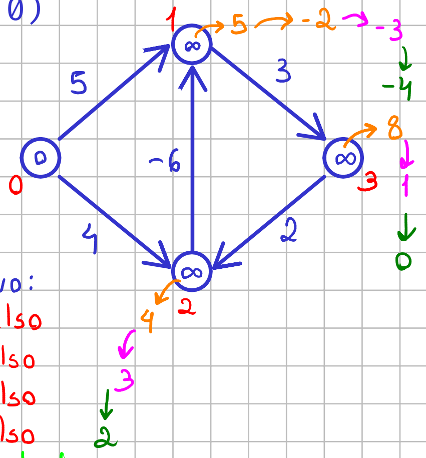
1. Belmann-Ford (verificar um ciclo negativo)
(inicio:vertice 0)
0-1:(5)
0-2:(4)
1-3:(3)
2-1:(-6)
3-2:(2)



Iterações	v[0]	v[1]	v[2]	v[3]
	0	∞	∞	∞
1	0	5 -2	4	8
2	0	-2 -3	4 3	1
3	0	-3 -4	2	0

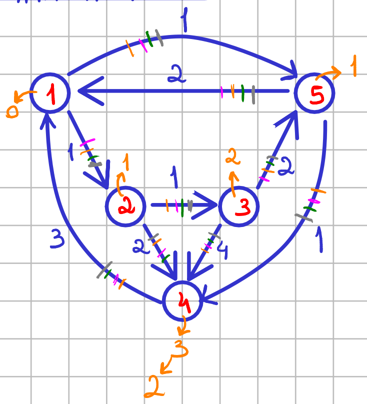
Teste Ciclo negativo:

1. -4 > 0 + 5 Falso
   -4 > 2 - 6 Falso
2. 2 > 0 + 4 Falso
   2 > 0 + 2 Falso
3. 0 > -4 + 3 Verdade

↳ Logo, há ciclo negativo

2. Algoritmos de Belmann-Ford e Floyd-Warshall
(inicio: vertice 1)
1-5:(1)
1-2:(1)
2-3:(1)
2-4:(2)
3-4:(4)
3-5:(2)
4-1:(3)
5-1:(2)
5-4:(1)

Bellman-Ford



Iterações	v[1]	v[2]	v[3]	v[4]	v[5]
	0	∞	∞	∞	∞
1	0	1	2	3 2	1
2	0	1	2	2	1
3	0	1	2	2	1
4	0	1	2	2	1

Teste ciclo neg.:

1. 0 > 2 + 3 ✗
   0 > 1 + 2 ✗
2. 1 > 0 + 1 ✗
3. 2 > 1 + 1 ✗
4. 2 > 1 + 2 ✗
   2 > 2 + 4 ✗
   2 > 1 + 1 ✗

Floyd-Warshall

$$M^0=\begin{bmatrix}0&1&\infty&\infty&1\\\infty&0&1&2&\infty\\\infty&\infty&0&4&2\\3&\infty&\infty&0&\infty\\2&\infty&\infty&1&0\end{bmatrix}\quad \Pi^0=\begin{bmatrix}1&1&1&1&1\\2&2&2&2&2\\3&3&3&3&3\\4&4&4&4&4\\5&5&5&5&5\end{bmatrix}\rightarrow M^1=\begin{bmatrix}0&1&\infty&\infty&1\\\infty&0&1&2&\infty\\\infty&\infty&0&4&2\\3&4&\infty&0&4\\2&3&\infty&1&0\end{bmatrix}\quad \Pi^1=\begin{bmatrix}1&1&1&1&1\\2&2&2&2&2\\3&3&3&3&3\\4&1&4&4&1\\5&1&5&5&5\end{bmatrix}$$

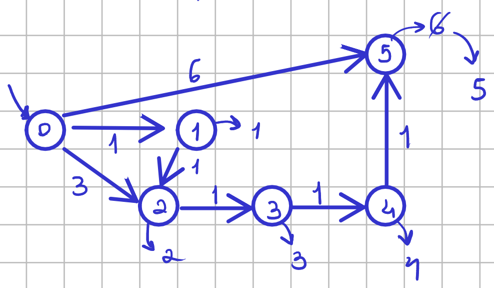
$$\rightarrow M^2=\begin{bmatrix}0&1&2&3&1\\\infty&0&1&2&\infty\\\infty&\infty&0&4&2\\3&4&5&0&4\\2&3&4&1&0\end{bmatrix}\quad \Pi^2=\begin{bmatrix}1&1&2&2&1\\2&2&2&2&2\\3&3&3&3&3\\4&1&2&4&1\\5&1&2&5&5\end{bmatrix}$$

$$\rightarrow M^3=\begin{bmatrix}0&1&2&3&1\\\infty&0&1&2&3\\\infty&\infty&0&4&2\\3&4&5&0&4\\2&3&4&1&0\end{bmatrix}\quad \Pi^3=\begin{bmatrix}1&1&2&2&1\\2&2&2&2&3\\3&3&3&3&3\\4&1&2&4&1\\5&1&2&5&5\end{bmatrix}\rightarrow M^4=\begin{bmatrix}0&1&2&3&1\\5&0&1&2&3\\7&8&0&4&2\\3&4&5&0&4\\2&3&4&1&0\end{bmatrix}\quad \Pi^4=\begin{bmatrix}1&1&2&2&1\\4&2&2&2&3\\4&4&3&3&3\\4&1&2&4&1\\5&1&2&5&5\end{bmatrix}$$

$$\rightarrow M^5=\begin{bmatrix}0&1&2&2&1\\5&0&1&2&3\\4&5&0&3&2\\3&4&5&0&4\\2&3&4&1&0\end{bmatrix}\quad \Pi^5=\begin{bmatrix}1&1&2&5&1\\4&2&2&2&3\\5&1&3&5&3\\4&1&2&4&1\\5&1&2&5&5\end{bmatrix}$$

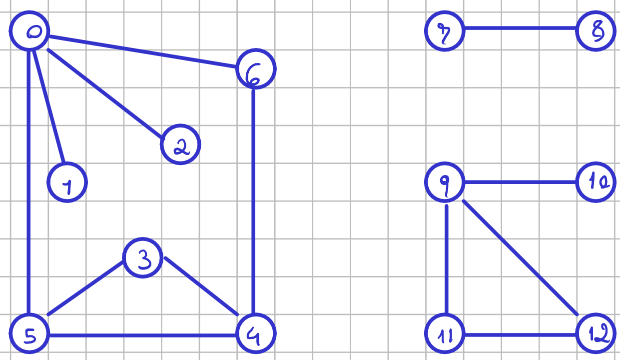
```
matriz de distância:
 [[0 1 2 2 1]
 [5 0 1 2 3]
 [4 5 0 3 2]
 [3 4 5 0 4]
 [2 3 4 1 0]]
matriz de antecessores:
 [[None 1 2 5 1]
 [4 None 2 2 3]
 [5 1 None 5 3]
 [4 1 2 None 1]
 [5 1 2 5 None]]
```

4. Algoritmo de Dijkstra
(inicio: vertice 0)
0-1:(1)
1-2:(1)
2-3:(1)
3-4:(1)
4-5:(1)
0-2:(3)
0-5:(6)



S	0	1	2	3	4	5
∅	0	~~∞~~	~~∞~~	~~∞~~	~~∞~~	~~∞~~
{0}		1	~~3~~			~~6~~
{0,1}			2			
{0,1,2}				3		
{0,1,2,3}					4	
{0,1,2,3,4}						5
{0,1,2,3,4,5}	0	1	2	3	4	5

Componentes conectadas

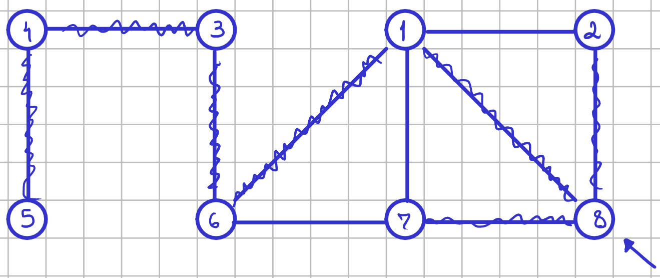


DFS(0)
marcar(0)
id[0] = 0
DFS(1)
marcar(1)
id[1] = 0
DFS(2)
marcar(2)
id[2] = 0
DFS(5)
marcar(5)
id[5] = 0
DFS(3)
marcar(3)
id[3] = 0
DFS(4)
marcar(4)
id[4] = 0
DFS(6)
marcar(6)
id[6] = 0

cont ++
DFS(7)
marcar(7)
id[7] = 1
DFS(8)
marcar(8)
id[8] = 1

cont ++
DFS(9)
marcar(9)
id[9] = 2
DFS(10)
marcar(10)
id[10] = 2
DFS(11)
marcar(11)
id[11] = 2
DFS(12)
marcar(12)
id[12] = 2

BFS



Q

~~5~~ ~~4~~ ~~3~~ ~~6~~ ~~7~~ ~~2~~ ~~1~~ ~~8~~

8
cor[8] = cinza
π[8] = Null
d[8] = 0

cor[1] = cinza
π[1] = 8
d[1] = d[8]+1 = 1

cor[2] = cinza
π[2] = 8
d[2] = d[0] + 1 = 1

cor[7] = cinza
π[7] = 8
d[7] = d[8]+1 = 1

cor[8] = preto

1 cor[6] = cinza
π[6] = 1
d[6] = d[1]+1 = 2

cor[1] = preto

2 cor[2] = preto

7 cor[7] = preto

6 cor[3] = cinza
π[3] = 6
d[3] = d[6]+1 = 3

cor[6] = preto

3 cor[4] = cinza
π[4] = 3
d[4] = d[3]+1 = 4

cor[3] = preto

4 cor[5] = cinza
π[5] = 4
d[5] = d[4]+1 = 5

cor[4] = preto

5 cor[5] = preto

Fecho Transitivo - Warshall

$W_0 = G = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$
$W_1 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
$W_2 = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
$W_3 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
$W_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$

$W_0 = G = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \end{pmatrix}$
$W_1 = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \end{bmatrix}$
$W_2 = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \end{bmatrix}$
$W_3 = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \end{bmatrix}$
$W_4 = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \end{bmatrix}$
$W_5 = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \end{bmatrix}$

Fechamento transitivo com multiplicação de matrizes

$$G = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \times \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} = G^2 = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} = G^3 = \begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} =$$

$$= G^4 = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} = G^* = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$