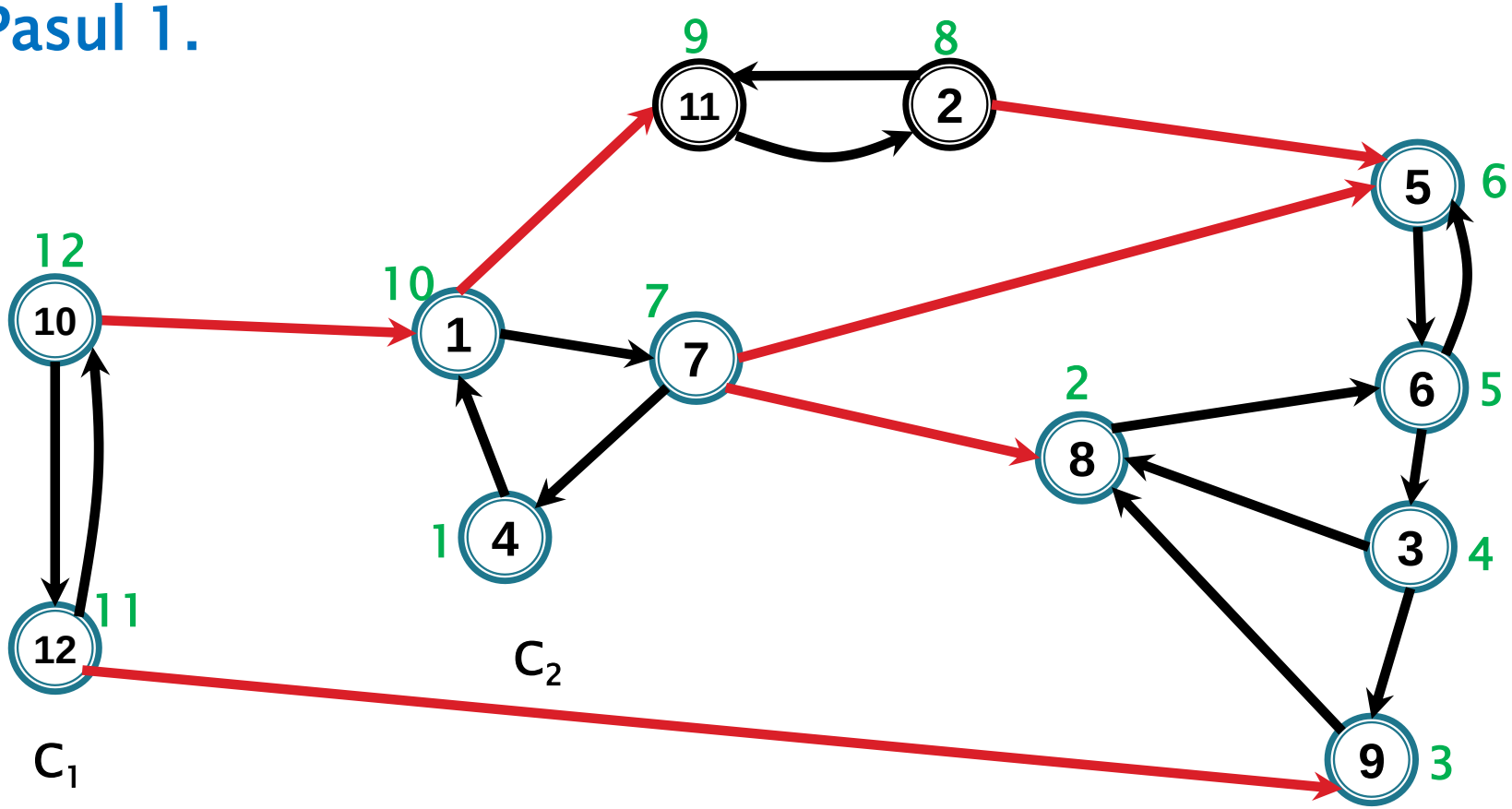


Timp de finalizare



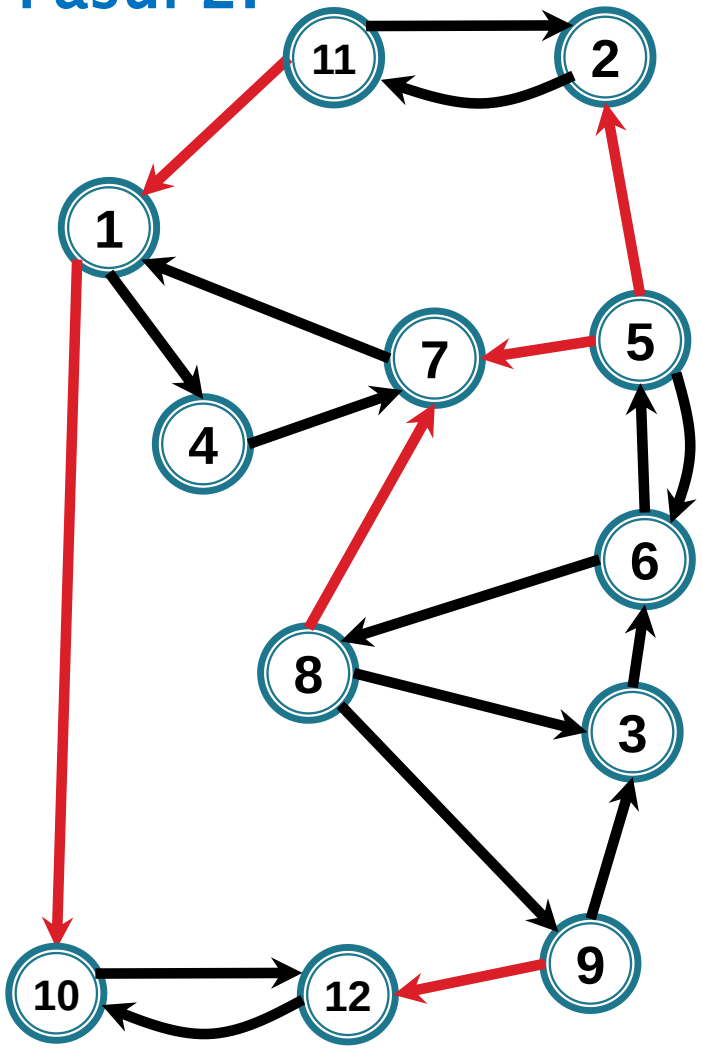
Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Pasul 1.



Algoritmul lui Kosaraju

Pasul 2.

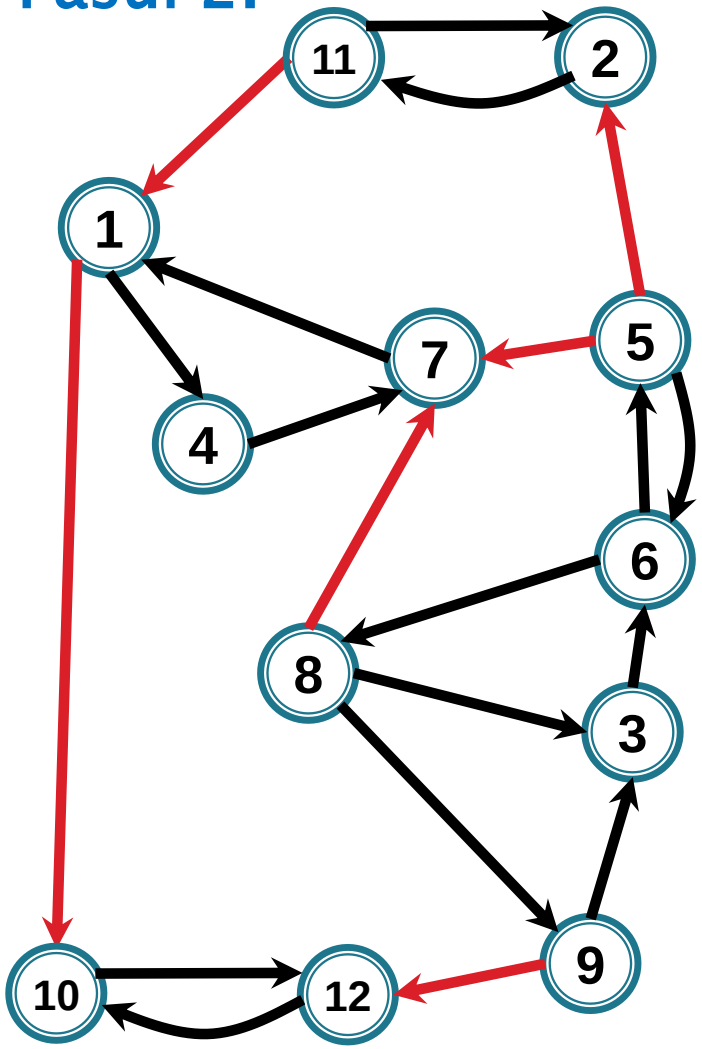


G^T

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

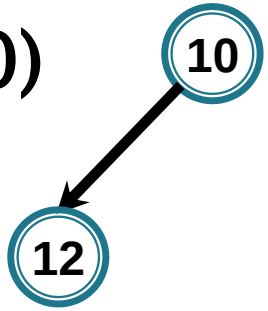
Algoritmul lui Kosaraju

Pasul 2.



G^T

DFS(10)

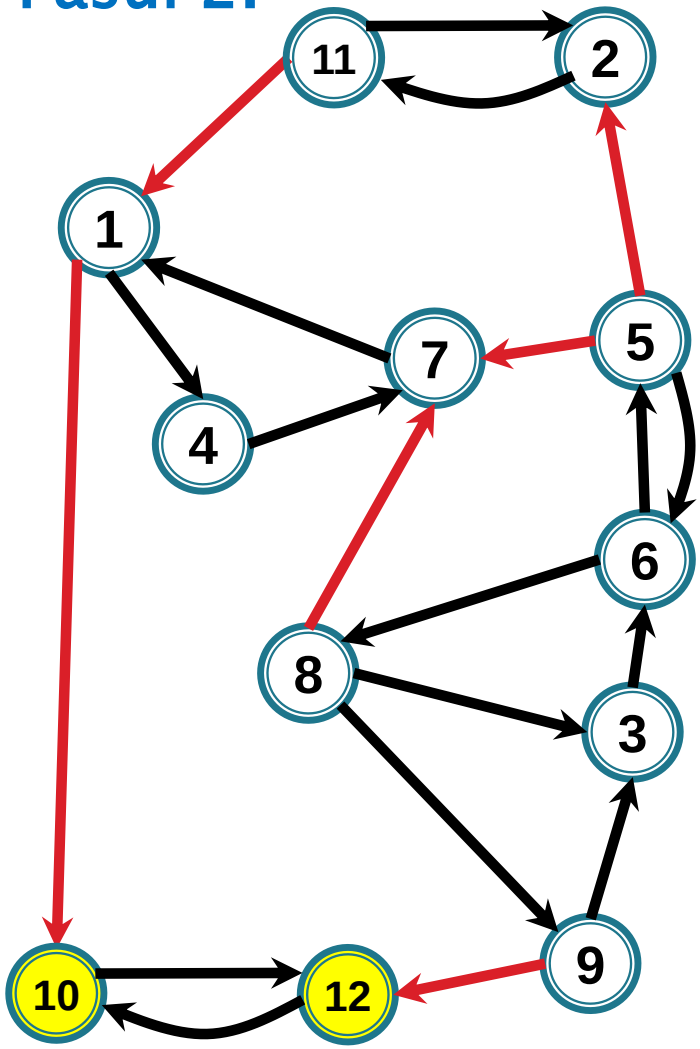


Componenta tare conexă: 10, 12

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 2.

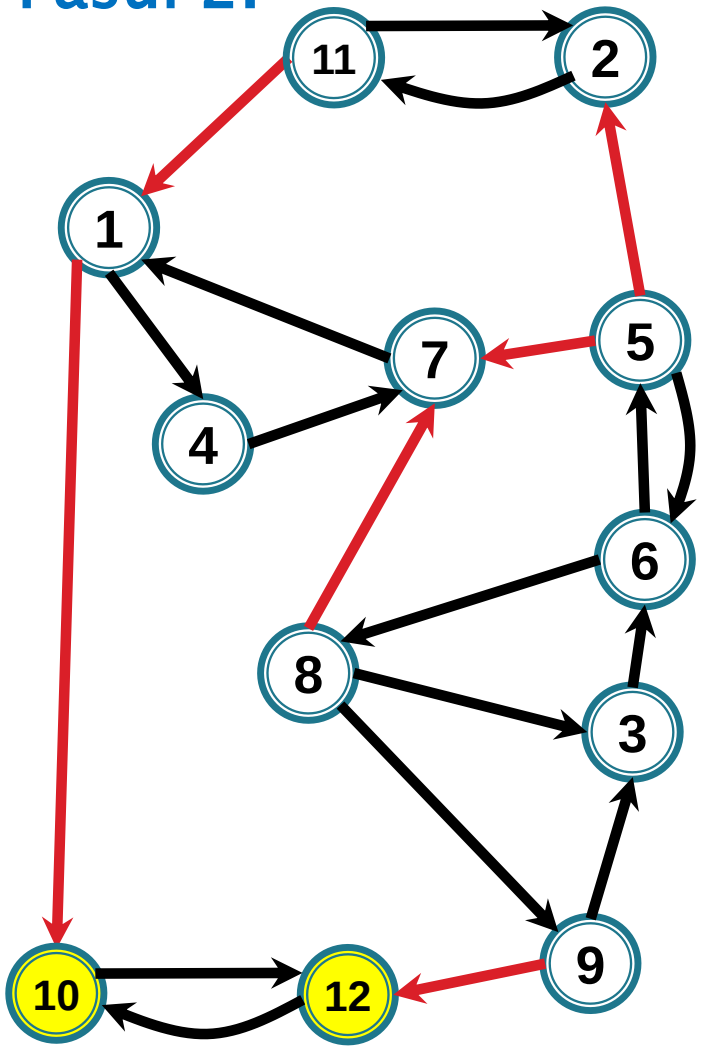


G^T

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

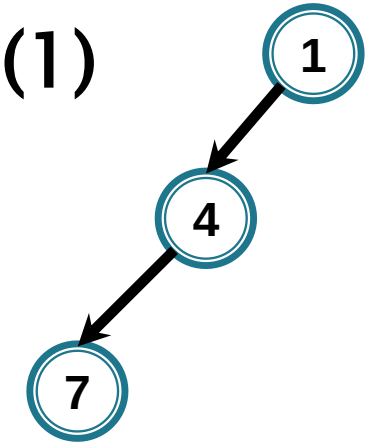
Algoritmul lui Kosaraju

Pasul 2.



G^T

DFS(1)

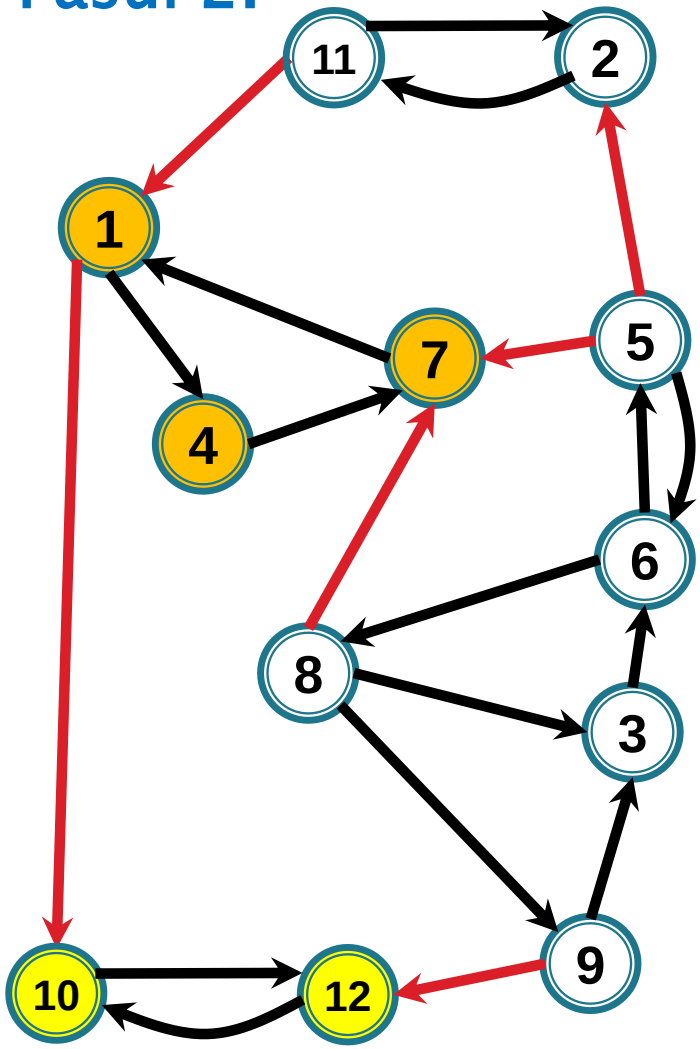


Componenta tare conexă: 1,4,7

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 2.

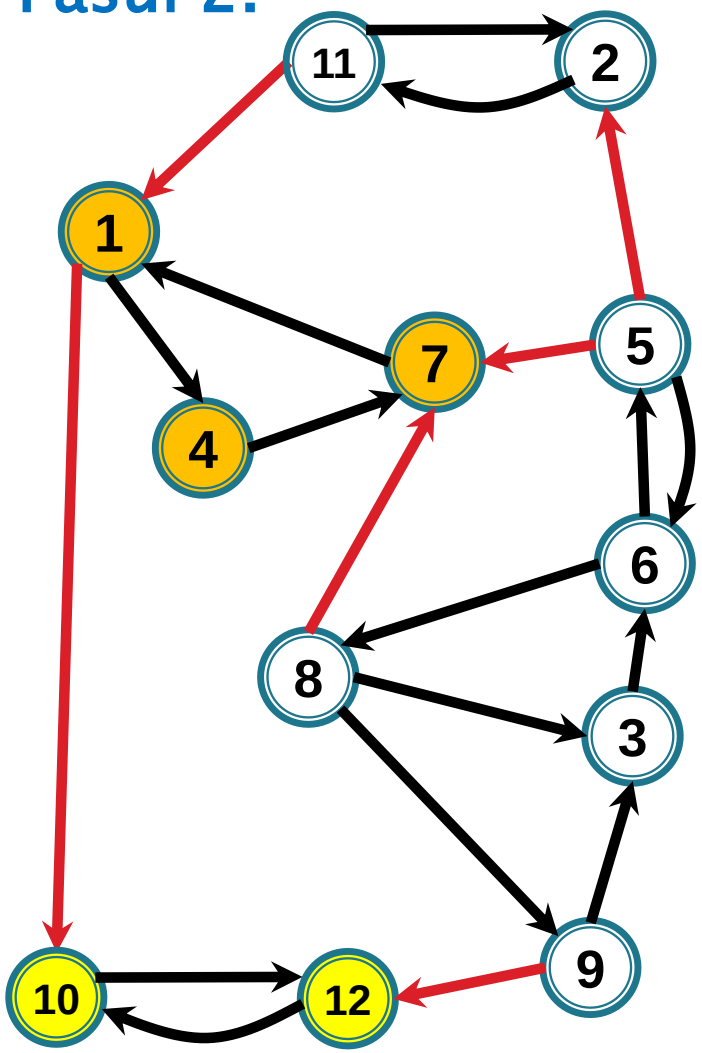


G^T

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 2.



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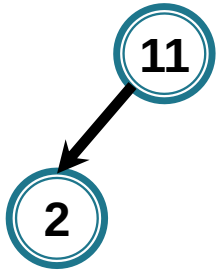
DFS(11)

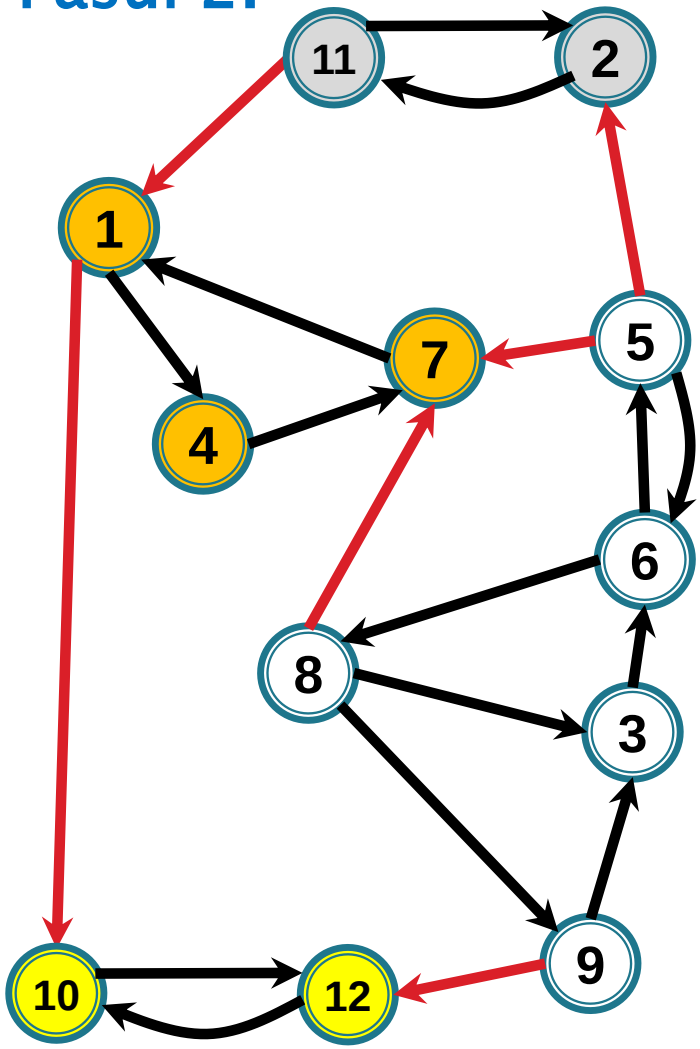


Componenta tare conexă: 11, 2

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 2.

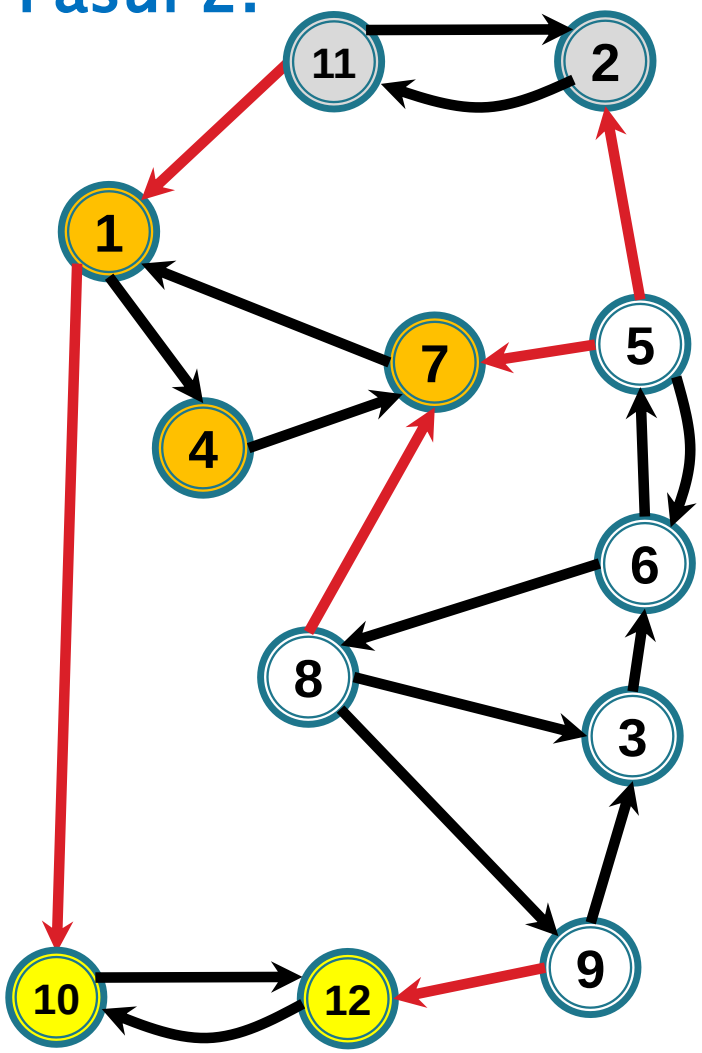


G^T

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 2.



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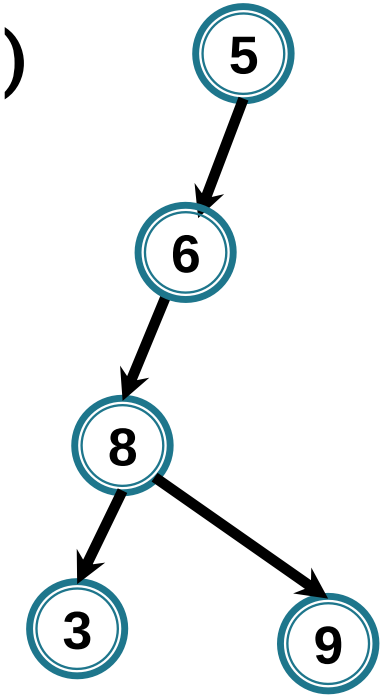
DFS(5)

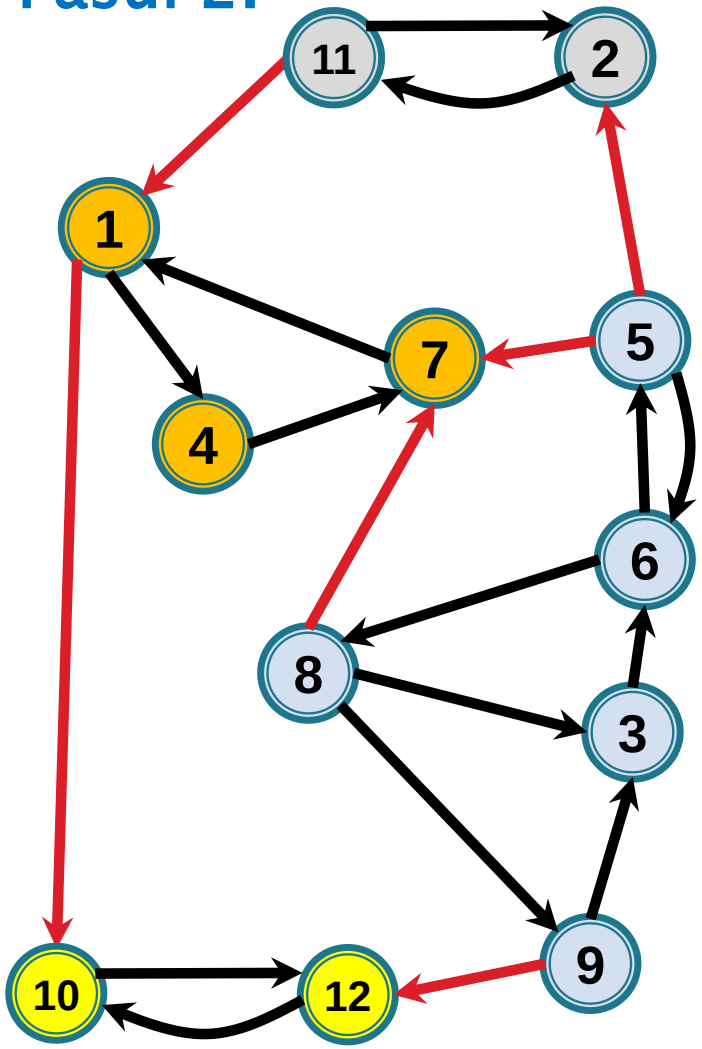


Componenta tare conexă: 5, 6, 8, 3, 9

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Algoritmul lui Kosaraju

Pasul 2.

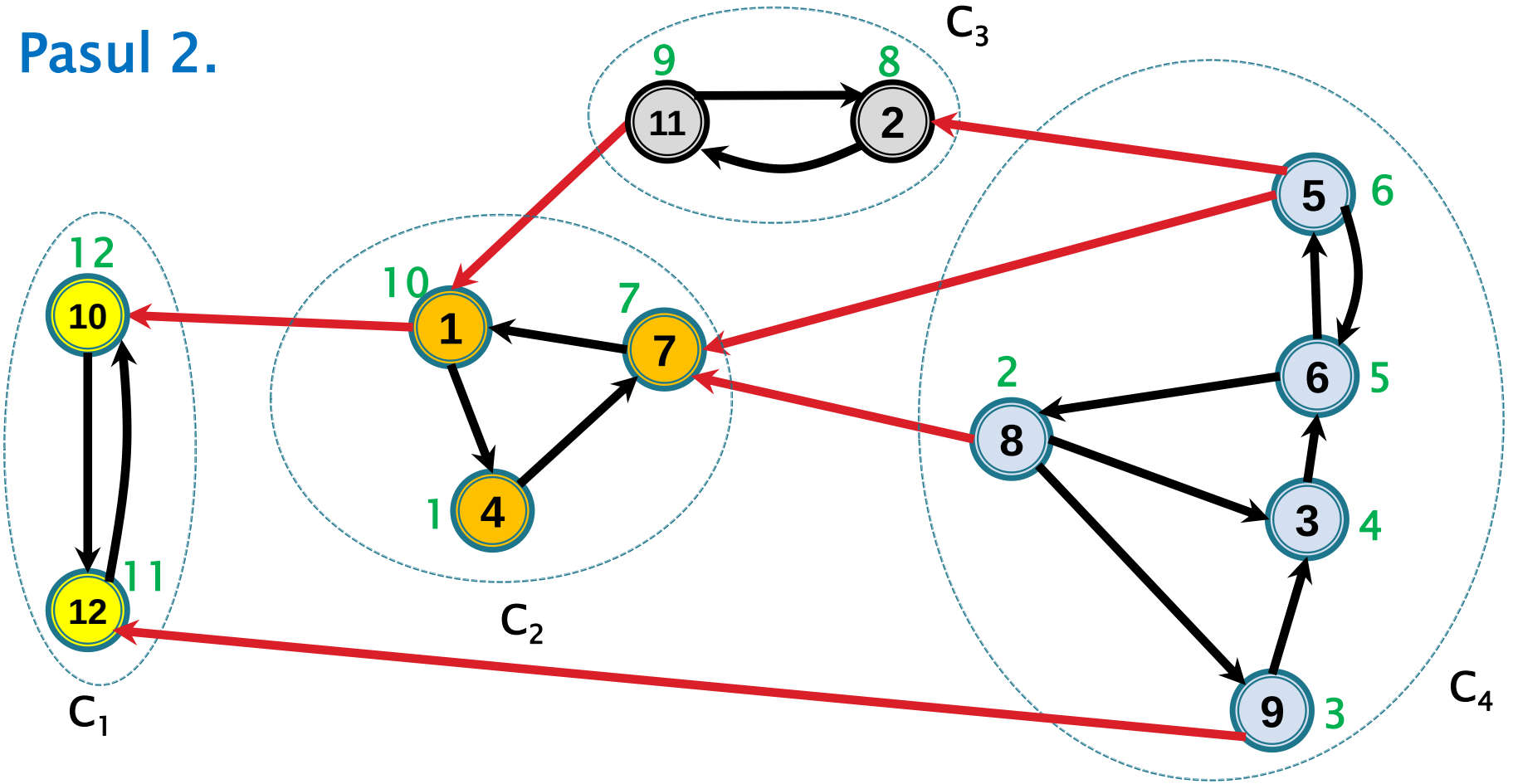


G^T

Componenta tare conexă: 5, 6, 8, 3, 9

Ordinea descrescătoare finalizare: 10, 12, 1, 11, 2, 7, 5, 6, 3, 9, 8, 4

Pasul 2.



G^T