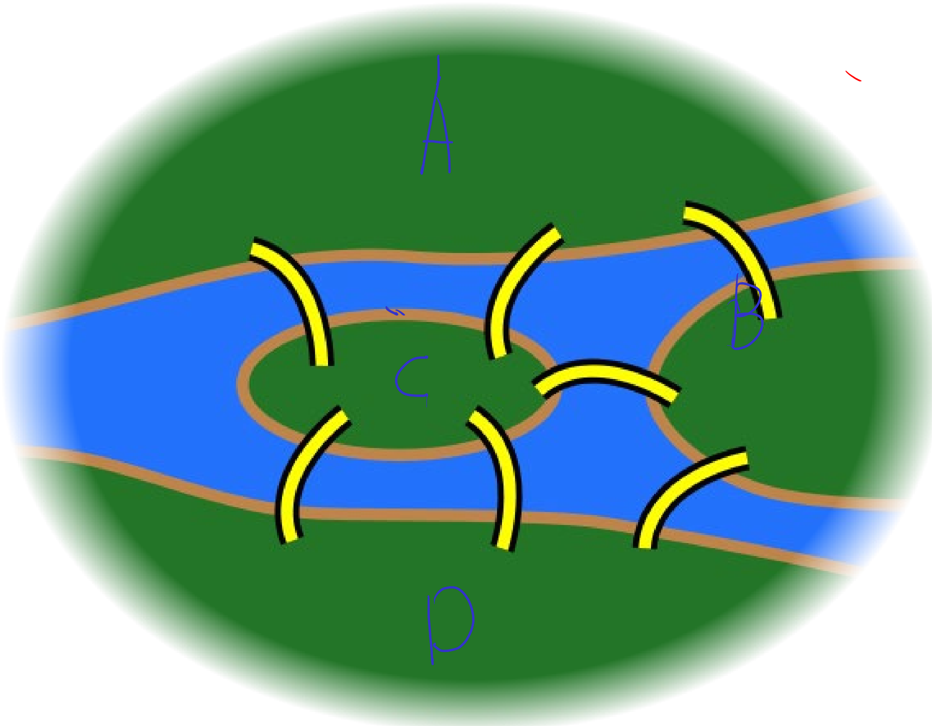
Estructuras de datos

Grafos

- Grafos
- Teorema de *Handshaking*
- Grafos completos
- Matriz de adyacencia
- Algoritmo de Warshall

Grafos

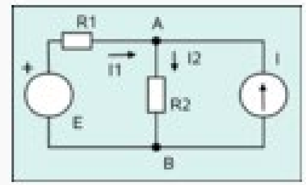


El problema de los puentes de Königsberg (Euler)

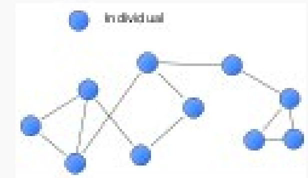
Grafos

Plano de estaciones del metro

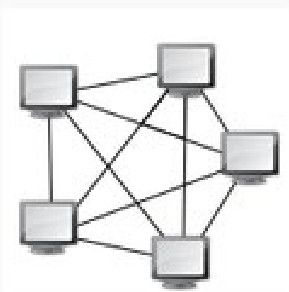
Plano de autopistas



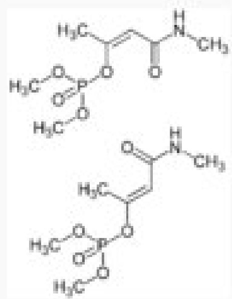
Circuitos eléctricos



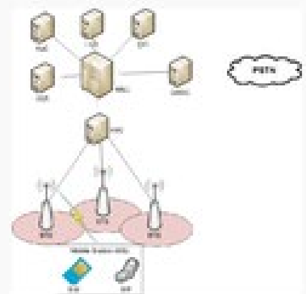
Sociograma de una red social



Topología de red de computadores



Isómeros



Redes de telefonía móvil

Draws de eliminación directa

Grafos

Un **grafo G** es un par ordenado **G=(V,E)**, donde:

- **V** es un conjunto de vértices o nodos
- **E** es un conjunto de aristas que relacionan los nodos

Grafos

Un **grafo G** es un par ordenado **G=(V,E)**, donde:

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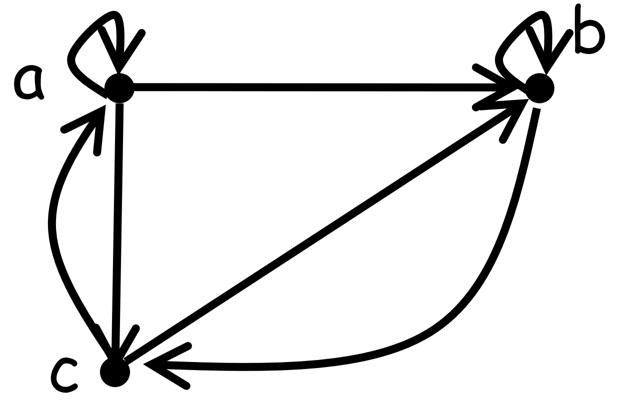
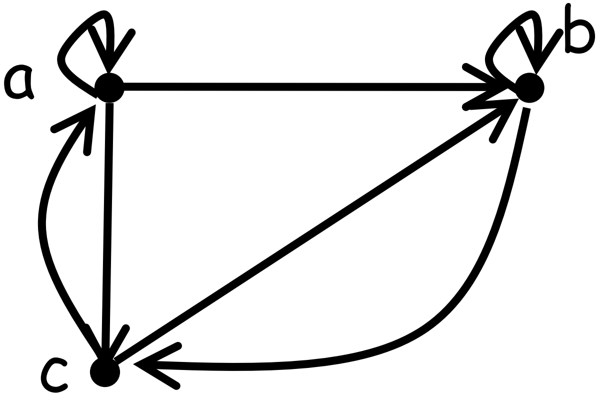
- **E** es un conjunto de aristas que relacionan los nodos



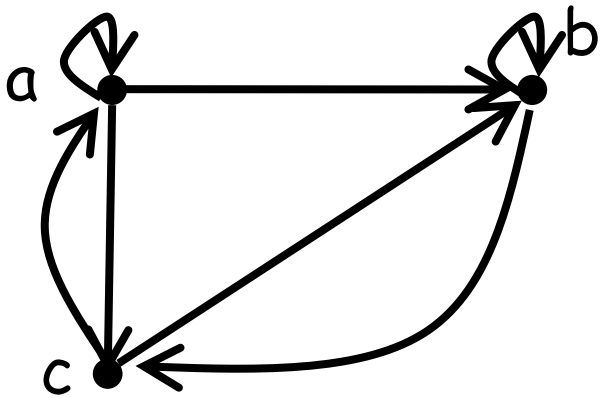
Grafos

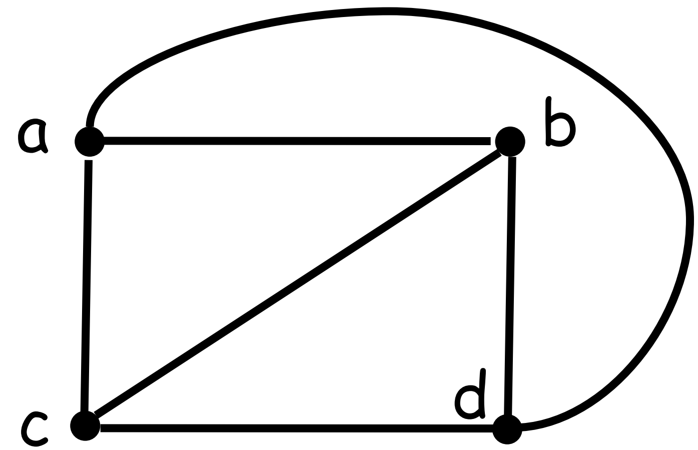
Un **grafo *G*** es un par ordenado **G=(V,E)**, donde:

- **V**={a,b,c}
- **E**={(a,a),(a,b),(a,c),(b,b),(b,c),(c,a),(c,b)}

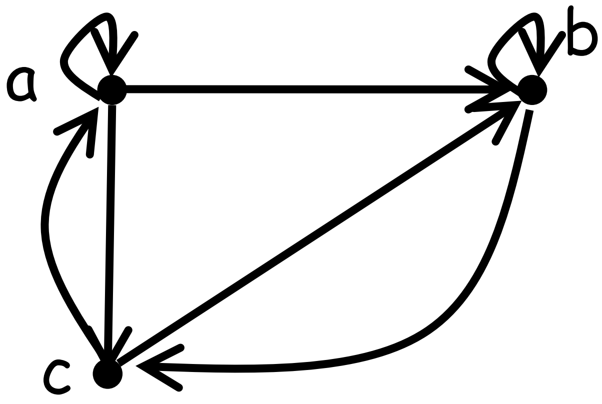


Grafos

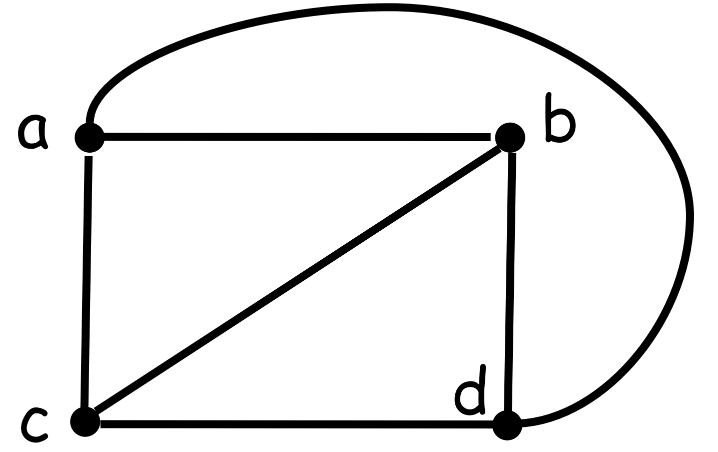




Grafos

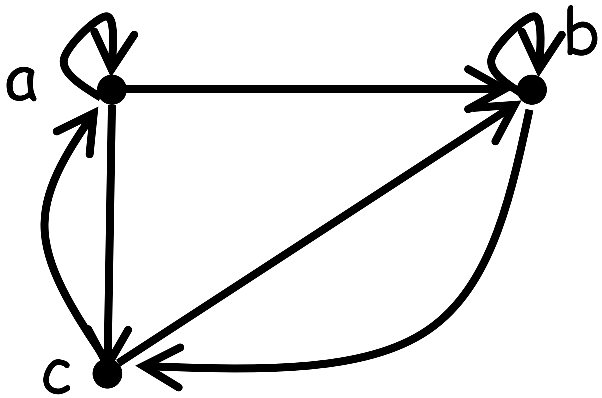


Grafo dirigido

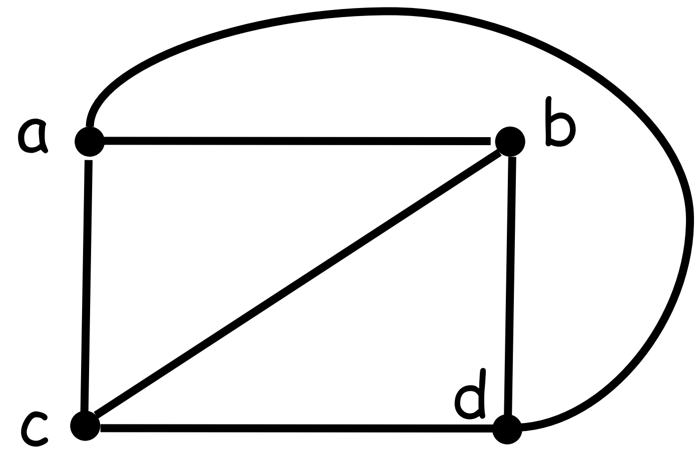


Grafo no dirigido

Grafos



Grafo dirigido



Grafo no dirigido

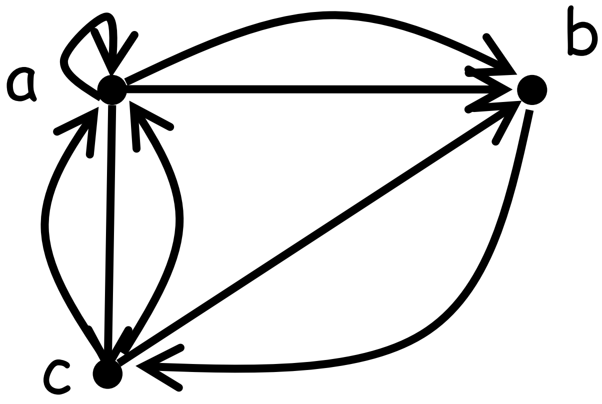
V={a,b,c}

E={(a,a),(a,b),(a,c),(b,b),(b,c),(c,a),(c,b)}

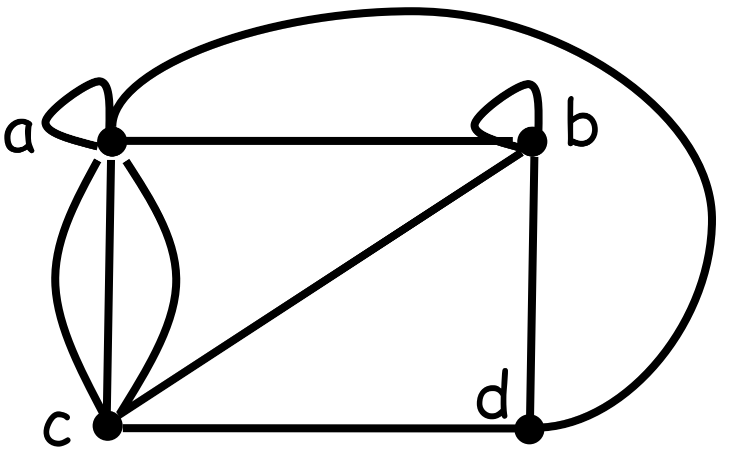
V={a,b,c}

E={{a,b},{a,c},{a,d},{b,c},{b,d},{c,d}}

Grafos

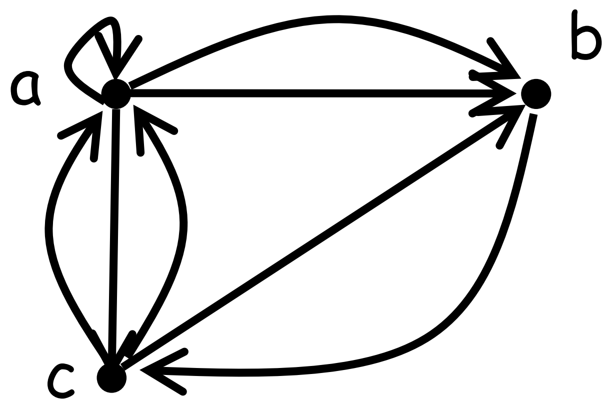


Grafo dirigido

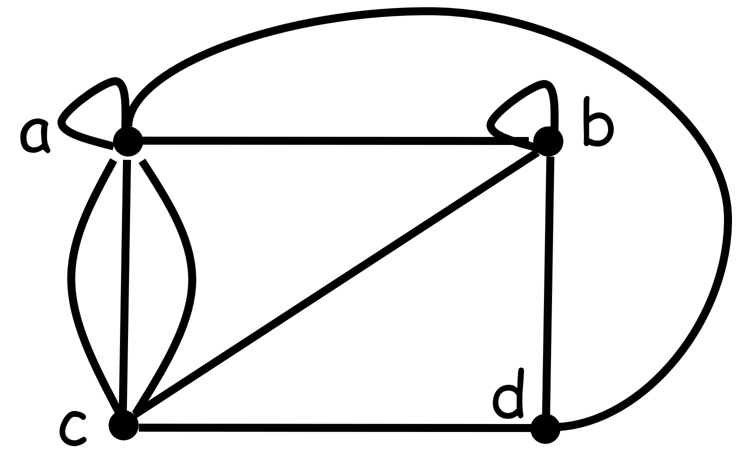


Grafo no dirigido

Grafos



Grafo dirigido

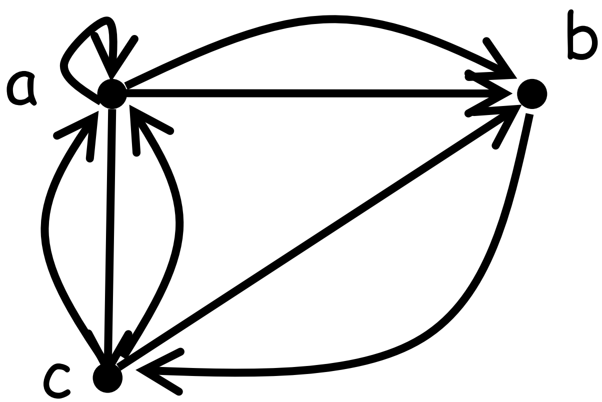


Grafo no dirigido

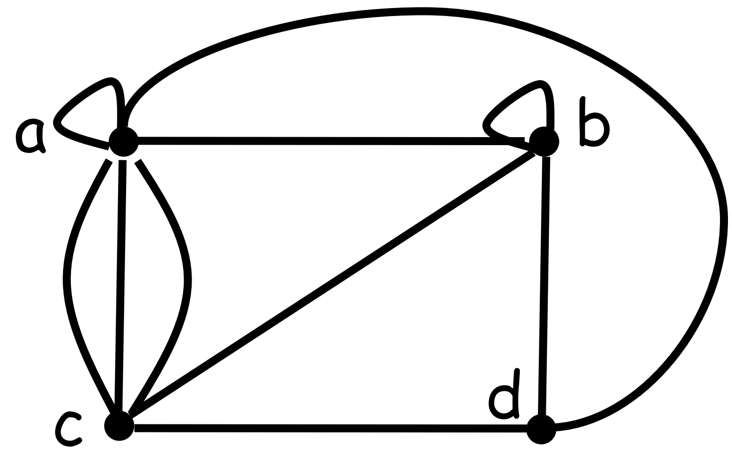
A las aristas (a,a), (c,c) se les conoce como **bucles**

A las aristas {a,a}, {b,b} se les conoce como **bucles**

Grafos



Grafo dirigido

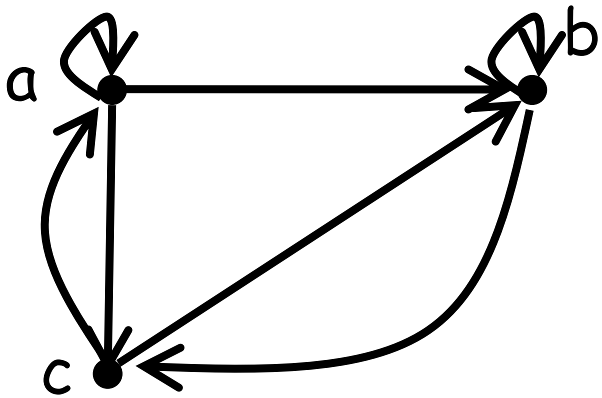


Grafo no dirigido

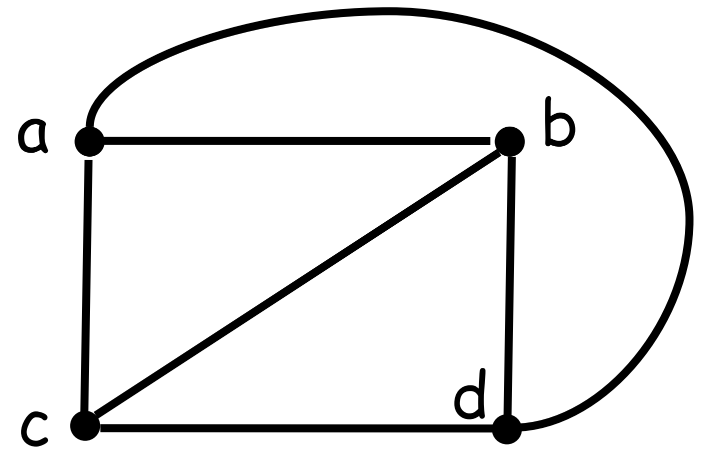
A las dos aristas que van de c hacia a se les conoce como **aristas paralelas**

A las tres aristas que relacionan los nodos a y c se les conoce como **aristas paralelas**

Grafos



Grafo dirigido

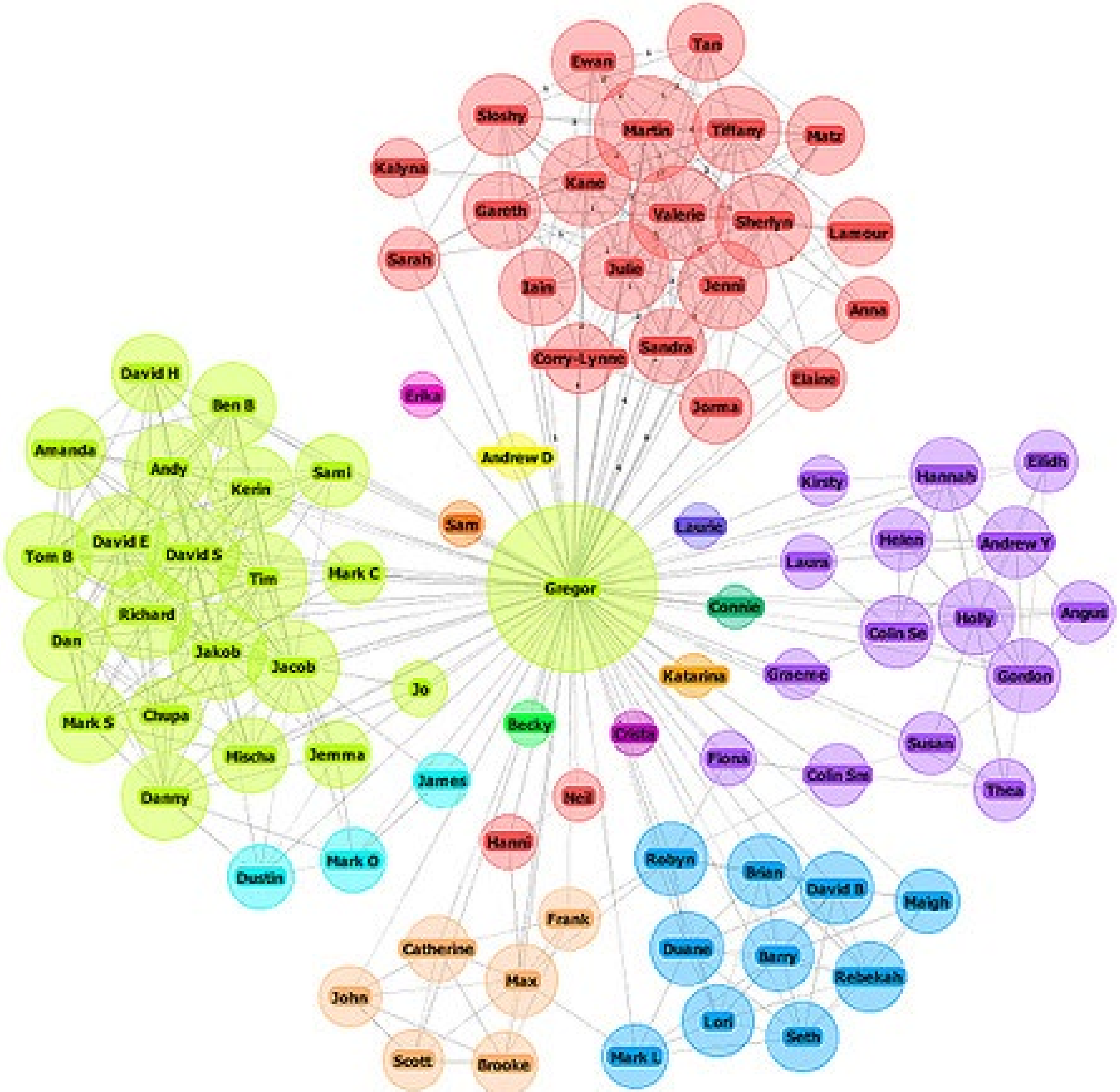


Grafo no dirigido

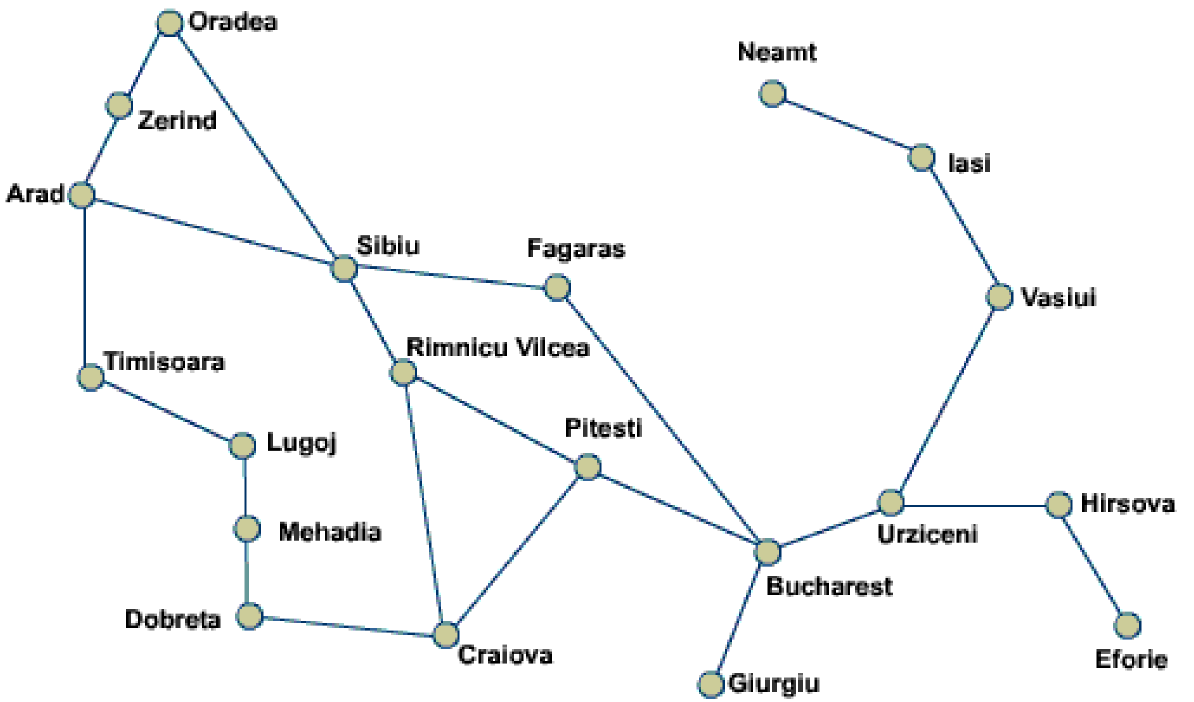
A las aristas (a,a), (b,b) y (c,c) se les conoce como **bucles**

V={a,b,c}

E={{a,b},{a,c},{a,d},{b,c},{b,d},{c,d}}

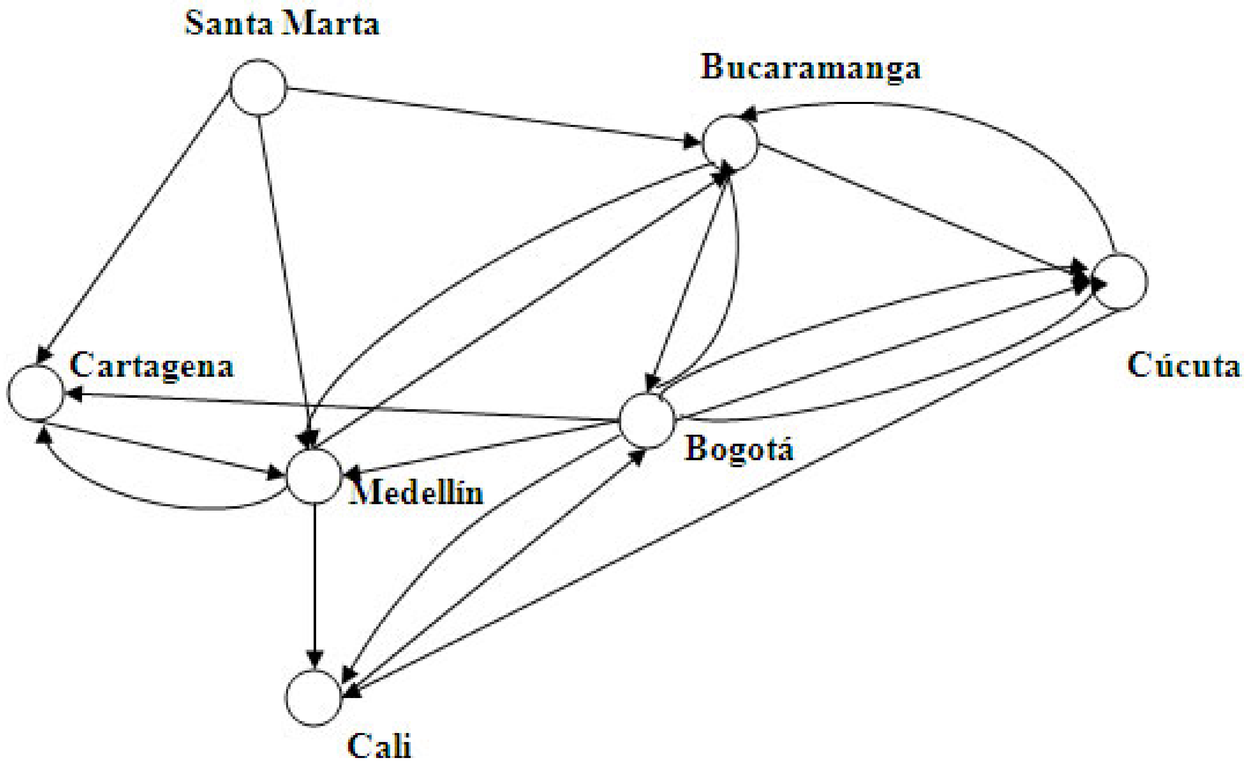

Tan
Ewan
Sloshy
Martin
Tiffany
Matz
Kalyna
Kane
Gareth
Valerie
Sherlyn
Lamour
Sarah
Julie
Iain
Jenni
Anna
Sandra
Corry-Lynne
Elaine
Jorna
David H
Ben B
Erika
Amanda
Andy
Andrew D
Sami
Kerin
Kirsty
Hannah
Eilidh
Sam
Laurie
Helen
Andrew Y
David E
David S
Tom B
Laura
Tim
Mark C
Gregor
Connie
Holly
Angus
Colin Se
Richard
Dan
Jakob
Jacob
Katarina
Graeme
Gordon
Jo
Mark S
Chupa
Becky
Susan
Mischa
Jemma
Fiona
Colin Sm
Thea
James
Neil
Danny
Hanni
Robyn
Brian
David B
Maigh
Dustin
Mark O
Frank
Catherine
Duane
Barry
Rebekah
Max
John
Lori
Seth
Scott
Brooke
Mark L

Grafos



Mapa simplificado de Rumania

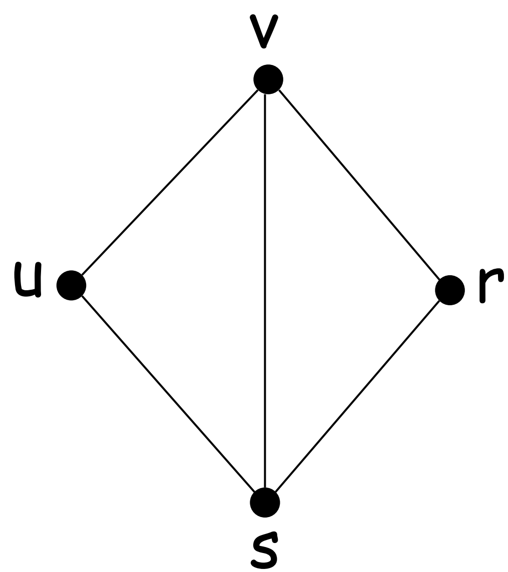
Grafos



Grafo de una red de tráfico aéreo

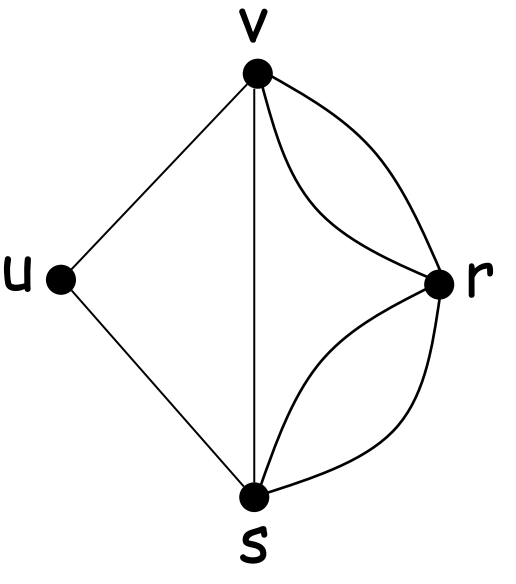
Grafo simple

Un **grafo simple** G=(V,E) es un grafo sin aristas paralelas ni bucles



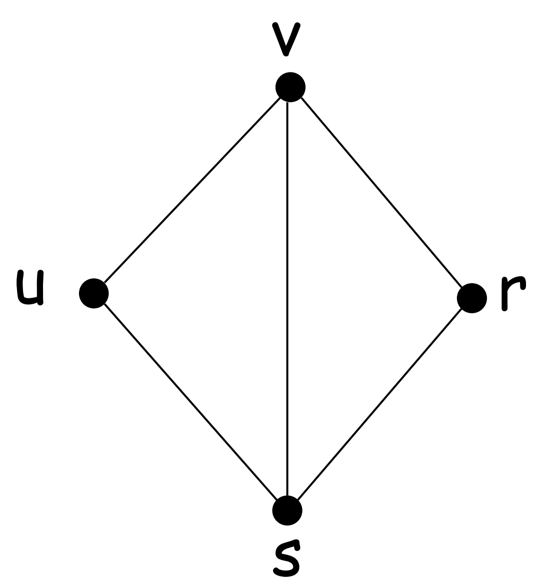
Multigrafo

Un **multigrafo** $G=(V,E)$ es un grafo con aristas paralelas



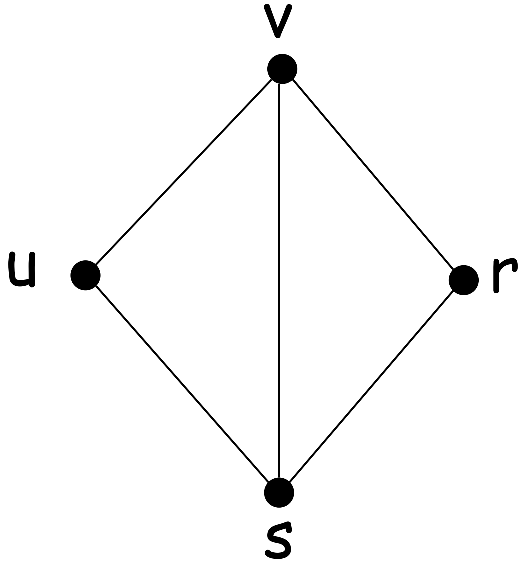
Adyacencia

Dos vértices u y v de un grafo no dirigido G son **adyacentes** si e={u,v} es una arista de G. Se dice que e es incidente con los vértices u y v



Grado de un vértice

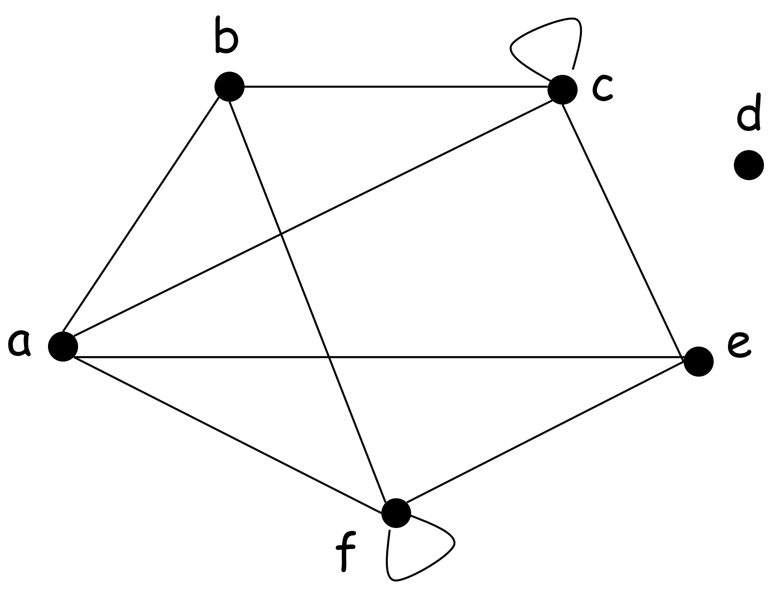
El grado de un vértice v de un grafo no dirigido es el número de aristas incidentes con él y se denota por $\delta(v)$



$\delta(u)=2$
$\delta(v)=3$
$\delta(r)=2$
$\delta(s)=3$

Grado de un vértice

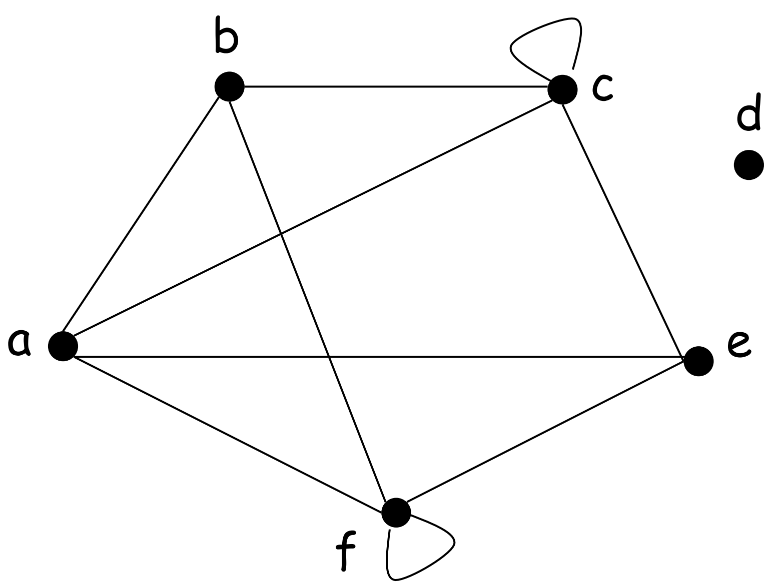
El grado de un vértice v de un grafo no dirigido es el número de aristas incidentes con él y se denota por $\delta(v)$



$\delta(a)=?$
$\delta(b)=?$
$\delta(c)=?$
$\delta(d)=?$
$\delta(e)=?$
$\delta(f)=?$

Grado de un vértice

El grado de un vértice v de un grafo no dirigido es el número de aristas incidentes con él y se denota por $\delta(v)$



$\delta(a)=4$
$\delta(b)=3$
$\delta(c)=5$
$\delta(d)=0$
$\delta(e)=3$
$\delta(f)=5$

Grafos

Teorema de *Handshaking*

Sea G=(V,E) un grafo no dirigido con **e** aristas. Se tiene que:

$$2e = \sum_{v \in V} \delta(v)$$

Grafos

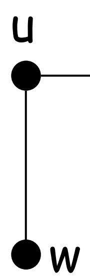
$e=1$
$\delta(u)=1$
$\delta(v)=1$

Grafos

$e=1$

$\delta(u)=1$

$\delta(v)=1$



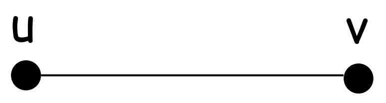
$e=2$

$\delta(u)=2$

$\delta(v)=1$

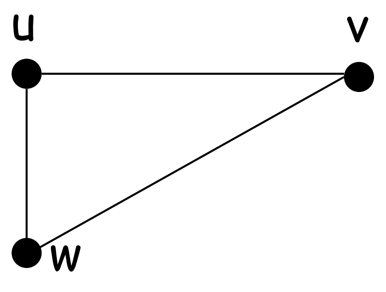
$\delta(w)=1$

Grafos



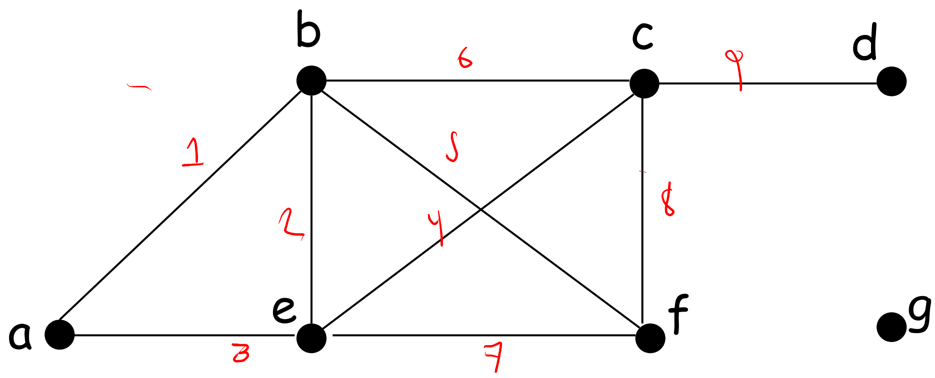
$e=1$
$\delta(u)=1$
$\delta(v)=1$

$e=2$
$\delta(u)=2$
$\delta(v)=1$
$\delta(w)=1$



$e=3$
$\delta(u)=2$
$\delta(v)=2$
$\delta(w)=2$

Grafos



e=?

δ(a)=? 2

δ(b)=? 4

δ(c)=? 4

δ(d)=? 1

δ(e)=? 4

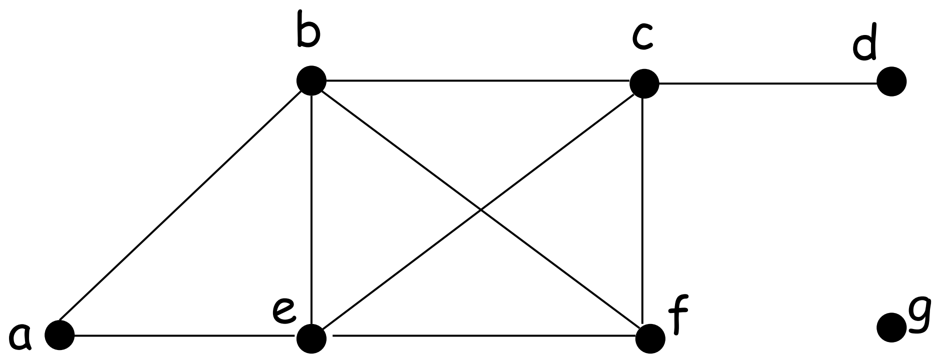
δ(f)=? 3

δ(g)=? 0

18

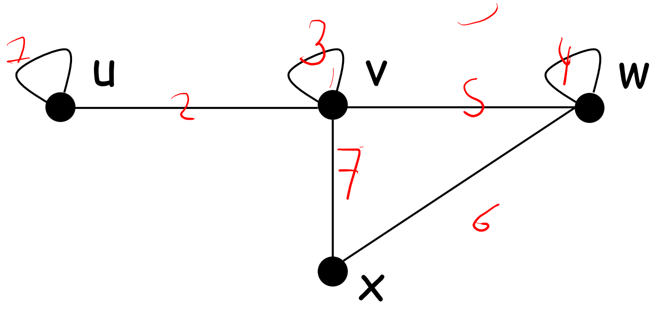
$e = \frac{18}{2} = 9$

Grafos



$e=9$
$\delta(a)=2$
$\delta(b)=4$
$\delta(c)=4$
$\delta(d)=1$
$\delta(e)=4$
$\delta(f)=3$
$\delta(g)=0$

Grafos



$e=?$

$\delta(u)=?$ 3

$\delta(v)=?$ 5

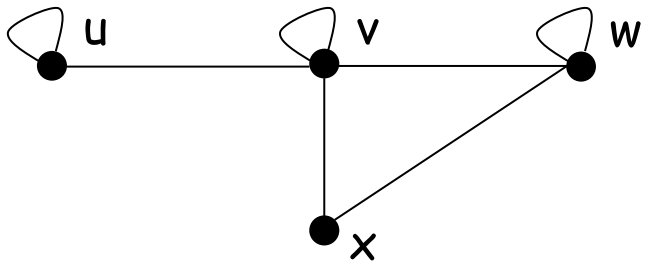
$\delta(w)=?$ 4

$\delta(x)=?$ 2

14

$e = \frac{14}{2} = 7$

Grafos



$e=7$

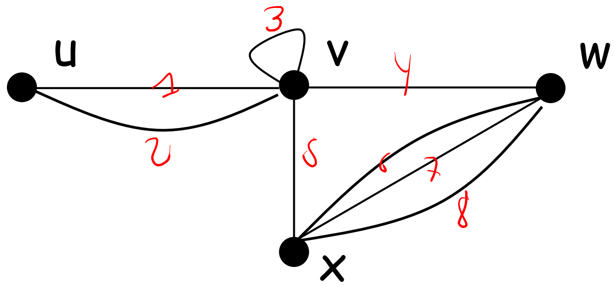
$\delta(u)=3$

$\delta(v)=5$

$\delta(w)=4$

$\delta(x)=2$

Grafos



$e=?$

$\delta(u)=?$ 2

$\delta(v)=?$ 6

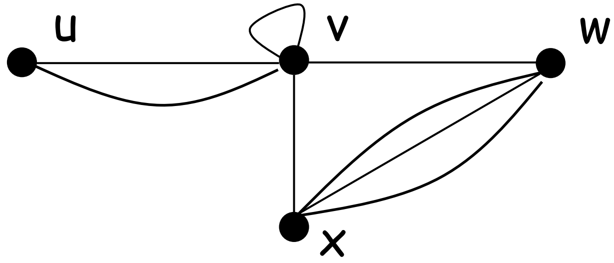
$\delta(w)=?$ 4

$\delta(x)=?$ 4

16

$e = \frac{16}{2} = 8$

Grafos



$e=8$

$\delta(u)=2$

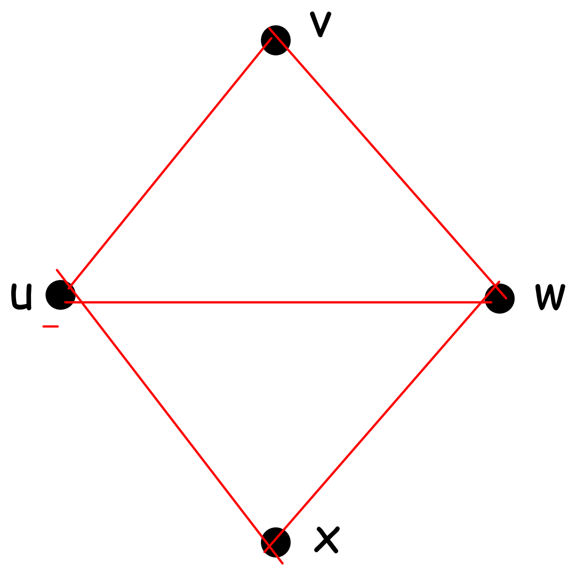
$\delta(v)=6$

$\delta(w)=4$

$\delta(x)=4$

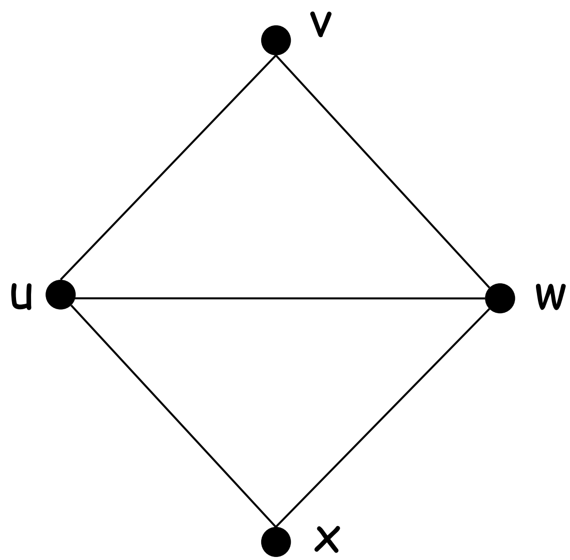
Grafos

Dibuje un grafo no dirigido con 4 vértices (u,v,w,x) cuyos grados sean $\delta(u)=3$, $\delta(v)=2$, $\delta(w)=3$, $\delta(x)=2$



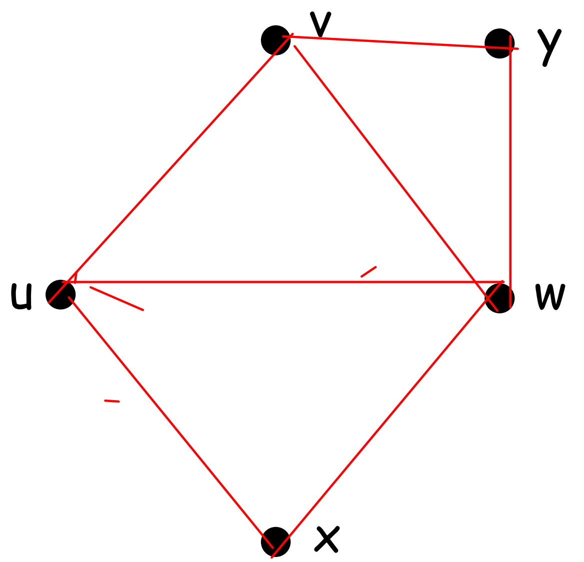
Grafos

Dibuje un grafo no dirigido con 4 vértices (u,v,w,x) cuyos grados sean $\delta(u)=3$, $\delta(v)=2$, $\delta(w)=3$, $\delta(x)=2$



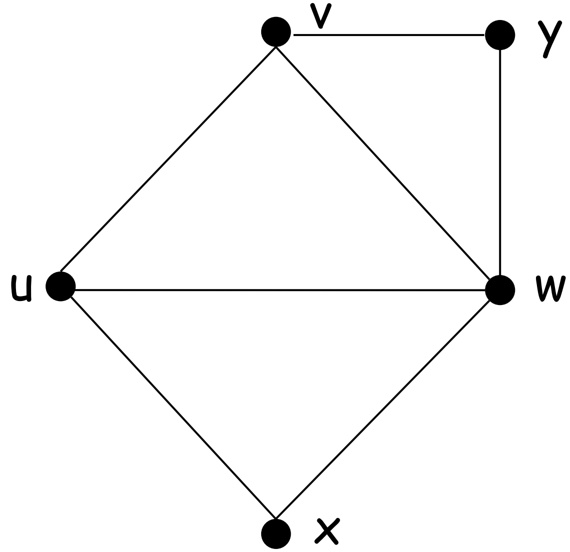
Grafos

Dibuje un grafo no dirigido con 4 vértices (u,v,w,x) cuyos grados sean $\delta(u)=3$, $\delta(v)=3$, $\delta(w)=4$, $\delta(x)=2$, $\delta(y)=2$

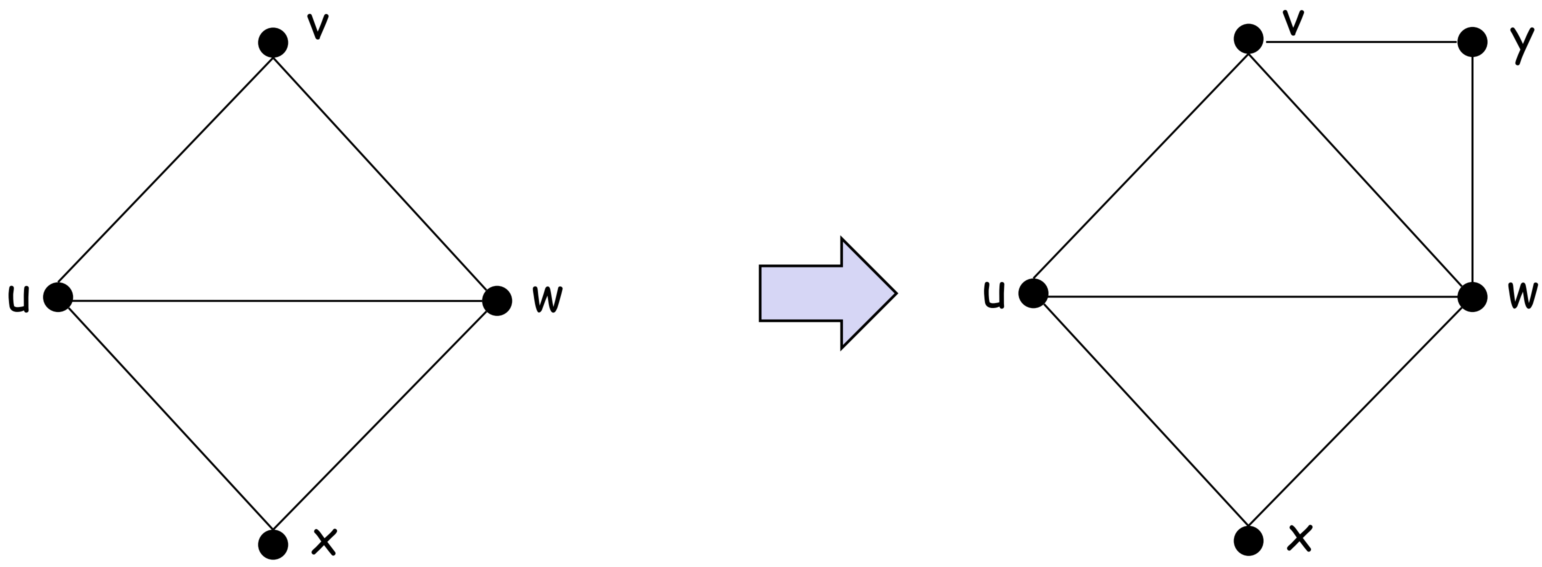


Grafos

Dibuje un grafo no dirigido con 4 vértices (u,v,w,x) cuyos grados sean $\delta(u)=3$, $\delta(v)=3$, $\delta(w)=4$, $\delta(x)=2$, $\delta(y)=2$



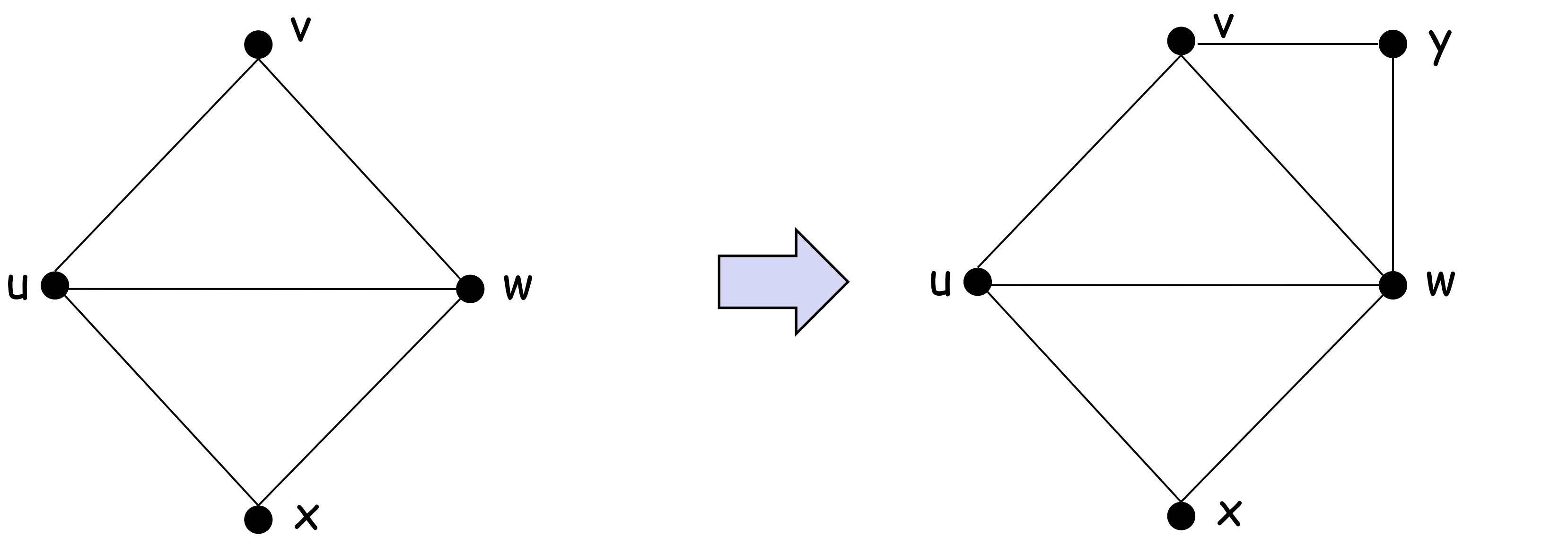
Grafos



$\delta(u)=3,\ \delta(v)=2,\ \delta(w)=3,\ \delta(x)=2$

$\delta(u)=3,\ \delta(v)=3,\ \delta(w)=4,\ \delta(x)=2,\ \delta(y)=2$

Grafos



$\delta(u)=3, \delta(v)=2, \delta(w)=3, \delta(x)=2$

$\delta(u)=3, \delta(v)=3, \delta(w)=4, \delta(x)=2, \delta(y)=2$

¿Cuántos nodos son de grado **impar**?

Grafos

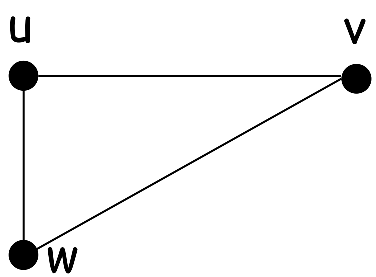
Teorema

Todo grafo no dirigido tiene un número par de vértices de grado impar

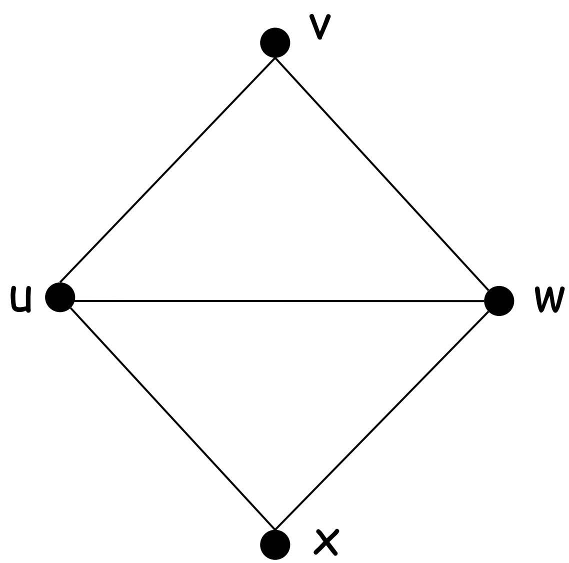
Grafos

Teorema

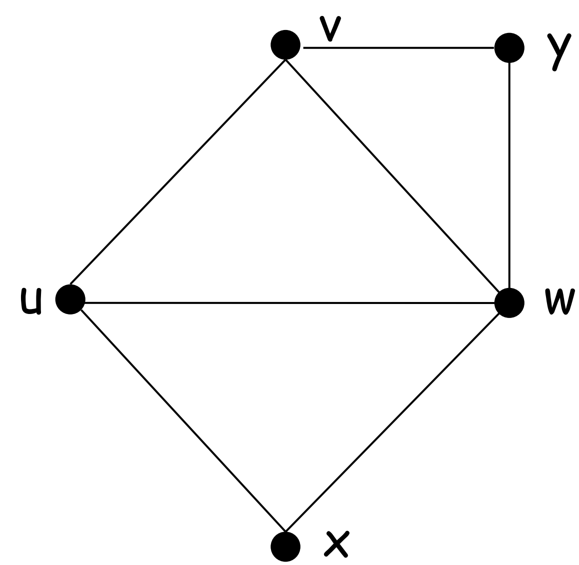
Todo grafo no dirigido tiene un número par de vértices de grado impar



$\delta(u)=2$, $\delta(v)=2$, $\delta(w)=2$



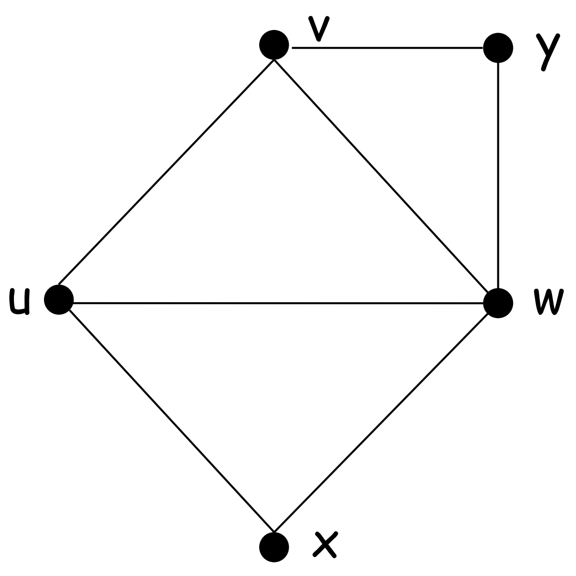
$\delta(u)=3$, $\delta(v)=2$,
$\delta(w)=3$, $\delta(x)=2$



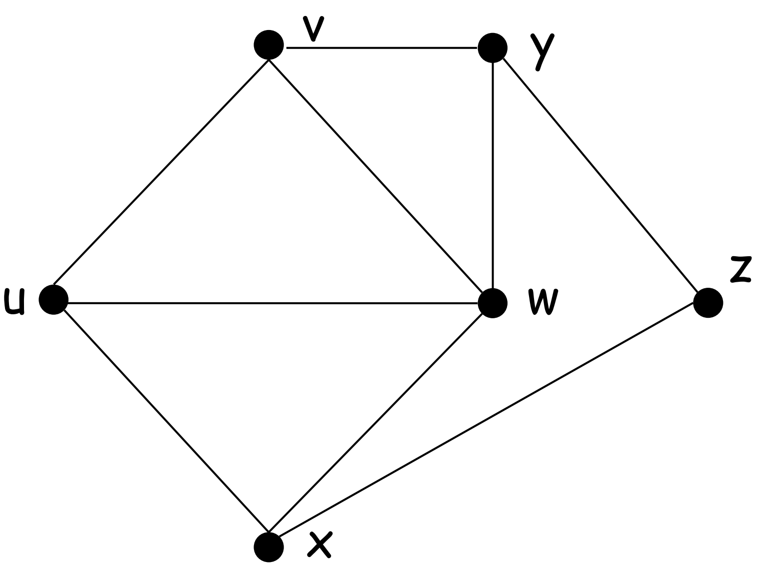
$\delta(u)=3$, $\delta(v)=3$, $\delta(w)=4$,
$\delta(x)=2$, $\delta(y)=2$

Teorema

Todo grafo no dirigido tiene un número par de vértices de grado impar



$\delta(u)=3$, $\delta(v)=3$, $\delta(w)=4$, $\delta(x)=2$, $\delta(y)=2$



$\delta(u)=3$, $\delta(v)=3$, $\delta(w)=4$, $\delta(x)=3$, $\delta(y)=3$, $\delta(z)=2$

Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

- 3, 3, 3, 3, 2
- 1, 2, 3, 4, 4
- 0, 1, 2, 2, 3
- 1, 2, 3, 4, 5
- 3, 4, 3, 4, 3
- 1, 1, 1, 1, 1

Grafos

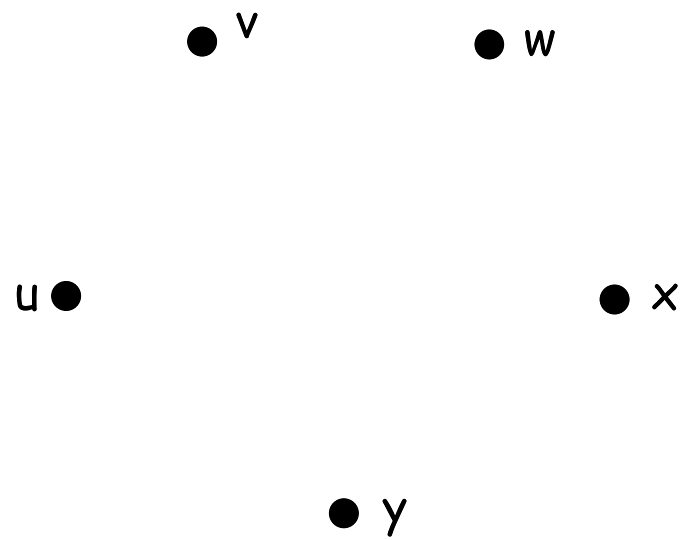
Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO

Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

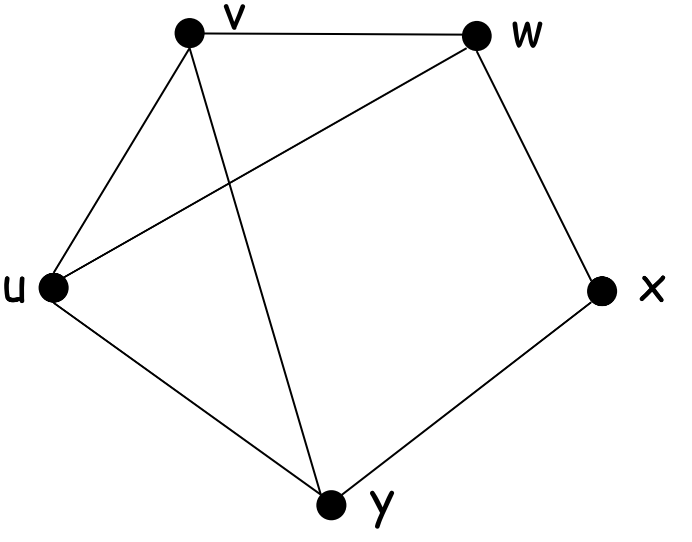
- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO



Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

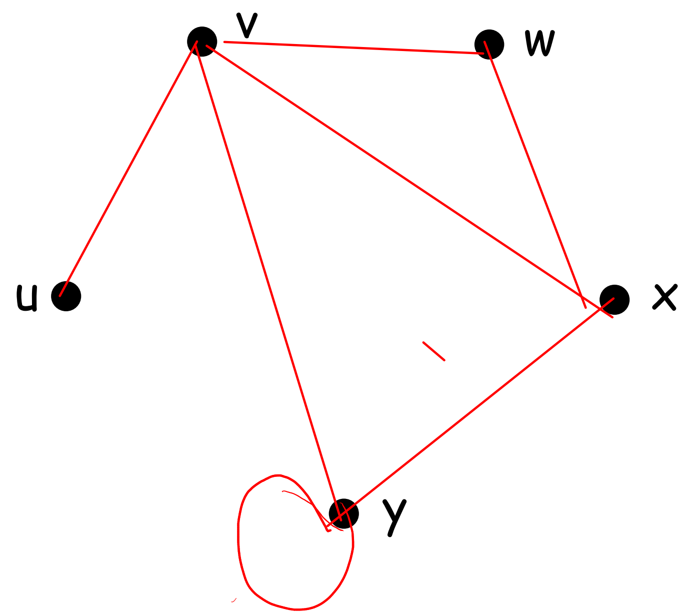
- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO



Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

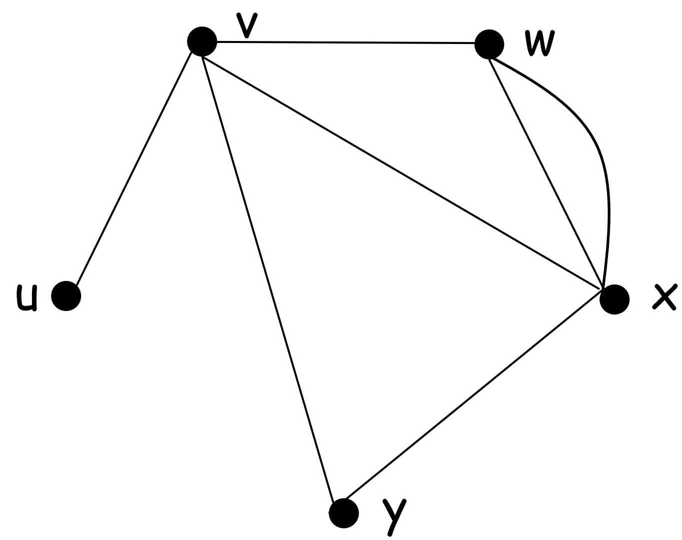
- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO



Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

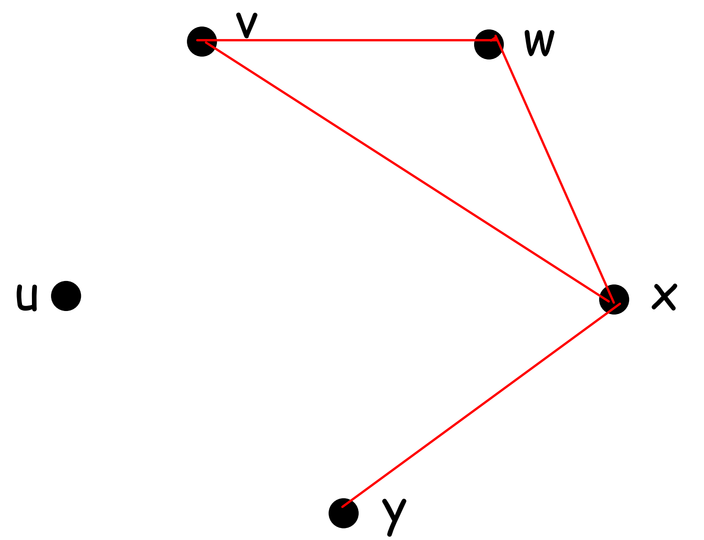
- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO



Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

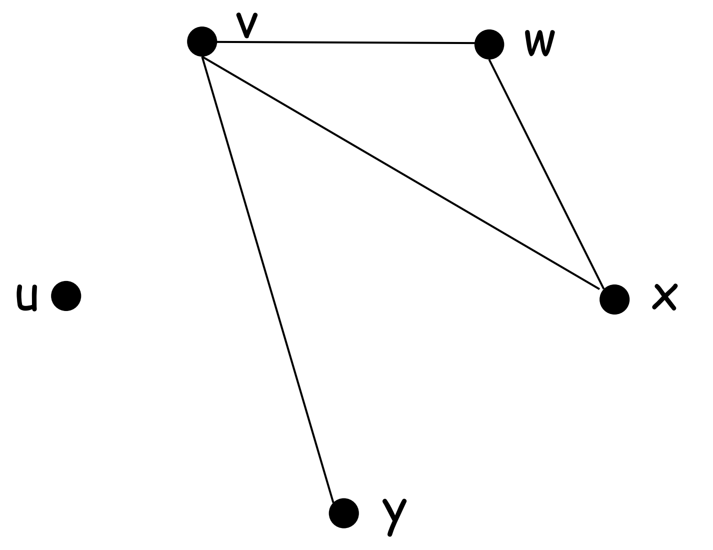
- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO



Grafos

Indique si existen grafos no dirigidos de 5 vértices con los siguientes grados:

- 3, 3, 3, 3, 2 SI
- 1, 2, 3, 4, 4 SI
- 0, 1, 2, 2, 3 SI
- 1, 2, 3, 4, 5 NO
- 3, 4, 3, 4, 3 NO
- 1, 1, 1, 1, 1 NO



Grafos

Indique la cantidad de aristas de un grafo si los grados de sus vértices son:

- 3, 3, 3, 3, 2 Sí e = 7
- 1, 2, 3, 4, 4 Sí e = 7
- 0, 1, 2, 2, 3 Sí e = 4
- 4, 5, 5, 2, 2 Sí e = 9
- 1, 3, 2, 2, 2, 2, 4 Sí e = 8

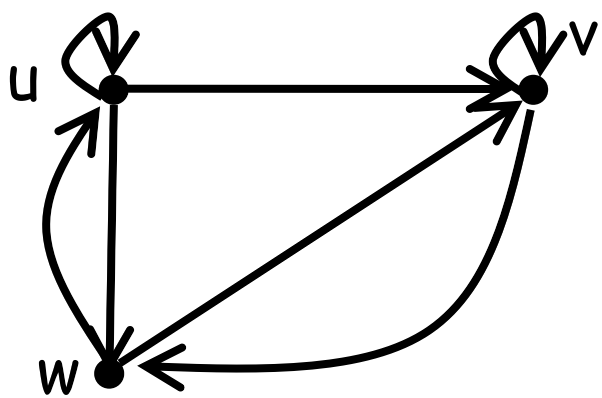
Grafos

Indique la cantidad de aristas de un grafo si los grados de sus vértices son:

- 3, 3, 3, 3, 2 (7)
- 1, 2, 3, 4, 4 (7)
- 0, 1, 2, 2, 3 (4)
- 4, 5, 5, 2, 2 (9)
- 1, 3, 2, 2, 2, 2, 4 (8)

Grafos dirigidos

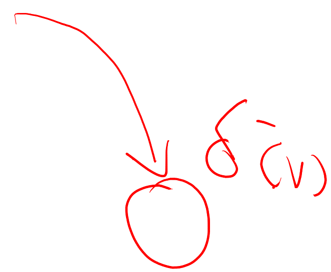
Dada una arista (u,v) en un grafo dirigido que inicia en u y termina en v, se dice que u es el **vértice inicial** y v es el **vértice final**

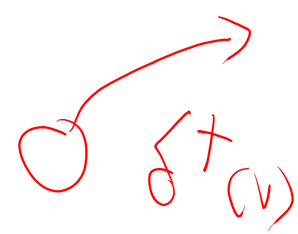


Grafos

Grado en un grafo dirigido

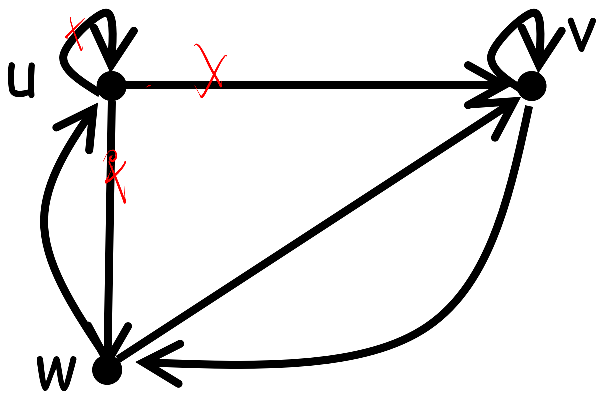
El **grado de entrada** de un vértice v, denotado como $\delta^{-}(v)$ es el número de aristas que llegan a v. El **grado de salida**, denotado como $\delta^{+}(v)$ es el número de aristas que salen de v





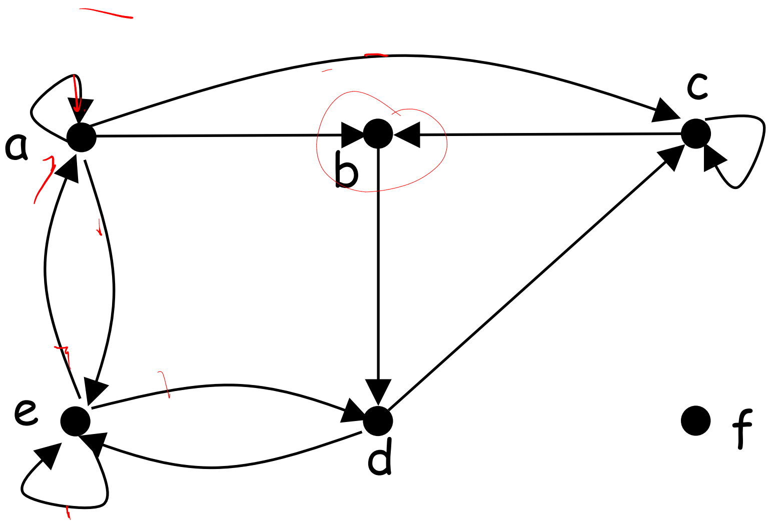
Grado en un grafo dirigido

El **grado de entrada** de un vértice v, denotado como $\delta^-(v)$ es el número de aristas que llegan a v. El **grado de salida**, denotado como $\delta^+(v)$ es el número de aristas que salen de v



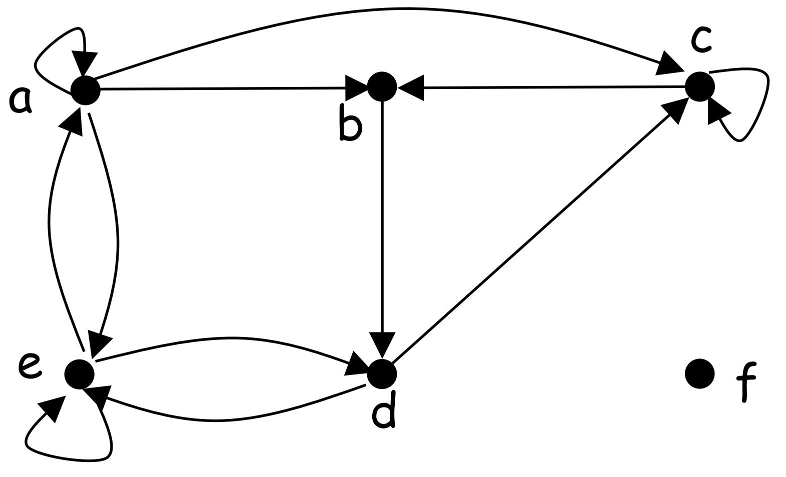
$\delta^-(u)=2$, $\delta^+(u)=3$
$\delta^-(v)=3$, $\delta^+(v)=2$
$\delta^-(w)=2$, $\delta^+(w)=2$

Grafos



$\delta^-(a)=?,\ \delta^+(a)=?$
$\delta^-(b)=?,\ \delta^+(b)=?$
$\delta^-(c)=?,\ \delta^+(c)=?$
$\delta^-(d)=?,\ \delta^+(d)=?$
$\delta^-(e)=?,\ \delta^+(e)=?$
$\delta^-(f)=?,\ \delta^+(f)=?$

Grafos



$\delta^-(a)=2$, $\delta^+(a)=4$
$\delta^-(b)=2$, $\delta^+(b)=1$
$\delta^-(c)=3$, $\delta^+(c)=2$
$\delta^-(d)=2$, $\delta^+(d)=2$
$\delta^-(e)=3$, $\delta^+(e)=3$
$\delta^-(f)=0$, $\delta^+(f)=0$

Grafos

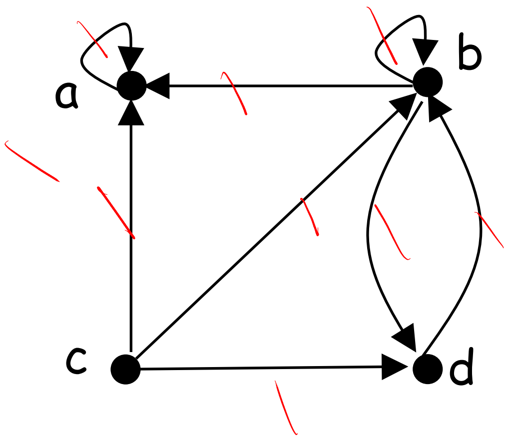
Teorema

Sea **G=(V,E)** un grado dirigido, se cumple que:

$$\sum \delta^{+}(v) = \sum \delta^{-}(v) = e$$

$$\sum_{v\in V} \delta^{-}(v) = \sum_{v\in V} \delta^{+}(v) = |E|$$

Grafos



3 = $\delta^-(a)=?$, $\delta^+(a)=?$ 1

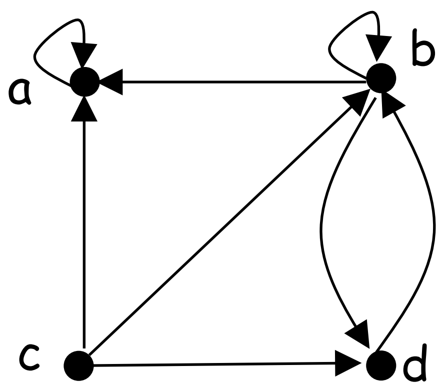
3 = $\delta^-(b)=?$, $\delta^+(b)=?$ 3

0 = $\delta^-(c)=?$, $\delta^+(c)=?$ 3

2 = $\delta^-(d)=?$, $\delta^+(d)=?$ 1

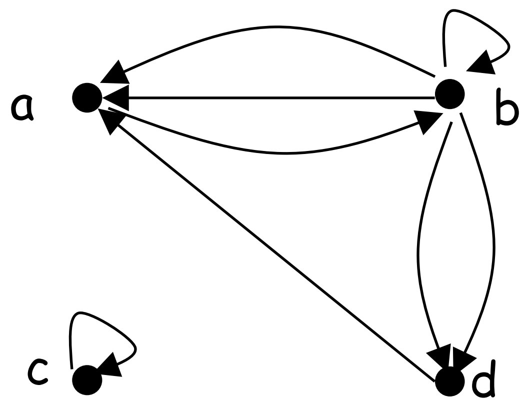
8 8

Grafos



$\delta^-(a)=3$, $\delta^+(a)=1$
$\delta^-(b)=3$, $\delta^+(b)=3$
$\delta^-(c)=0$, $\delta^+(c)=3$
$\delta^-(d)=2$, $\delta^+(d)=1$

Grafos



$3 = \delta^-(a)=?,\ \delta^+(a)=? = 1$

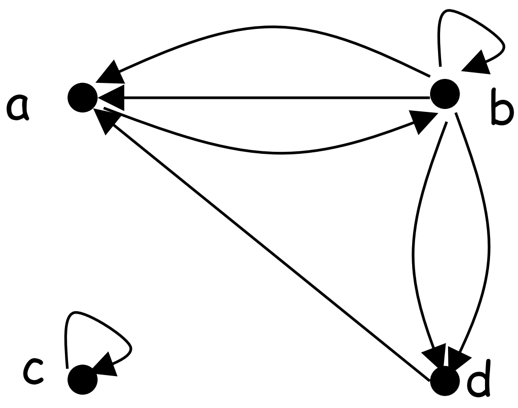
$2 = \delta^-(b)=?,\ \delta^+(b)=? = 5$

$1 = \delta^-(c)=?,\ \delta^+(c)=? = 1$

$2 = \delta^-(d)=?,\ \delta^+(d)=? = 1$

$8 \qquad\qquad 8$

Grafos



$\delta^{-}(a)=3$, $\delta^{+}(a)=1$
$\delta^{-}(b)=2$, $\delta^{+}(b)=5$
$\delta^{-}(c)=1$, $\delta^{+}(c)=1$
$\delta^{-}(d)=2$, $\delta^{+}(d)=1$

Grafos

Grafo completo

El **grafo completo** de n vértices, se denota por $\mathbf{K_n}$, es el grafo simple que contiene exactamente una arista entre cada par de vértices distintos

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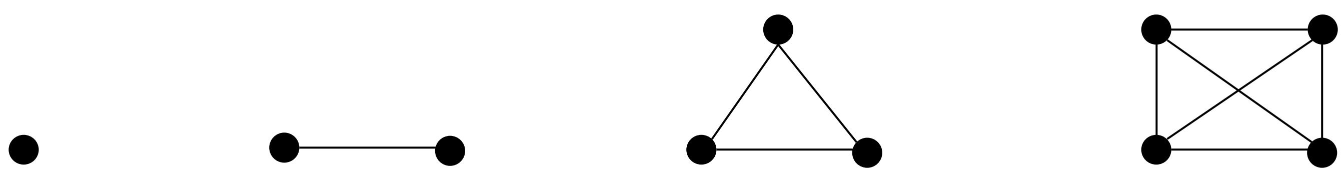
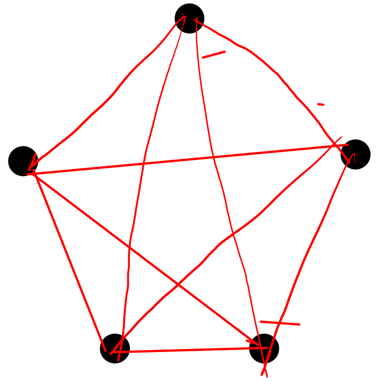


K_1 K_2 K_3 K_4

Grafo completo

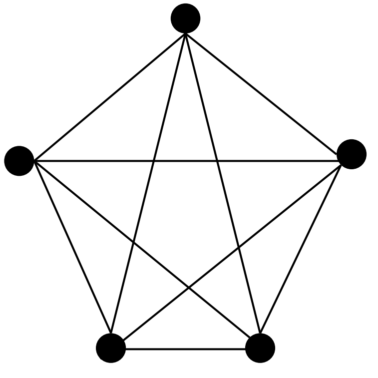
El **grafo completo** de n vértices, se denota por $\mathbf{K_n}$, es el grafo simple que contiene exactamente una arista entre cada par de vértices distintos



$\mathbf{K_5}$

Grafo completo

El **grafo completo** de n vértices, se denota por $\mathbf{K_n}$, es el grafo simple que contiene exactamente una arista entre cada par de vértices distintos

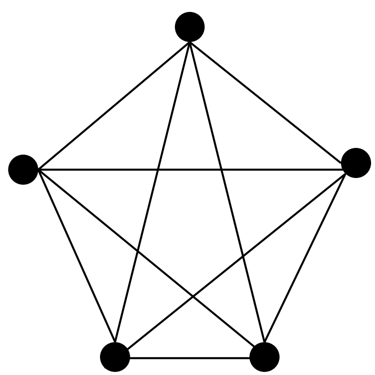


$\mathbf{K_5}$

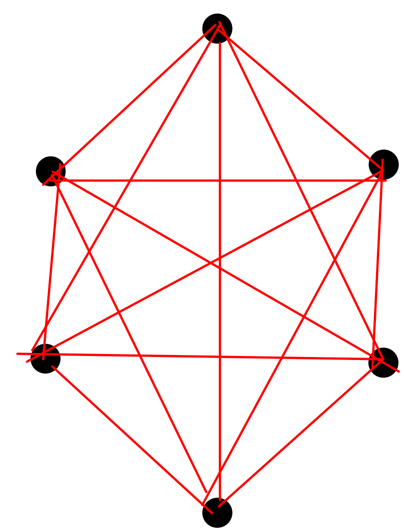
Grafos

Grafo completo

El **grafo completo** de n vértices, se denota por $\mathbf{K_n}$, es el grafo simple que contiene exactamente una arista entre cada par de vértices distintos



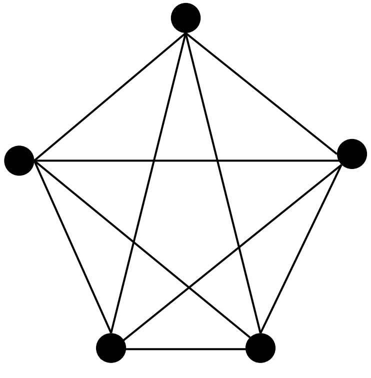
$\mathbf{K_5}$



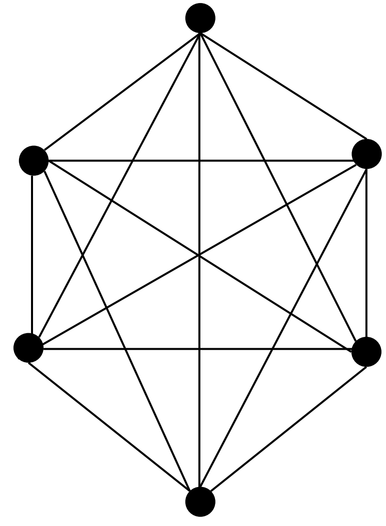
$\mathbf{K_6}$

Grafo completo

El **grafo completo** de n vértices, se denota por $\mathbf{K_n}$, es el grafo simple que contiene exactamente una arista entre cada par de vértices distintos



$\mathbf{K_5}$

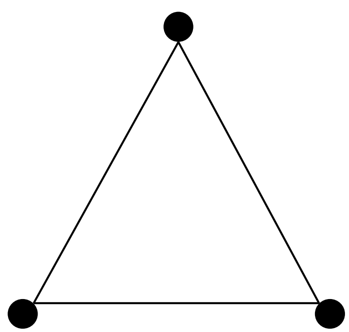


$\mathbf{K_6}$

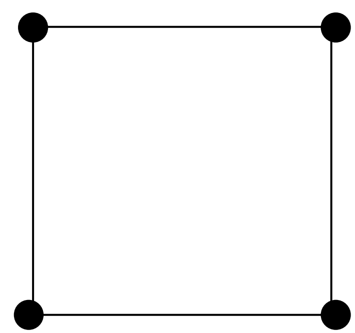
Ciclo completo

El **ciclo C_n** $(n \geq 3)$, consta de n vértices $v_1, v_2, \dots, v_n$ y las aristas:

$$\{v_1,v_2\}, \{v_2,v_3\}, \dots, \{v_{n-1},v_n\}, \{v_n,v_1\}$$



C_3

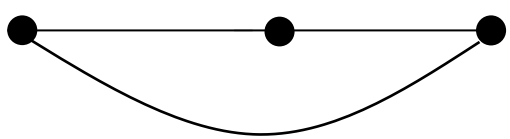


C_4

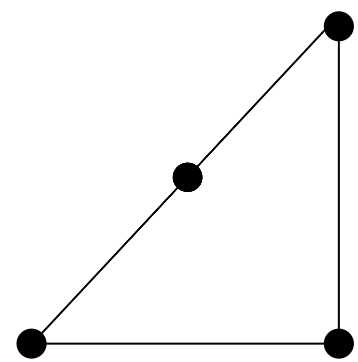
Ciclo completo

El **ciclo C_n** $(n \geq 3)$, consta de n vértices $v_1, v_2, \ldots, v_n$ y las aristas:

$$\{v_1,v_2\}, \{v_2,v_3\}, \ldots, \{v_{n-1},v_n\}, \{v_n,v_1\}$$



C_3

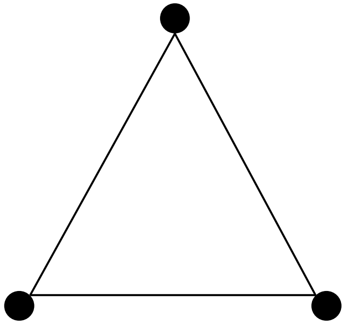


C_4

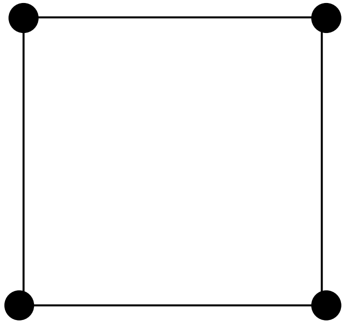
Ciclo completo

El **ciclo C_n** $(n \geq 3)$, consta de n vértices $v_1, v_2, \ldots, v_n$ y las aristas:

$$\{v_1,v_2\}, \{v_2,v_3\}, \ldots, \{v_{n-1},v_n\}, \{v_n,v_1\}$$



C_3

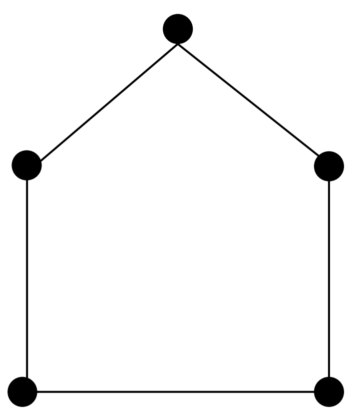


C_4

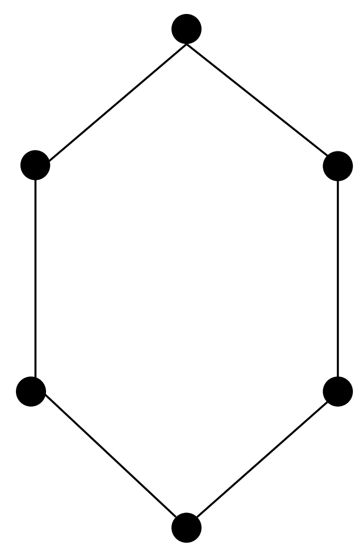
Ciclo completo

El **ciclo C_n** $(n \geq 3)$, consta de n vértices $v_1, v_2, \ldots, v_n$ y las aristas:

$$\{v_1, v_2\}, \{v_2, v_3\}, \ldots, \{v_{n-1}, v_n\}, \{v_n, v_1\}$$



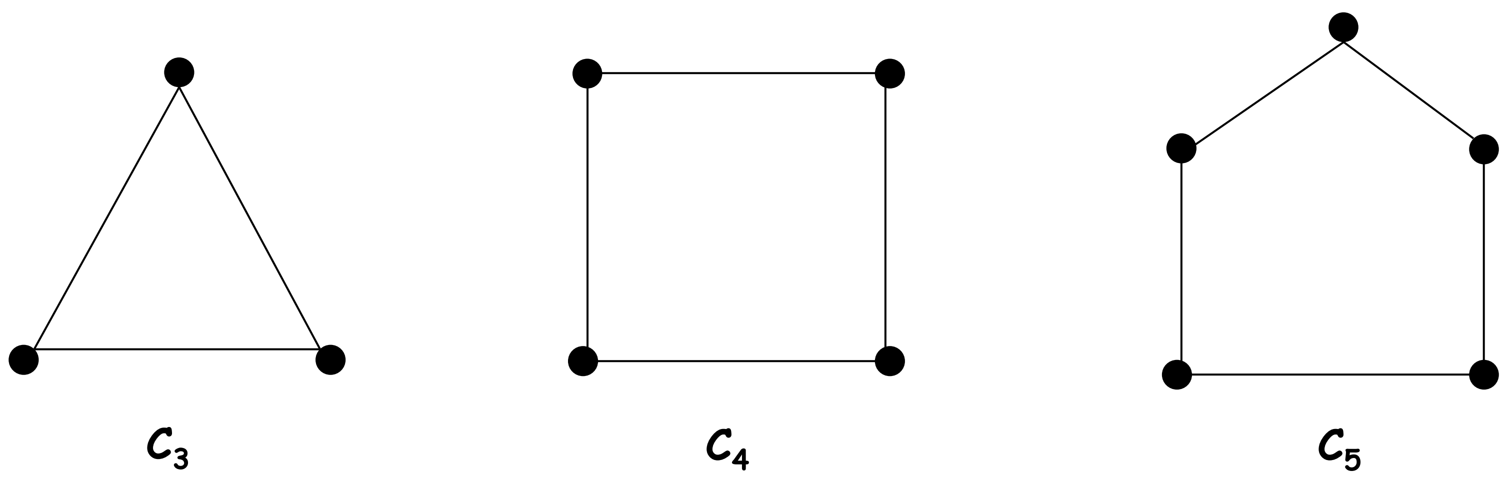
C_5



C_6

Rueda

Una **rueda W_n** se obtiene al añadir un vértice al ciclo C_n que se conecta con cada uno de los n vértices del ciclo



Rueda

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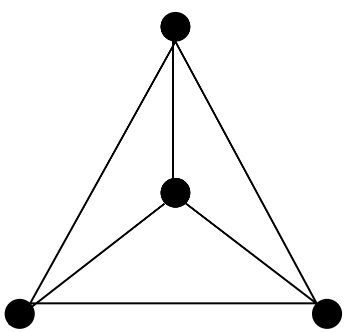
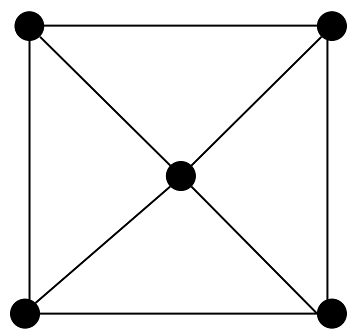
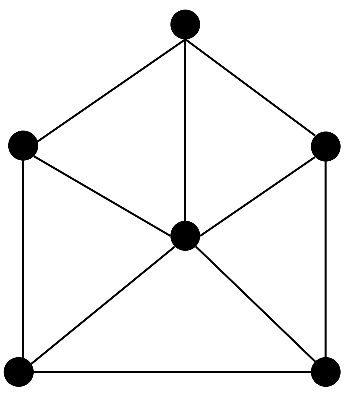


W_3



W_4



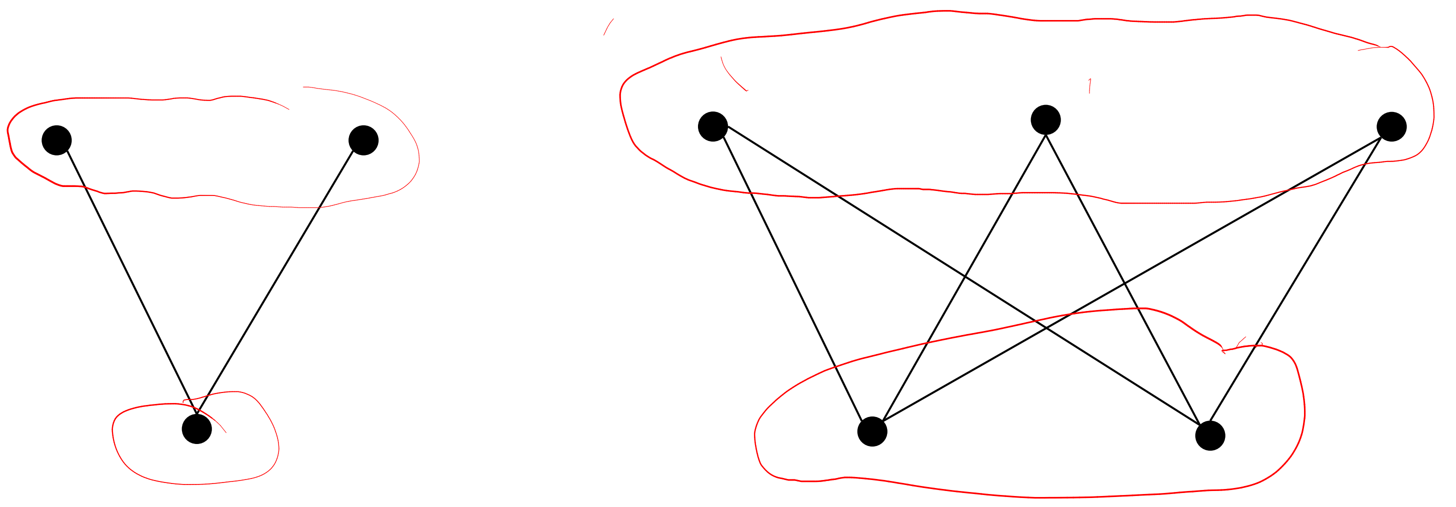
W_5

Grafo bipartito

Un grafo simple $G=(V,E)$ es **bipartito** si su conjunto de vértices V se puede dividir en dos conjuntos disjuntos V_1 y V_2 tales que cada arista del grafo conecte un vértice de V_1 con un vértice de V_2 (de manera que no haya ninguna arista que conecte entre sí dos vértices de V_1 ni tampoco dos vértices de V_2)

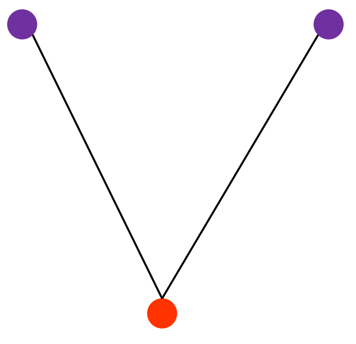
Grafos

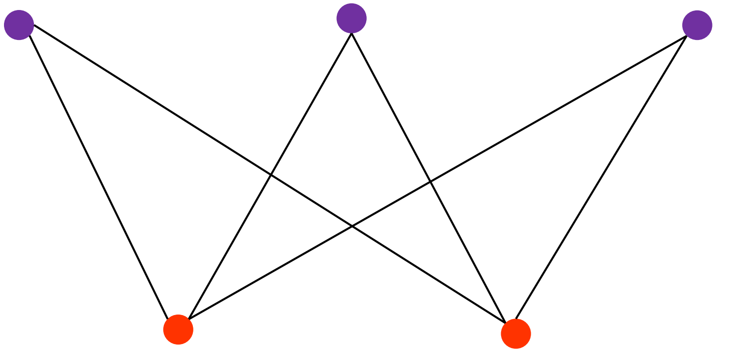
Grafo bipartito



Grafos

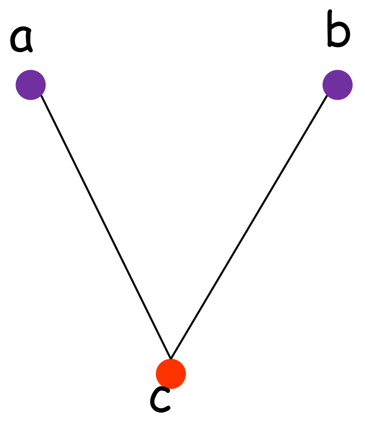
Grafo bipartito





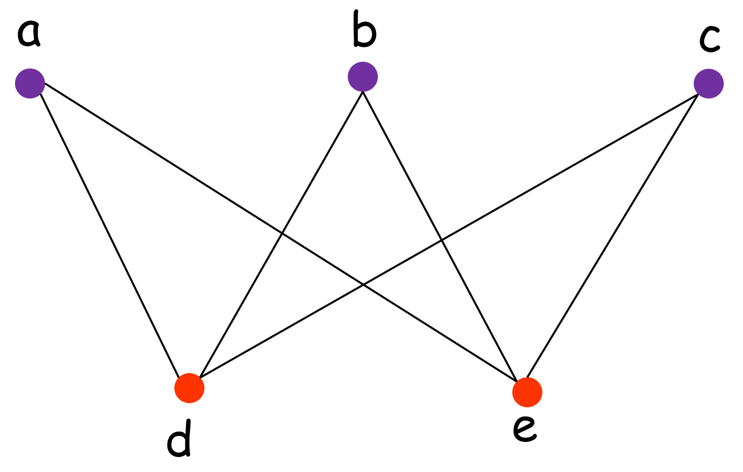
Grafos

Grafo bipartito



$V_1=\{a,b\}$

$V_2=\{c\}$

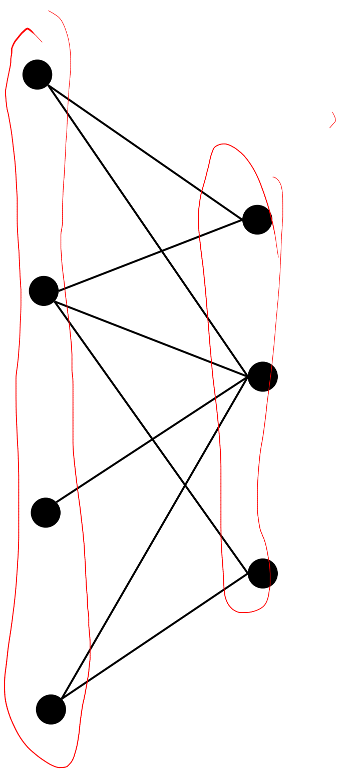


$V_1=\{a,b,c\}$

$V_2=\{d,e\}$

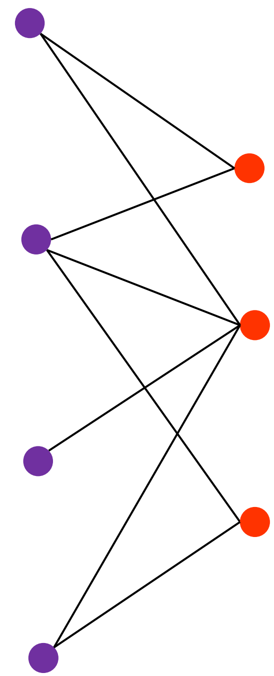
Grafos

Grafo bipartito

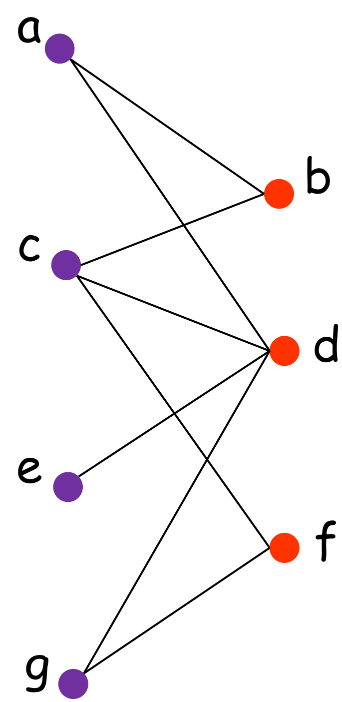


Grafos

Grafo bipartito



Grafo bipartito

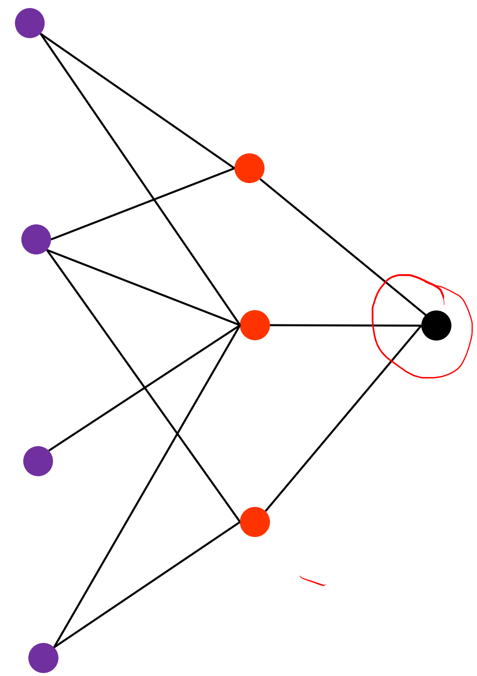


$V_1=\{a,c,e,g\}$

$V_2=\{b,d,f\}$

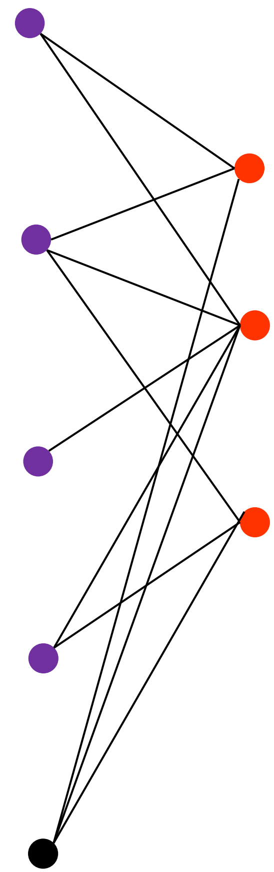
Grafos

Grafo bipartito



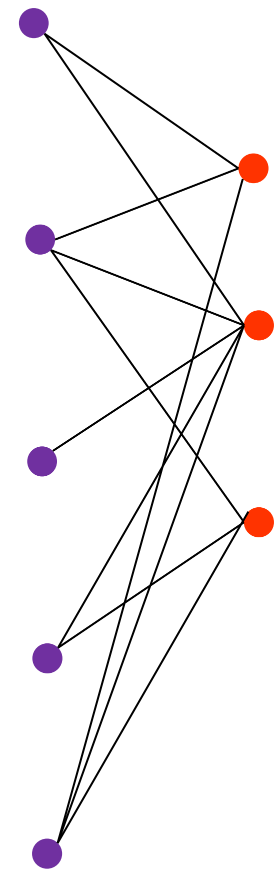
Grafos

Grafo bipartito

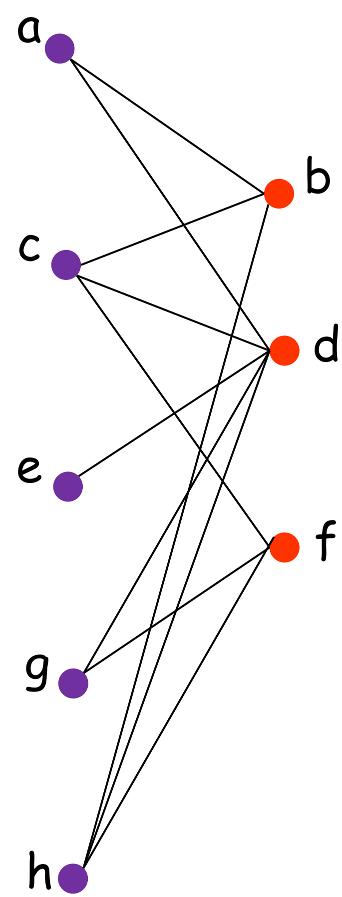


Grafos

Grafo bipartito



Grafo bipartito

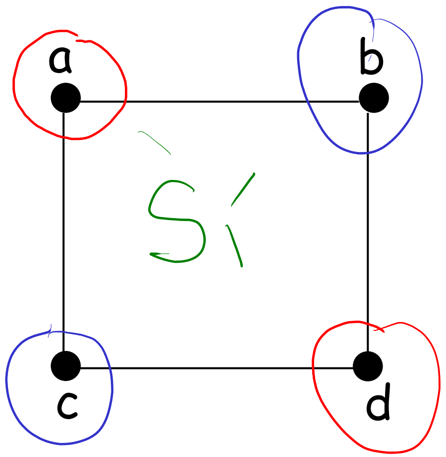


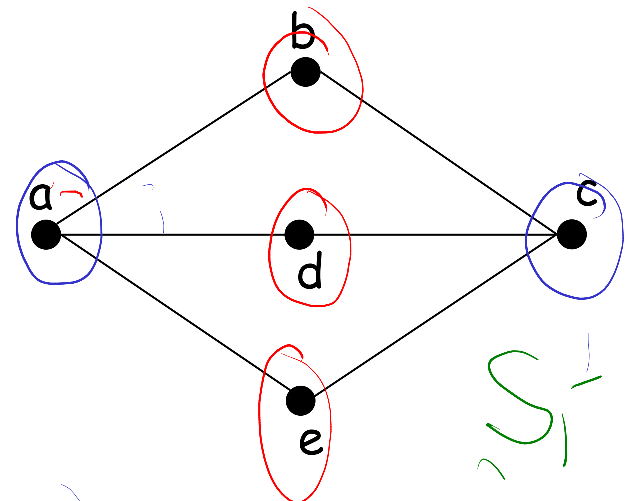
$V_1=\{a,c,e,g,h\}$

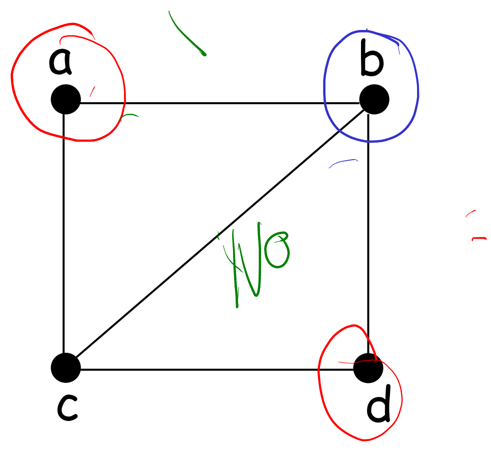
$V_2=\{b,d,f\}$

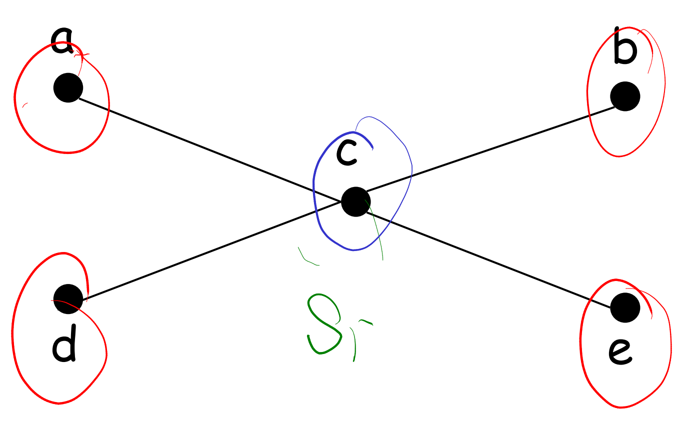
Grafos

Indique cuáles de los siguientes grafos son bipartitos.
Muestre V_1 y V_2 para los que sean bipartitos



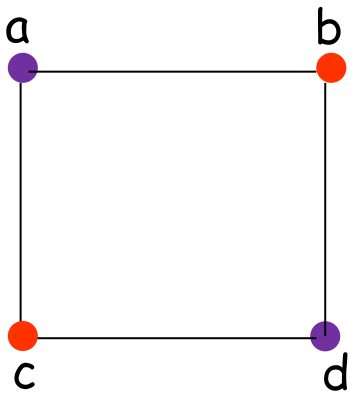


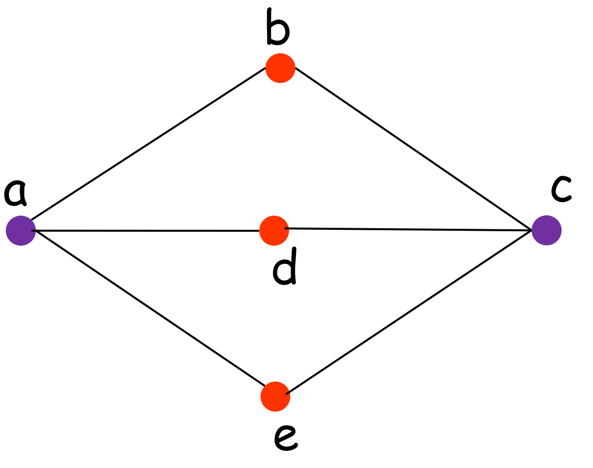


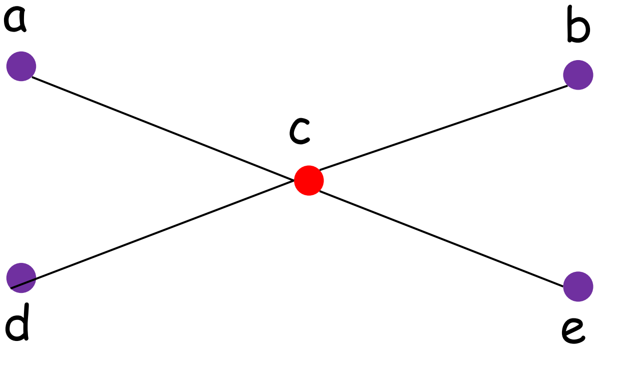


Grafos

Indique cuáles de los siguientes grafos son bipartitos. Muestre V_1 y V_2 para los que sean bipartitos





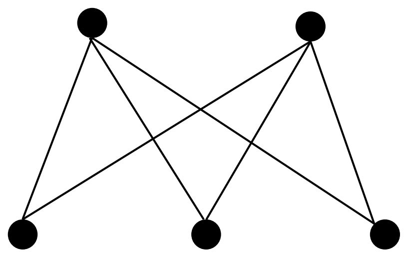


Grafo bipartito completo

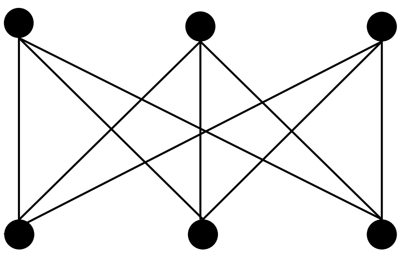
El **grafo bipartito completo $K_{m,n}$** es el grafo cuyo conjunto de vértices está formado por dos subconjuntos de m y n vértices tal que hay una arista entre dos vértices si, y solo sí, un vértice está en el primer subconjunto y el otro vértices está en el segundo subconjunto

Grafos

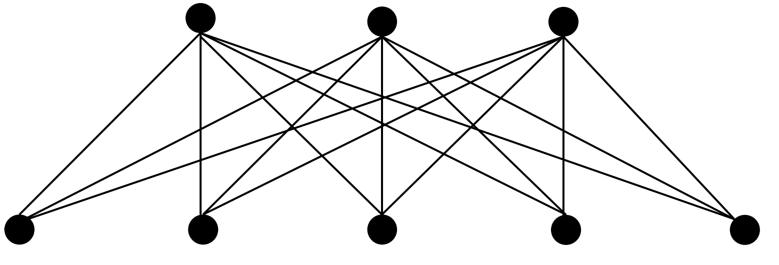
Grafo bipartito completo $K_{n,m}$



$K_{2,3}$



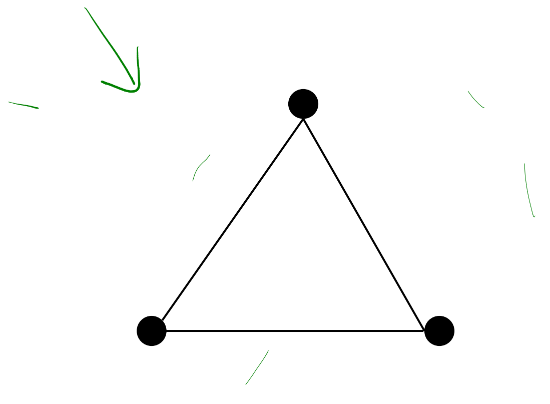
$K_{3,3}$

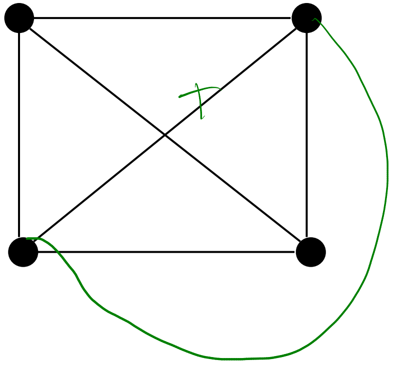


$K_{3,5}$

Grafo plano

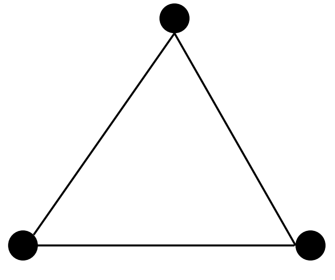
Un grafo (o multigrafo) G es **plano** si se puede dibujar en el plano de modo que sus aristas no se crucen

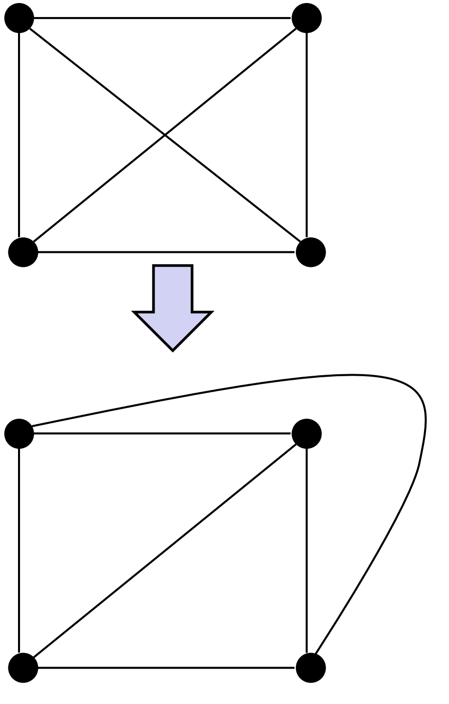




Grafo plano

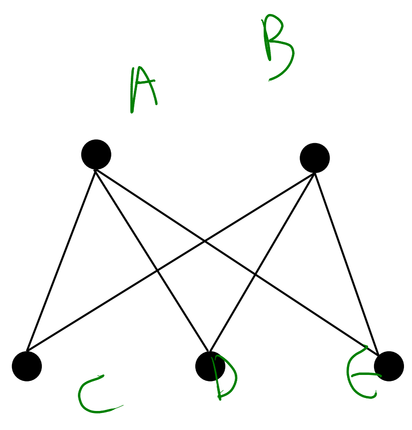
Un grafo (o multigrafo) *G* es **plano** si se puede dibujar en el plano de modo que sus aristas no se crucen

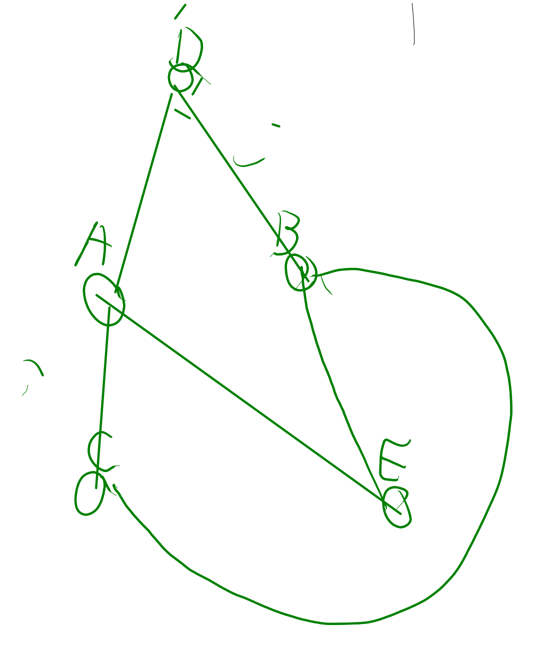




Grafo plano

Un grafo (o multigrafo) G es **plano** si se puede dibujar en el plano de modo que sus aristas no se crucen





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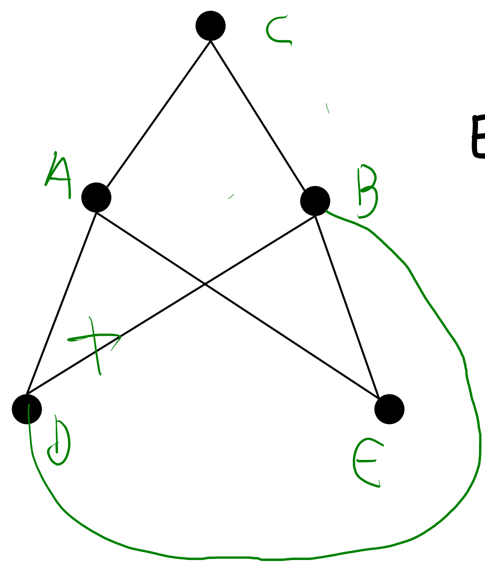
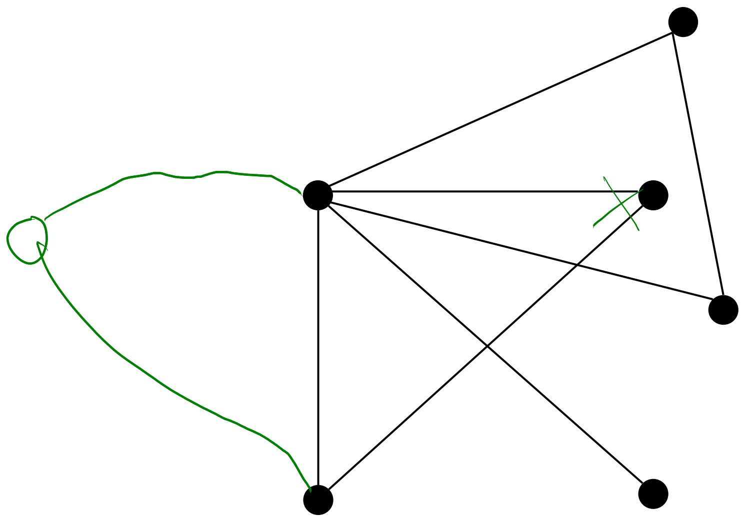


El grafo no
es plano

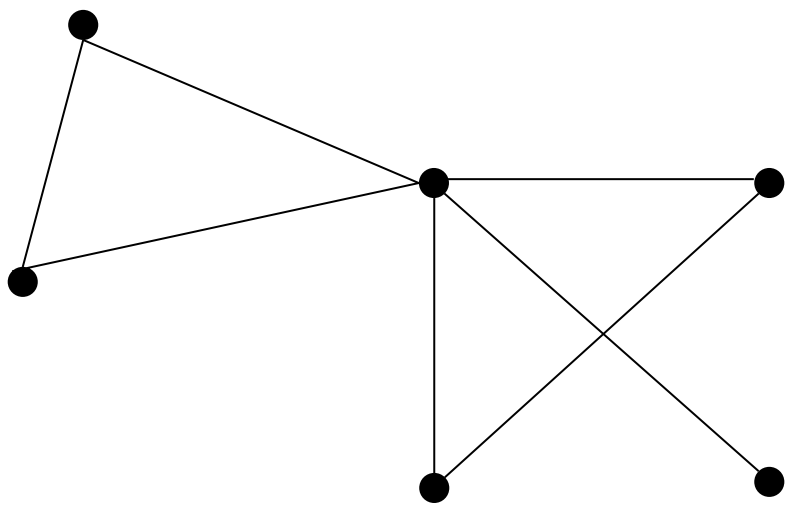
Grafo plano

Un grafo (o multigrafo) G es **plano** si se puede dibujar en el plano de modo que sus aristas no se crucen



Grafo plano

Un grafo (o multigrafo) G es **plano** si se puede dibujar en el plano de modo que sus aristas no se crucen



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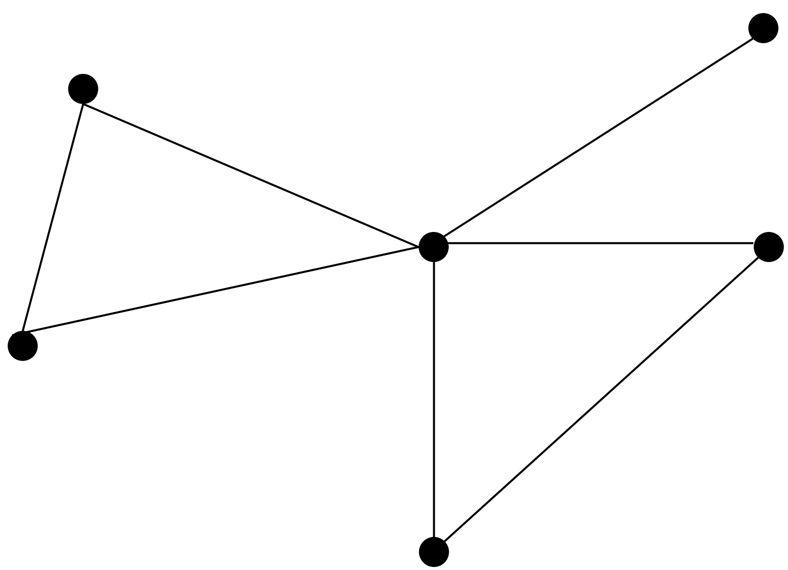

Grafo plano

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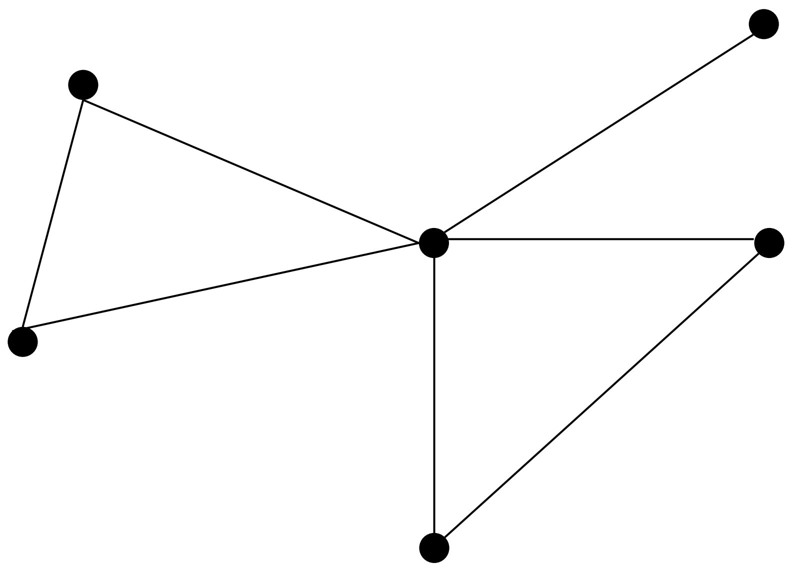


El grafo es plano

Teorema

Se G un grafo simple con e aristas y v vértices, entonces el **número de regiones** de una representación plana de G es $r=e-v+2$

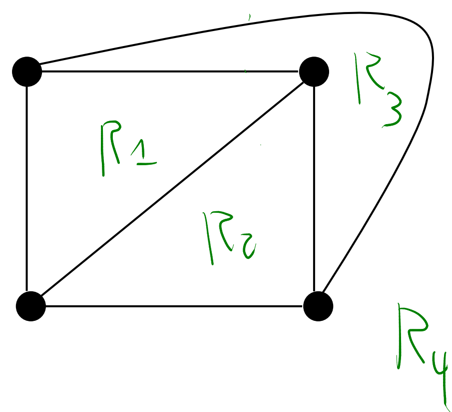
menos

Teorema de rechazo: Es un teorea que rechaza que alguna información (Que es plano) sin embargo si pasa el teorema NO QUIERE DECIR QUE SEA PLANO.

Teorema

Se G un grafo simple con e aristas y v vértices, entonces el **número de regiones** de una representación plana de G es r=e-v+2

$r = 6 - 4 + 2 = 4$



Grafos

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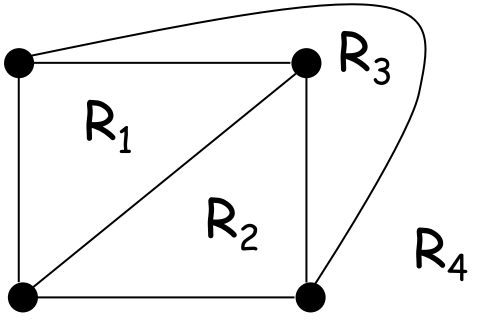

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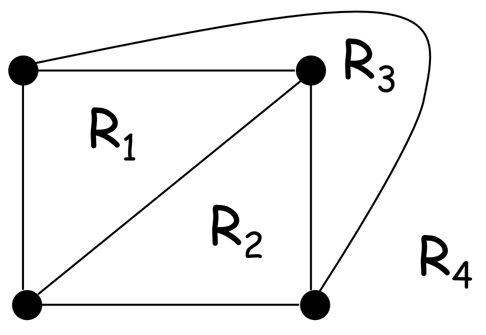
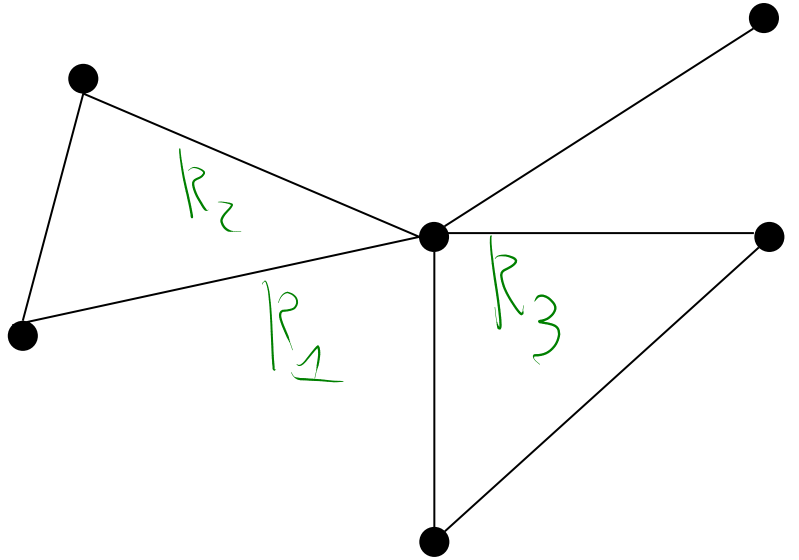


e=6
v=4
r=6-4+2=4

Teorema

Se G un grafo simple con e aristas y v vértices, entonces el **número de regiones** de una representación plana de G es r=e-v+2



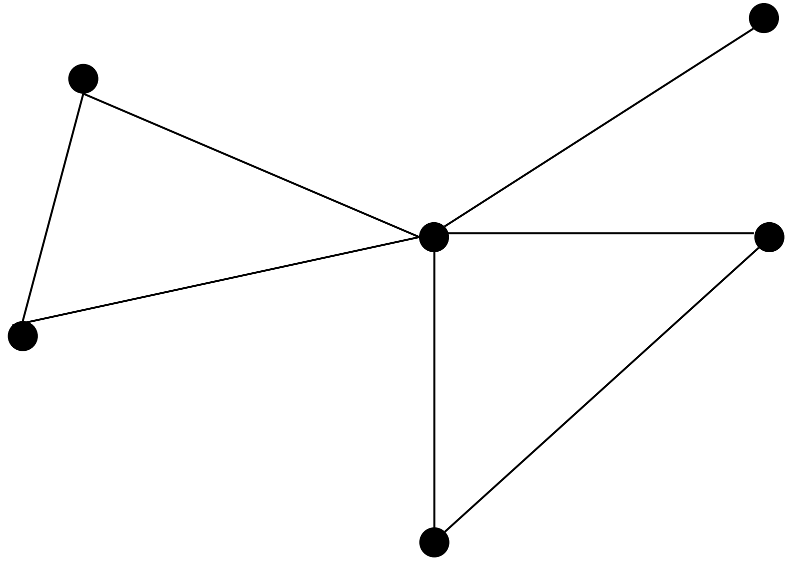
e=? 7

v=? 6

r=? 3

Teorema

Sea G un grafo simple con e aristas y v vértices, entonces el **número de regiones** de una representación plana de G es r=e-v+2



e=7
v=6
r=7-6+2=3

Grafos

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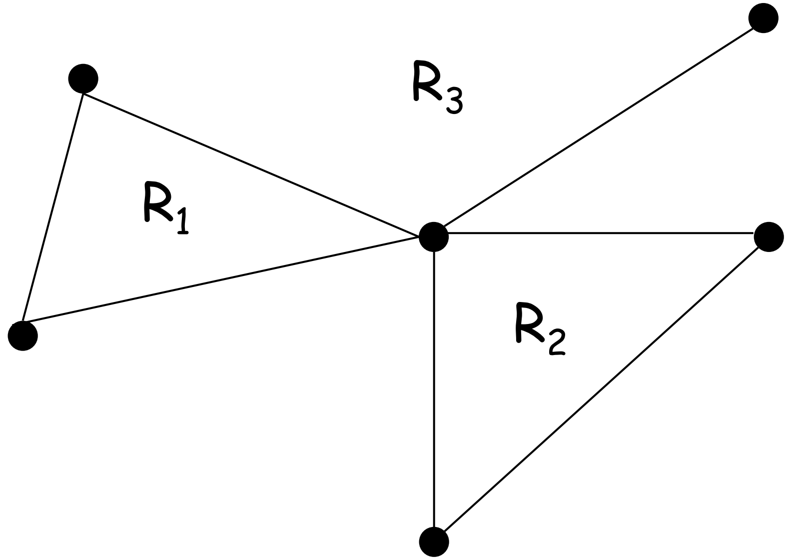
Sea G un grafo simple con e aristas y v vértices, entonces el **número de regiones** de una representación plana de G es r=e-v+2



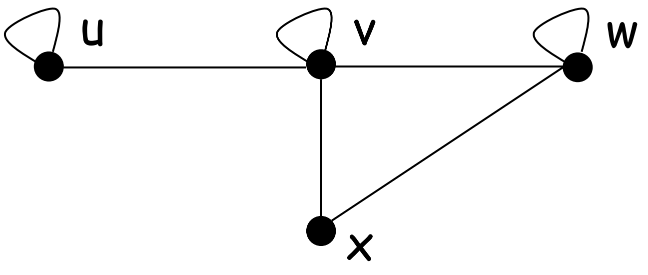
e=7
v=6
r=7-6+2=3

Matriz de adyacencia

Sea G=(V,E) un grafo con n vértices, la **matriz de adyacencia** es la matriz booleana de nxn tal que:

$$a_{ij} = \begin{cases} 1 & \text{si } \{v_i, v_j\} \text{ es una arista de } G \\ 0 & \text{en caso contrario} \end{cases}$$

Matriz de adyacencia



$$
\begin{array}{c|c}
 & \begin{matrix} u & v & w & x \end{matrix} \\
\begin{matrix} u \\ v \\ w \\ x \end{matrix} & \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{pmatrix}
\end{array}
$$

Matriz de adyacencia

La matriz de adyacencia de un grafo con aristas paralelas indica la cantidad de aristas que hay entre cada par de nodos v_i y v_j

Matriz de adyacencia

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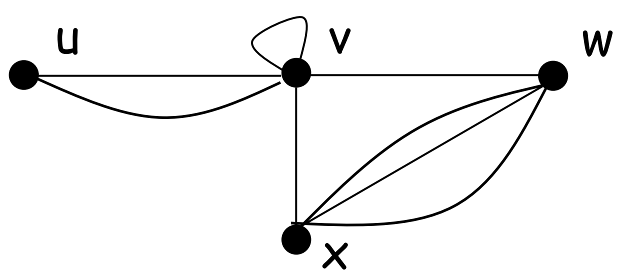

$$
\begin{array}{c c}
 & \begin{array}{cccc} u & v & w & x \end{array} \\
\begin{array}{c} u \\ v \\ w \\ x \end{array} & \begin{pmatrix} 0 & 2 & 0 & 0 \\ 2 & 1 & 1 & 1 \\ 0 & 1 & 0 & 3 \\ 0 & 1 & 3 & 0 \end{pmatrix}
\end{array}
$$

Matriz de adyacencia

La matriz de adyacencia de un **grafo dirigido** $G=(V,E)$ tiene un 1 en la posición (i,j) de la matriz si existe una arista que va de v_i a v_j

Matriz de adyacencia

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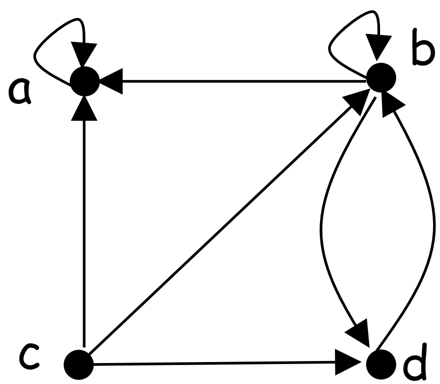


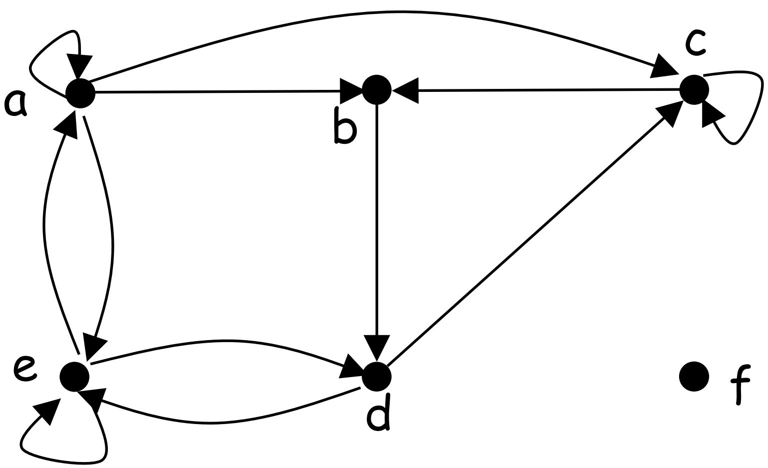
Salida

Entrada

$$\begin{array}{c|c} & \begin{matrix} a & b & c & d \end{matrix} \\ \begin{matrix} a \\ b \\ c \\ d \end{matrix} & \begin{pmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Matriz de adyacencia

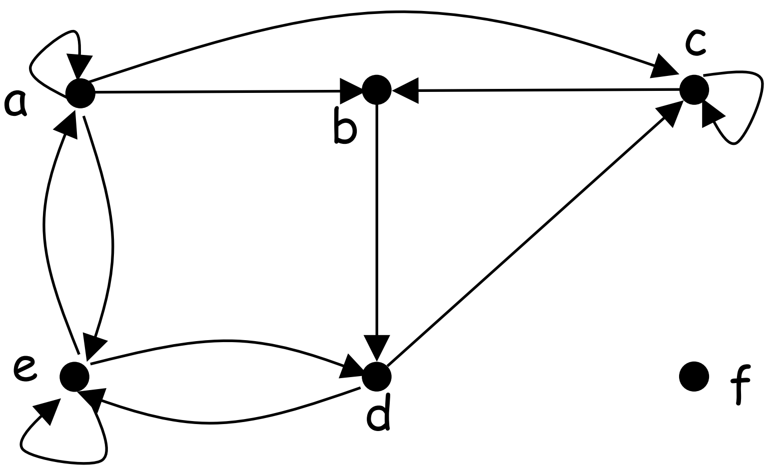
La matriz de adyacencia de un **grafo dirigido** G=(V,E) tiene un 1 en la posición (i,j) de la matriz si existe una arista que va de v_i a v_j



$$\begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline a & 1 & 1 & 0 & 0 & 1 & 0 \\ b & 0 & 0 & 0 & 1 & 0 & 0 \\ c & 0 & 1 & 1 & 0 & 0 & 0 \\ d & 0 & 0 & 1 & 0 & 1 & 0 \\ e & 1 & 0 & 0 & 1 & 1 & 0 \\ f & 0 & 0 & 0 & 0 & 0 & 0 \end{array}$$

Matriz de adyacencia

La matriz de adyacencia de un **grafo dirigido** $G=(V,E)$ tiene un 1 en la posición (i,j) de la matriz si existe una arista que va de v_i a v_j



$$
\begin{array}{c|cccccc}
 & a & b & c & d & e & f \\
\hline
a & 1 & 1 & 1 & 0 & 1 & 0 \\
b & 1 & 0 & 0 & 1 & 0 & 0 \\
c & 0 & 1 & 1 & 0 & 0 & 0 \\
d & 0 & 0 & 1 & 0 & 1 & 0 \\
e & 1 & 0 & 0 & 1 & 1 & 0 \\
f & 0 & 0 & 0 & 0 & 0 & 0
\end{array}
$$

Teorema

Sea M_R la matriz de adyacencia de un grafo, se tiene que:

$$M_R \otimes M_R = M_R^2$$

$\otimes$ es el producto booleano y M_R^2 es la matriz que indica si hay caminos de longitud 2 en el grafo

Producto booleano de matrices

Dadas dos matrices A y B de órdenes mxk y kxn, respectivamente, $A \otimes B$ es una matriz de orden mxn en la que cada elemento c_{ij} se calcula como:

and

$$c_{ij} = (a_{i1} \wedge b_{1j}) \vee (a_{i2} \wedge b_{2j}) \vee \ldots (a_{in} \wedge b_{nj})$$

or

$$\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

$1 \times a + b \times 4 + c \times 7$

Producto booleano de matrices

$$A=\begin{pmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \end{pmatrix} \qquad B=\begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \end{pmatrix}$$

$$A \otimes B = \begin{pmatrix} (1\wedge 1)\vee(0\wedge 0) = 1 \vee 0 = 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

Producto booleano de matrices

$$A=\begin{pmatrix}1 & 0\\ 0 & 1\\ 1 & 1\end{pmatrix} \qquad B=\begin{pmatrix}1 & 1 & 0\\ 0 & 1 & 1\end{pmatrix}$$

$$A\otimes B=\begin{pmatrix}(1\wedge 1)\vee(0\wedge 0) & (1\wedge 1)\vee(0\wedge 1) & (1\wedge 0)\vee(0\wedge 1)\\ (0\wedge 1)\vee(1\wedge 0) & (0\wedge 1)\vee(1\wedge 1) & (0\wedge 0)\vee(1\wedge 1)\\ (1\wedge 1)\vee(1\wedge 0) & (1\wedge 1)\vee(1\wedge 1) & (1\wedge 0)\vee(1\wedge 1)\end{pmatrix}$$

Producto booleano de matrices

$$A=\begin{pmatrix}1 & 0\\ 0 & 1\\ 1 & 1\end{pmatrix} \qquad B=\begin{pmatrix}1 & 1 & 0\\ 0 & 1 & 1\end{pmatrix}$$

$$A\otimes B=\begin{pmatrix}(1\wedge 1)\vee(0\wedge 0) & (1\wedge 1)\vee(0\wedge 1) & (1\wedge 0)\vee(0\wedge 1)\\ (0\wedge 1)\vee(1\wedge 0) & (0\wedge 1)\vee(1\wedge 1) & (0\wedge 0)\vee(1\wedge 1)\\ (1\wedge 1)\vee(1\wedge 0) & (1\wedge 1)\vee(1\wedge 1) & (1\wedge 0)\vee(1\wedge 1)\end{pmatrix}$$

$$A\otimes B=\begin{pmatrix}1\vee 0 & 1\vee 0 & 0\vee 0\\ 0\vee 0 & 0\vee 1 & 0\vee 1\\ 1\vee 0 & 1\vee 1 & 0\vee 1\end{pmatrix}=\begin{pmatrix}1 & 1 & 0\\ 0 & 1 & 1\\ 1 & 1 & 1\end{pmatrix}$$

Grafos

Teorema

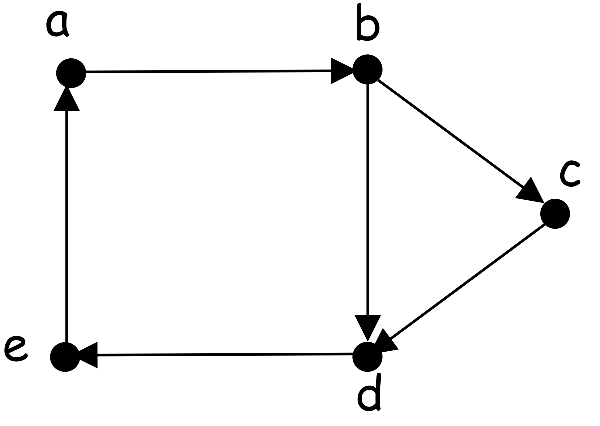
Sea M_R la matriz de adyacencia de un grafo, se tiene que:

$$M_R \otimes M_R = M_R^2$$

$\otimes$ es el producto booleano y M_R^2 es la matriz que indica si hay caminos de longitud 2 en el grafo

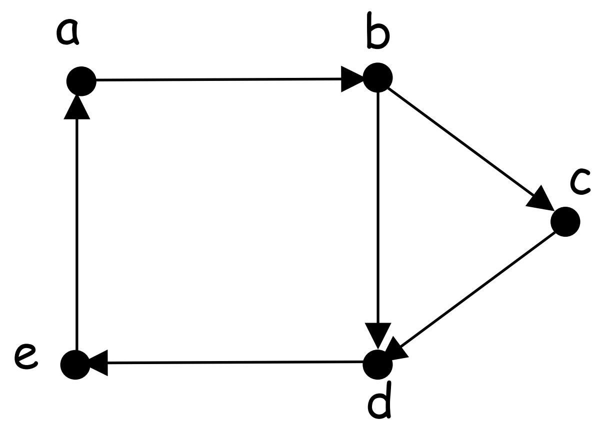
Grafos

$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



Grafos

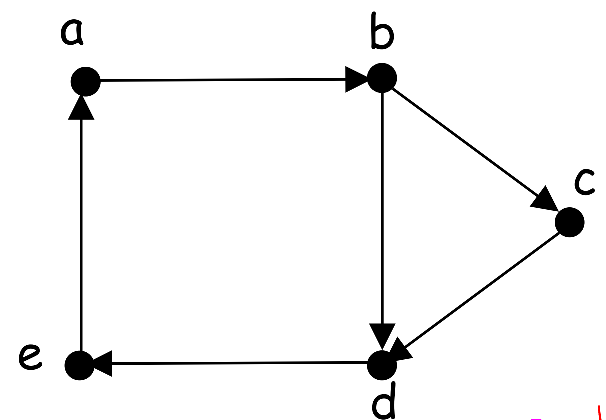
$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



$$M_R^2 = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Grafos

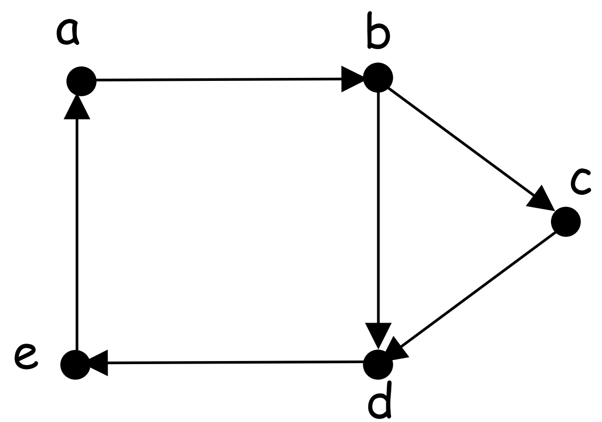
$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



$$M_R^2 = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

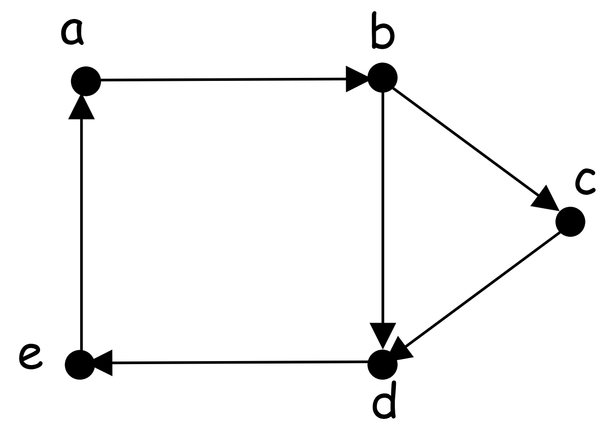
$$M_R = \begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 0 & 1 & 0 & 0 & 0 \\ b & 0 & 0 & 1 & 1 & 0 \\ c & 0 & 0 & 0 & 1 & 0 \\ d & 0 & 0 & 0 & 0 & 1 \\ e & 1 & 0 & 0 & 0 & 0 \end{array}$$



$$M_R^2 = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} = \begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 0 & 0 & 1 & 1 & 0 \\ b & 0 & 0 & 0 & 1 & 1 \\ c & 0 & 0 & 0 & 0 & 1 \\ d & 1 & 0 & 0 & 0 & 0 \\ e & 0 & 1 & 0 & 0 & 0 \end{array}$$

Grafos

$$M_R = \begin{array}{c|c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

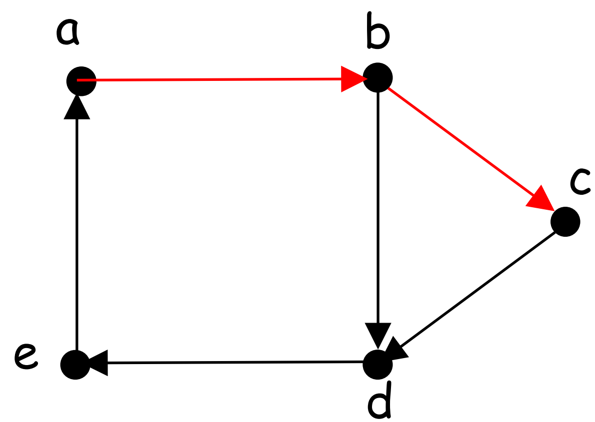


$$M_R^2 = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} = \begin{array}{c|c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Indica si hay caminos de longitud 2 en el grafo

Grafos

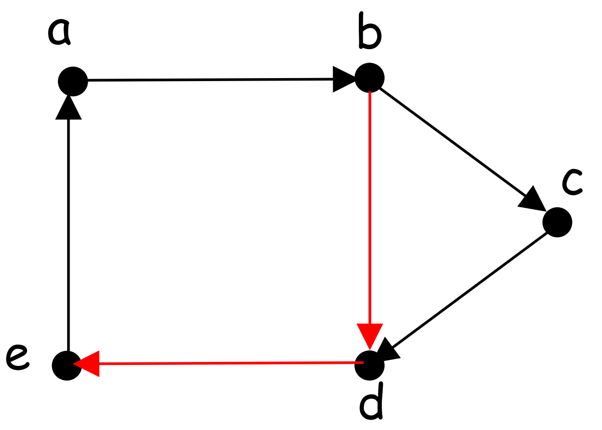
$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



$$M_R^2 = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



$$M_R^2 = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Teorema

Sea M_R la matriz de adyacencia de un grafo, se tiene que:

$M_R \otimes M_R = M_R^2$

$M_R \otimes M_R \otimes M_R = M_R^3$

$M_R \otimes M_R \otimes M_R \otimes M_R = M_R^4$

$\cdots$

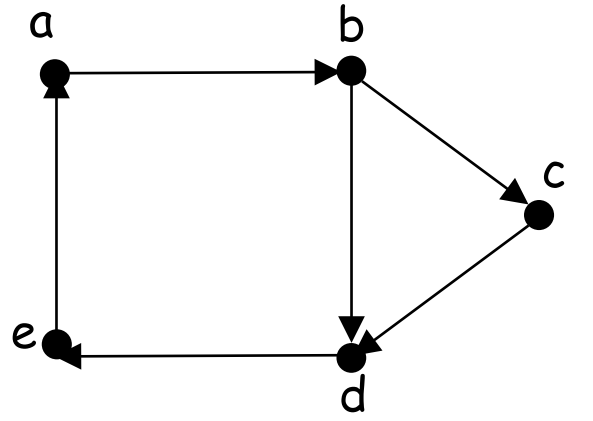
$M_R \otimes M_R \otimes M_R \otimes \ldots \otimes M_R = M_R^n$

M_R^i es la matriz que indica si hay caminos de longitud i en el grafo

Grafos

$$M_R^3 = M_R^2 \otimes M_R$$

$$= \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

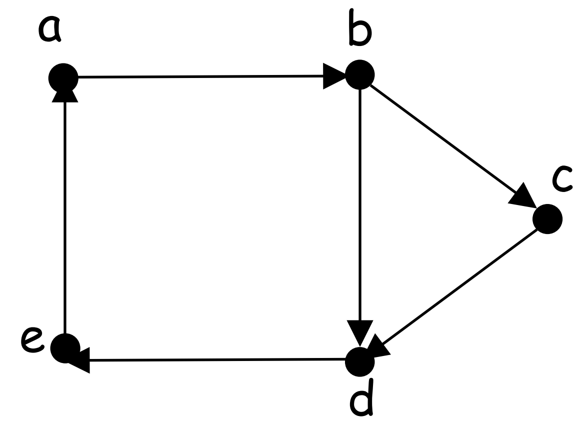


Grafos

$$M_R^3 = M_R^2 \otimes M_R$$

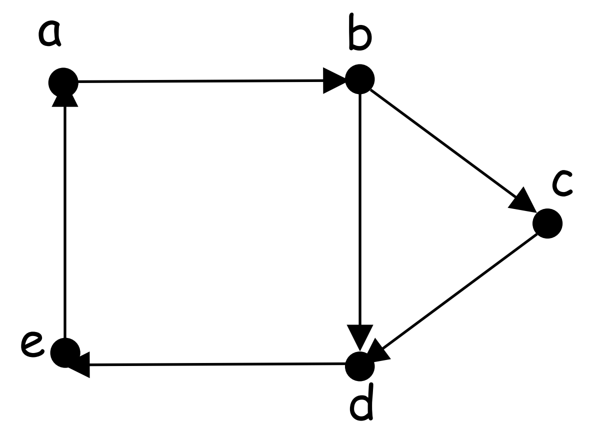
$$= \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= \begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix} \end{array}$$



Grafos

$$M_R^3 = M_R^2 \otimes M_R$$



$$= \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

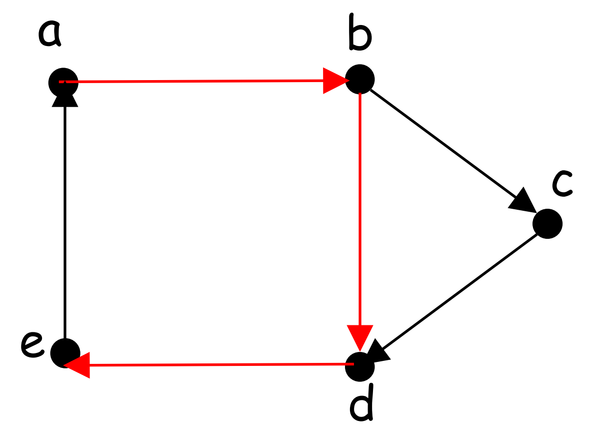
Indica si hay caminos de longitud 3 en el grafo

Grafos

$$M_R^3 = M_R^2 \otimes M_R$$

$$= \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 0 & 0 & 1 & \mathbf{\color{red}{1}} \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

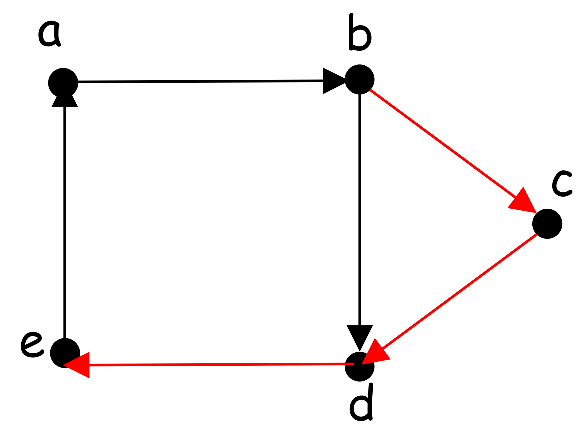


Grafos

$$M_R^3 = M_R^2 \otimes M_R$$

$$= \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & \color{red}{\mathbf{1}} \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix} \end{array}$$



Matriz de conectividad

Se define como:

$$M_R^{\infty} = M_R \vee M_R^2 \vee M_R^3 \vee \ldots \vee M_R^n$$

$$M_R^{\infty} = M_R \vee M_R^2 \vee M_R^3 \vee M_R^4 \vee \ldots \vee M_R^n$$

$$M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \qquad M_R^2 = \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \qquad M_R^3 = \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix}$$

Grafos

$$M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \qquad M_R^2 = \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \qquad M_R^3 = \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix}$$

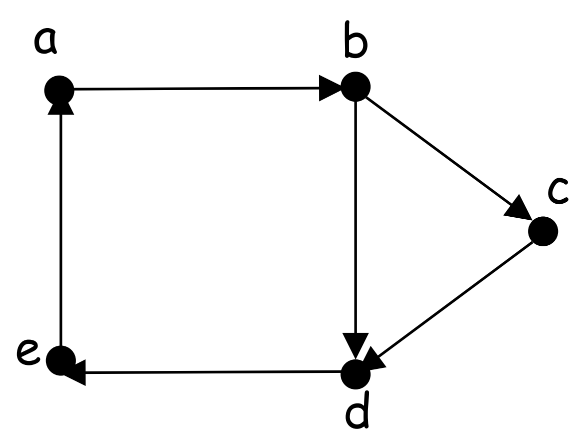
$$M_R \vee M_R^2 \vee M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

Grafos

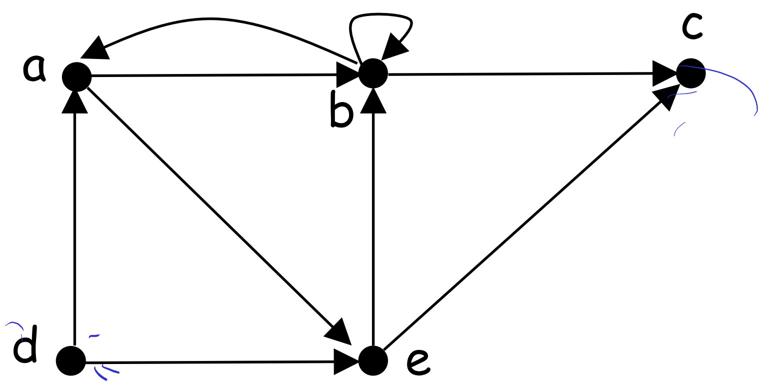
$$M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix} \qquad M_R^2 = \begin{pmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \qquad M_R^3 = \begin{pmatrix} 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix}$$

$$M_R \vee M_R^2 \vee M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

Indica si existe un camino de longitud 1, 2, ó 3 en el grafo



Mostrar M_R y M_R^2 para el siguiente grafo:



	a	b	c	d	e
a	0	1	0	0	1
b	1	1	1	0	0
c	0	0	0	0	0
d	1	0	0	0	1
e	0	1	1	0	0

	a	b	c	d	e
a	1	1	1	0	0
b	1	1	1	0	1
c	0	0	0	0	0
d	0	1	1	0	1
e	1	1	1	0	0

$\boxed{b - c}$

b - b - c ✓

$\boxed{b - e}$

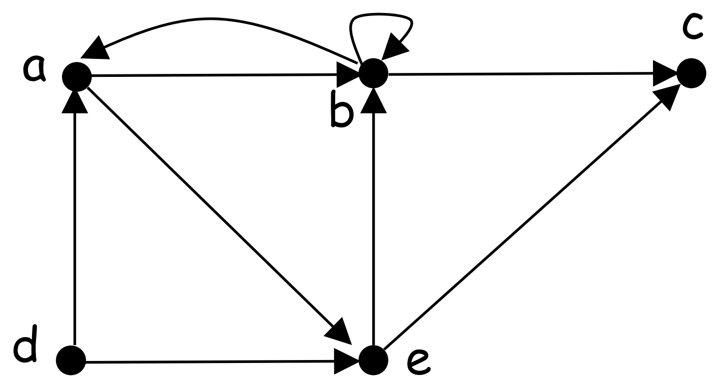
b - a - e

d - b

d - e - b

Grafos

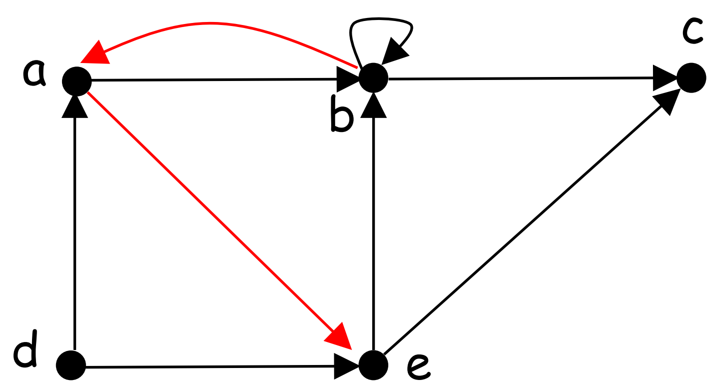
Mostrar M_R y M_R^2 para el siguiente grafo:



$$M_R = \begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

$$M_R^2 = \begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Mostrar M_R y M_R^2 para el siguiente grafo:

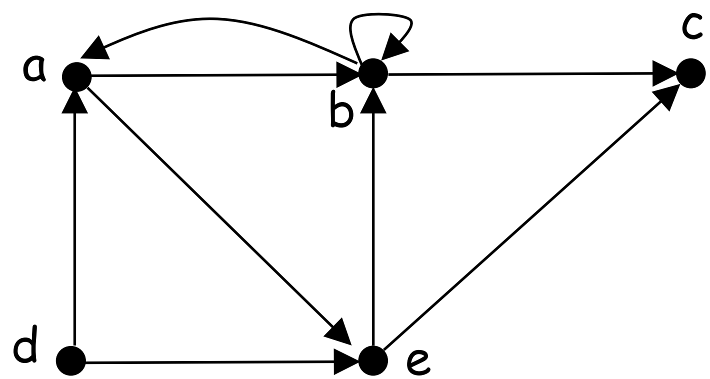


$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

$$M_R^2 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

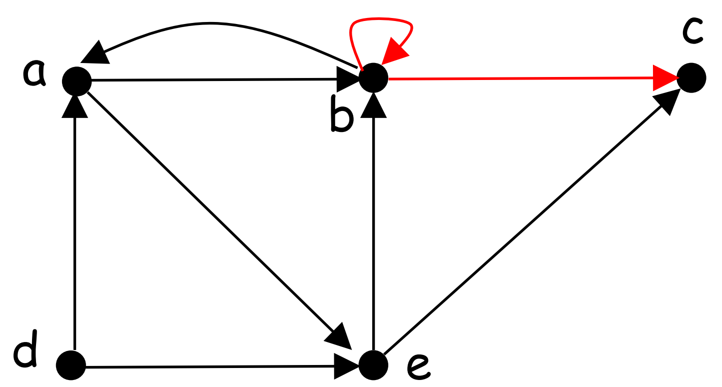
Mostrar M_R y M_R^2 para el siguiente grafo:



$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

$$M_R^2 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & \mathbf{1} & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Mostrar M_R y M_R^2 para el siguiente grafo:

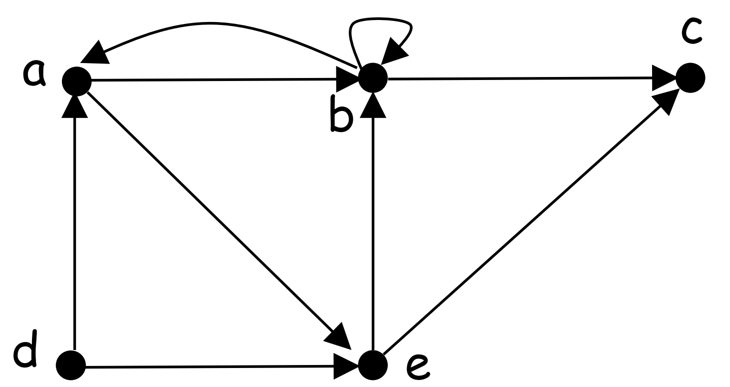


$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

$$M_R^2 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & \mathbf{1} & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

Mostrar M_R^3

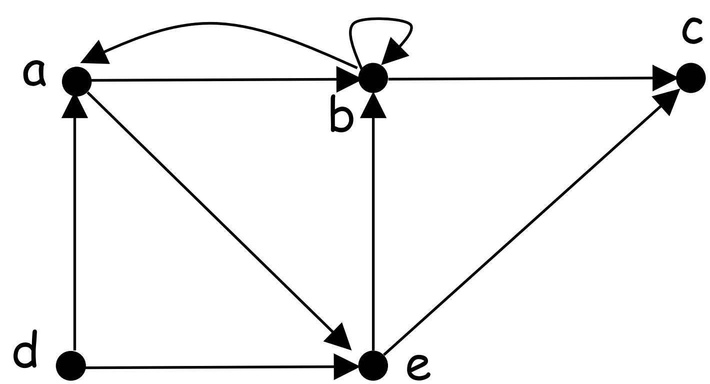


$$M_R = \begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 0 & 1 & 0 & 0 & 1 \\ b & 1 & 1 & 1 & 0 & 0 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & 0 & 0 & 0 & 1 \\ e & 0 & 1 & 1 & 0 & 0 \end{array}$$

$$M_R^2 = \begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 1 & 1 & 1 & 0 & 0 \\ b & 1 & 1 & 1 & 0 & 1 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 0 & 1 & 1 & 0 & 1 \\ e & 1 & 1 & 1 & 0 & 0 \end{array}$$

Grafos

Mostrar M_R^3



$$M_R^3 = \begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 1 & 1 & 1 & 0 & 1 \\ b & 1 & 1 & 1 & 0 & 1 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & 1 & 1 & 0 & 0 \\ e & 1 & 1 & 1 & 0 & 1 \end{array}$$

d - c

$\underbrace{d - a}_{1} - \underbrace{}_{2}\, b - \underbrace{}_{3}\, c$

d - e - b - c

a - a

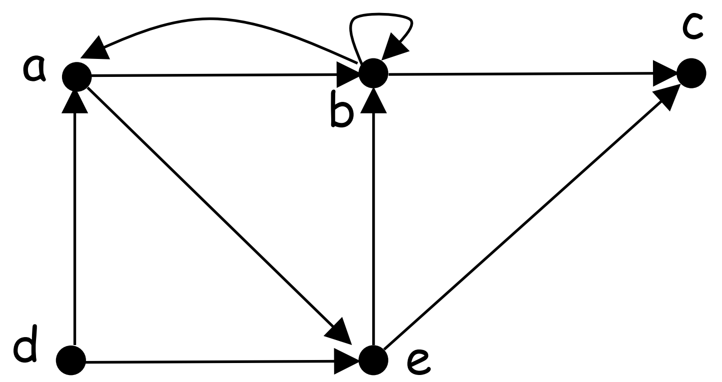
$\underbrace{a - b}_{1} - \underbrace{b - b}_{2} - \underbrace{b - a}_{3}$

e - e

e - b - a - e

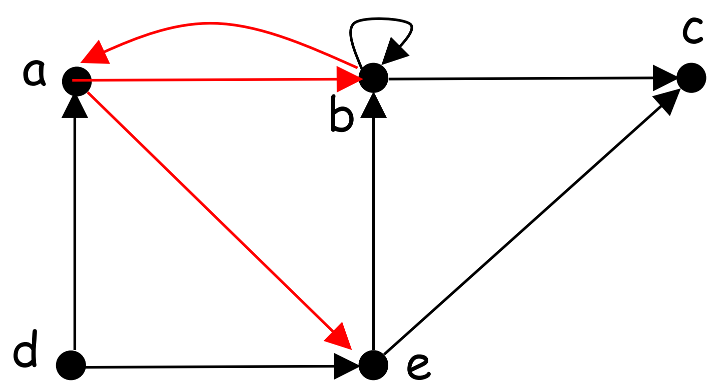
Grafos

Mostrar M_R^3



$$M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & \color{red}{1} \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

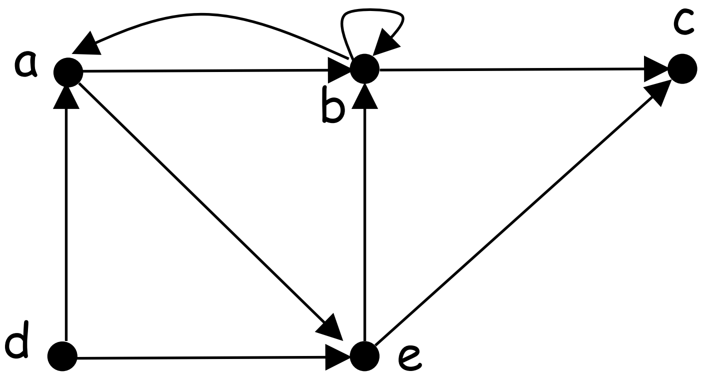
Mostrar M_R^3



$$M_R^3 = \begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

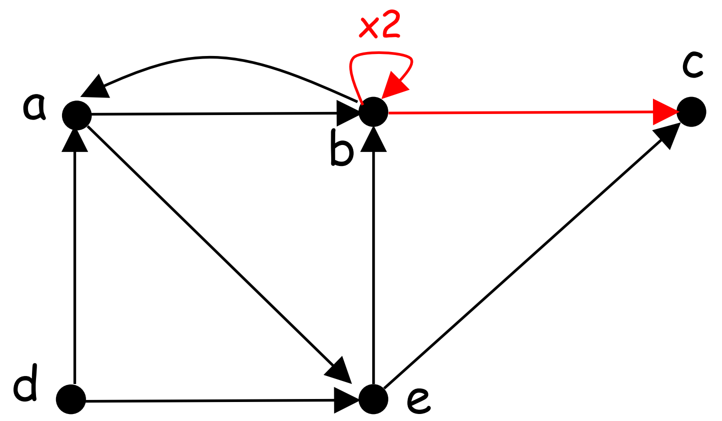
Mostrar M_R^3



$$M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & \color{red}{1} & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

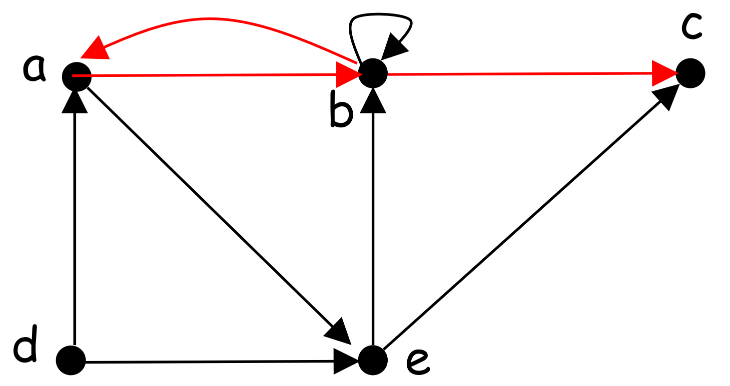
Grafos

Mostrar M_R^3



$$M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & \color{red}{1} & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

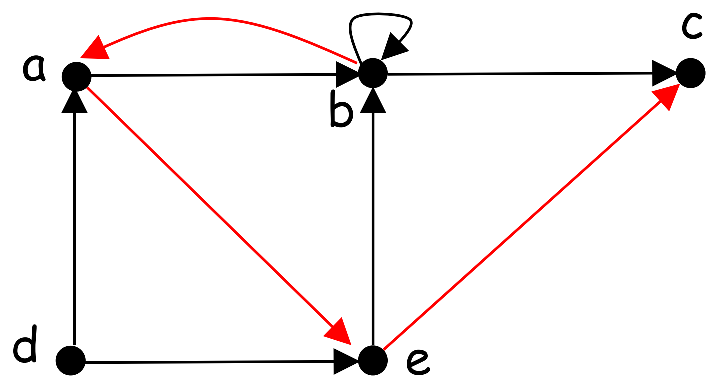
Mostrar M_R^3



$$M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

Mostrar M_R^3



a – b

a – b – b — a – e
1 2 3 4

$$M_R^3 = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & \color{red}{1} & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

$M_R^\infty = M_R \vee M_R^2 \vee M_R^3 \vee \ldots M_R^n$

conectividad

Algoritmo de Warshall

Permite conocer la matriz de conectividad de un grafo realizando menos operaciones que con la multiplicación de matrices booleanas

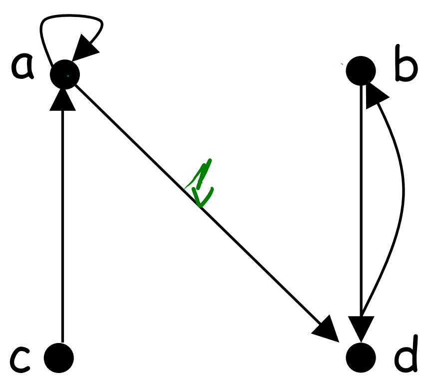
n^3

$M_R^\infty = M_R^1 \vee M_R^2 \vee M_R^3 \vee M_R^4$ n^4

Algoritmo de Warshall

$4 \times 4 \times 4$

Permite conocer la matriz de conectividad de un grafo realizando menos operaciones que con la multiplicación de matrices booleanas

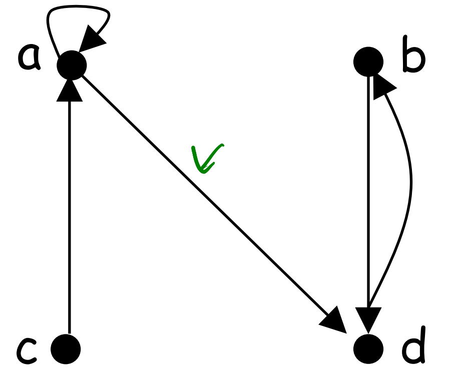


1 1 0 1

$$M_R^\infty = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} ? & ? & ? & ? \\ ? & ? & ? & ? \\ ? & ? & ? & ? \\ ? & ? & ? & ? \end{pmatrix} \end{array}$$

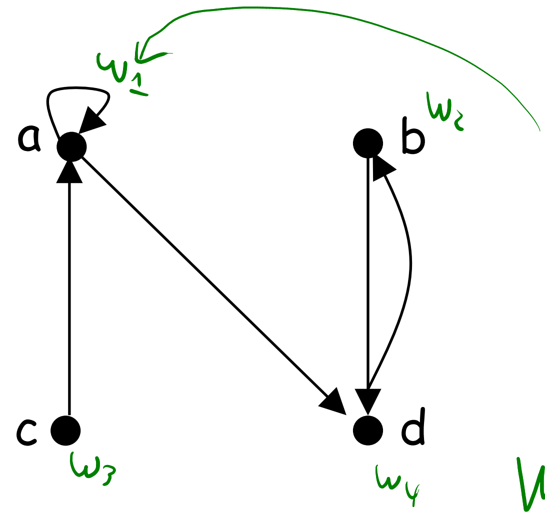
Grafos

$$M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$



Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

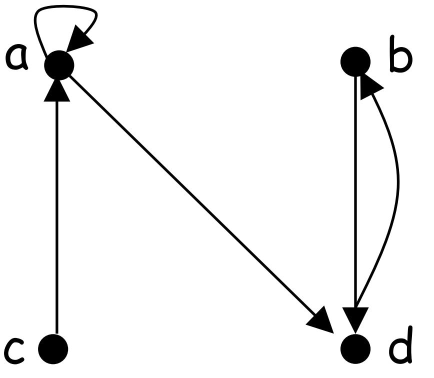


$$\left.\begin{array}{l} W_0 \\ W_1 \\ \vdots \\ W_4 \end{array}\right\} \underline{n+1}$$

$W_4 = M_R^\infty$

Grafos

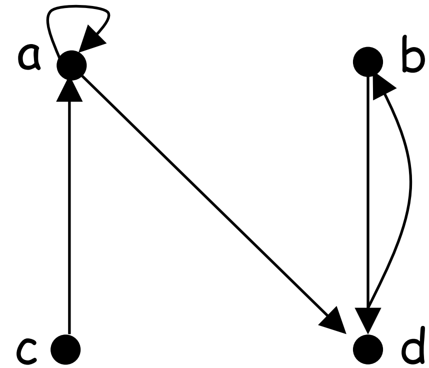
$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$

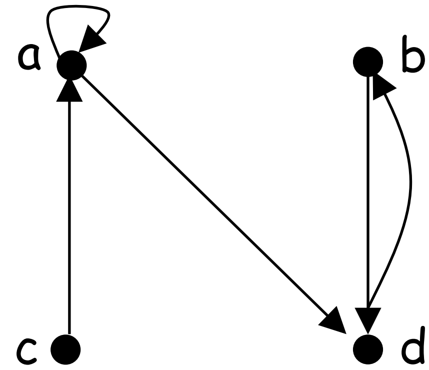


W_1 (pivote a)

$$W_1 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & & & \\ c & 1 & & & \\ d & 0 & & & \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

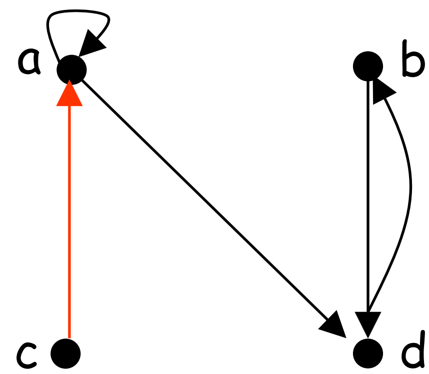
$$W_1 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & & & \\ 1 & & & 1 \\ 0 & & & \end{pmatrix} \end{array}$$

$a \longrightarrow d$

$c \longrightarrow a \longrightarrow d$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



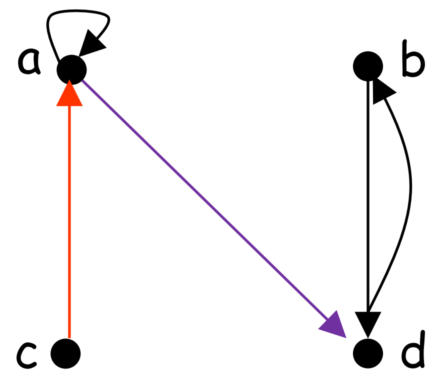
W_1 (pivote a)

$$W_1 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & & & \\ 1 & & & 1 \\ 0 & & & \end{pmatrix} \end{array}$$

$c \longrightarrow a \longrightarrow d$

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$

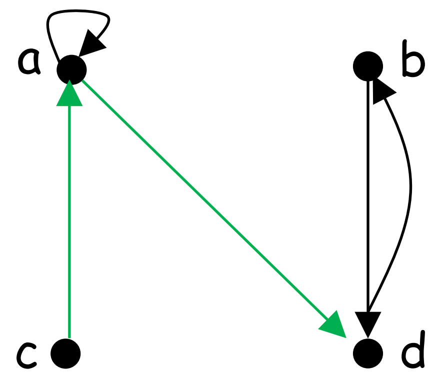


W_1 (pivote a)

$$W_1 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & & & \\ c & 1 & & & 1 \\ d & 0 & & & \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



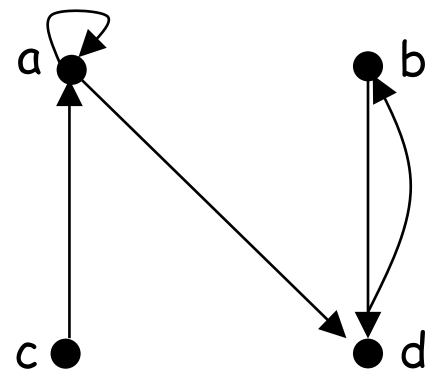
W_1 (pivote a)

$$W_1 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & & & \\ 1 & & & 1 \\ 0 & & & \end{pmatrix} \end{array}$$

1 significa que hay un camino desde c hasta d

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

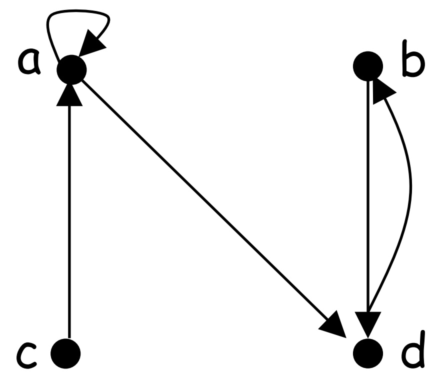


W_1 (pivote a)

$$W_1 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & & & \\ 1 & & & 1 \\ 0 & & & \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & \boxed{1} \\ c & 1 & \boxed{0} & \boxed{0} & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$



k

W_1 (pivote a)

$$W_1 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & \boxed{0} & \boxed{0} & 1 \\ b & 0 & 0 & 0 & 1 \\ c & \boxed{1} & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

b → d si
b → a → d X

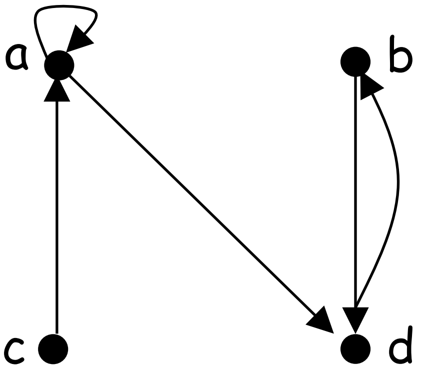
Se completa la matriz W_1 con las demás aristas de W_0

$W^1_{ij} = W_{0_{ij}} \vee (W_{0_{kj}} \wedge W_{0_{ik}})$

c → b NO
c → a → b no

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$

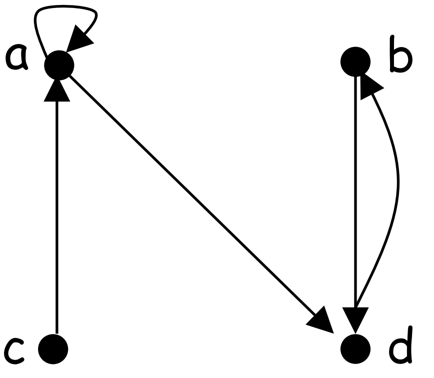


W_1 (pivote a)

$$W_1 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



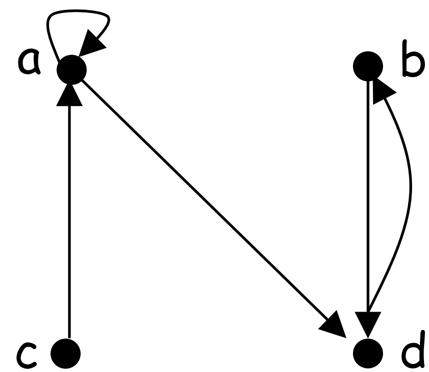
W_1 (pivote a)

$$\begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



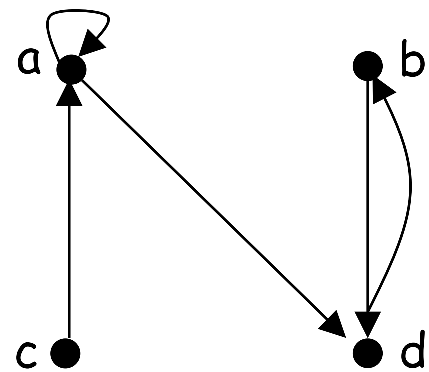
W_1 (pivote a) $\longleftarrow$ W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & \cancel{0} & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

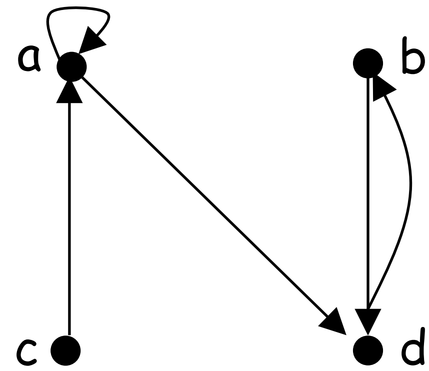
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

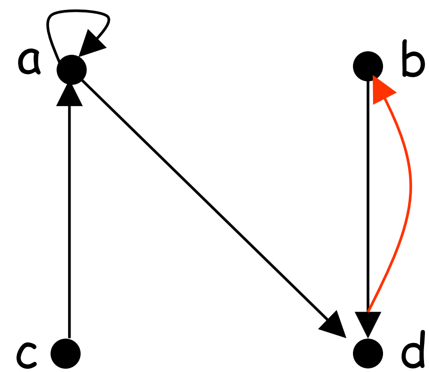
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

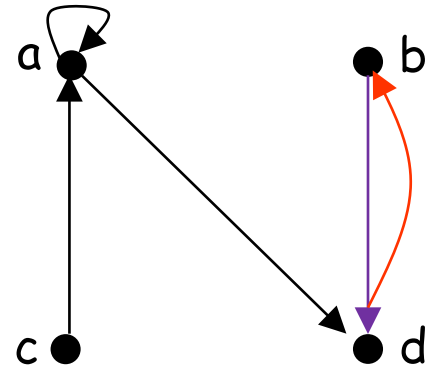
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

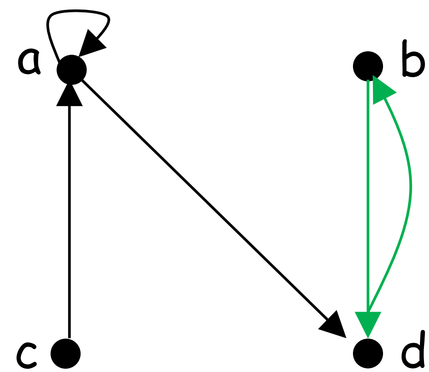
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

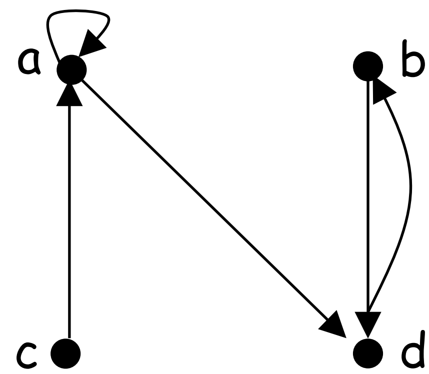
$$\begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$W_2 = \begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

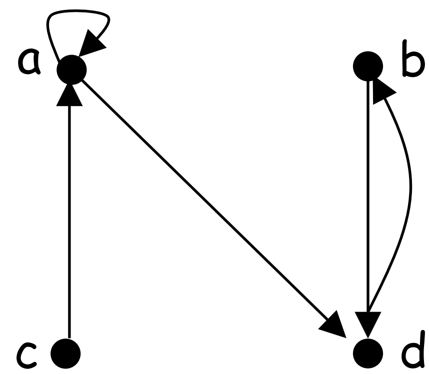
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

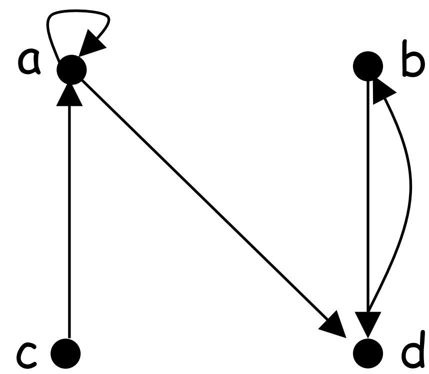
W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 0 & & \\ 0 & 0 & 0 & 1 \\ & 0 & & \\ & 1 & & 1 \end{pmatrix} \end{array}$$

Se completa la matriz W_2 con las demás aristas de W_1

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

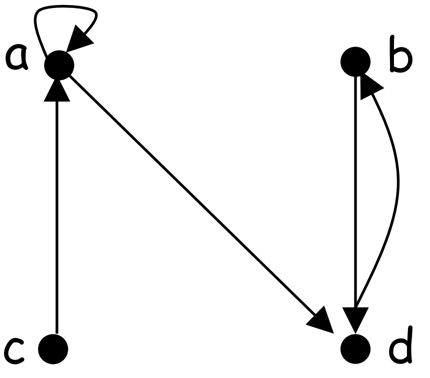
W_2 (pivote b)

$$W_2 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Se completa la matriz W_2 con las demás aristas de W_1

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$



W_1 (pivote a)

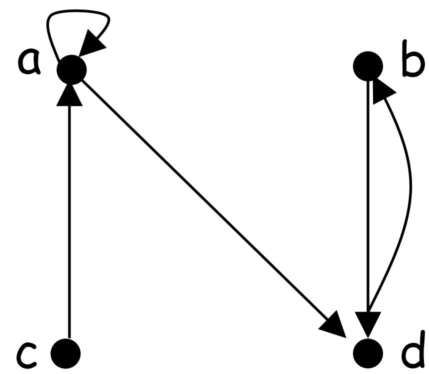
$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

W_2 (pivote b)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$



W_1 (pivote a)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

W_2 (pivote b)

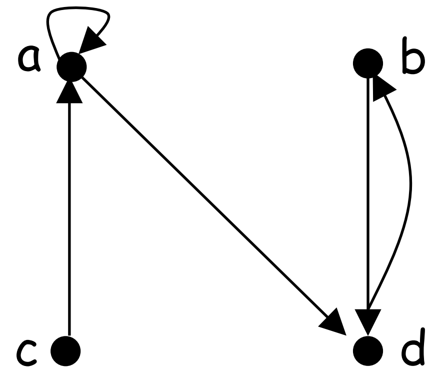
$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

W_3 (pivote c)

$$W_3 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

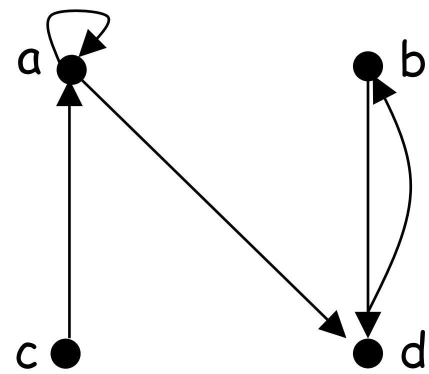
W_3 (pivote c)

$$W_3 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & & 0 & \\ & & 0 & \\ 1 & 0 & 0 & 1 \\ & & 0 & \end{pmatrix} \end{array}$$

No se adicionan aristas!

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

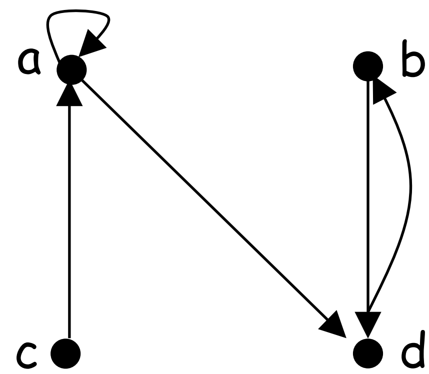
W_3 (pivote c)

$$W_3 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & & 0 & \\ & & 0 & \\ 1 & 0 & 0 & 1 \\ & & 0 & \end{pmatrix} \end{array}$$

Se completa la matriz W_3 con las demás aristas de W_2

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

W_2 (pivote b)

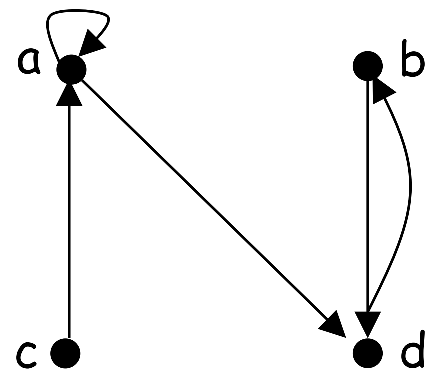
$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

W_3 (pivote c)

$$W_3 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

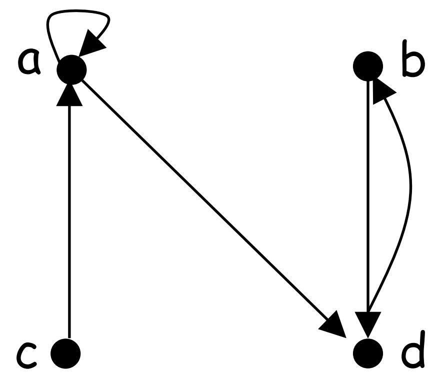
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$



W_1 (pivote a)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

W_2 (pivote b)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

W_3 (pivote c)

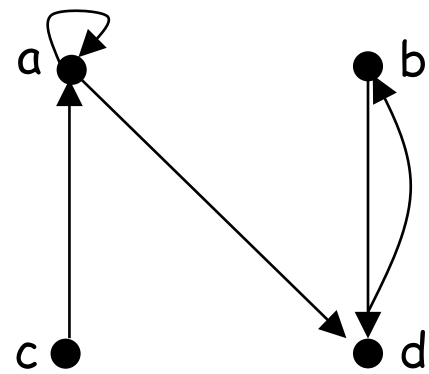
$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

W_4 (pivote d)

$$W_4 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 1 & 0 & 1 \\ b & 0 & 1 & 0 & 1 \\ c & 1 & 1 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

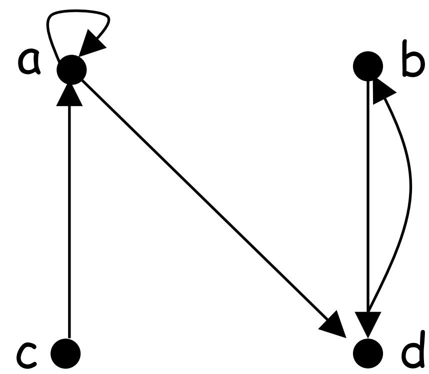
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$W_4 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 1 & & 1 \\ & & & 1 \\ & & & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

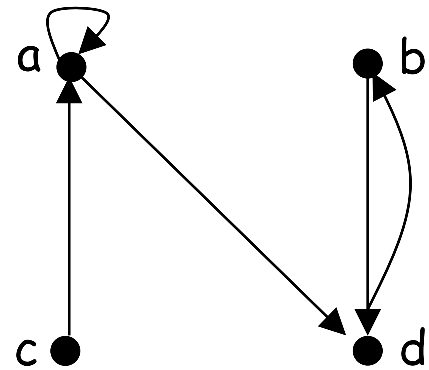
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$W_4 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\!\!\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 1 & & 1 \\ & 1 & & 1 \\ & & & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

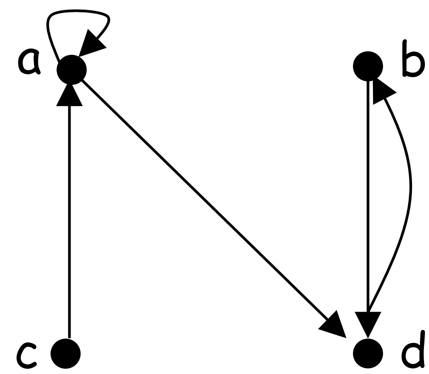
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$W_4 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} & 1 & & 1 \\ & 1 & & 1 \\ & 1 & \leftarrow & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 0 \\ d & 0 & 1 & 0 & 0 \end{array}$$



W_1 (pivote a)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 0 \end{array}$$

W_2 (pivote b)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

W_3 (pivote c)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 0 & 0 & 1 \\ b & 0 & 0 & 0 & 1 \\ c & 1 & 0 & 0 & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

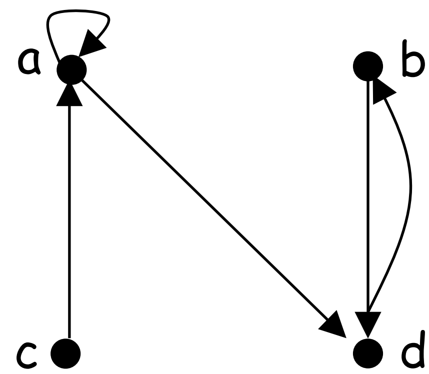
W_4 (pivote d)

$$W_4 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & & 1 & & 1 \\ b & & 1 & & 1 \\ c & & 1 & & 1 \\ d & 0 & 1 & 0 & 1 \end{array}$$

Se completa la matriz W_4 con las demás aristas de W_3

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

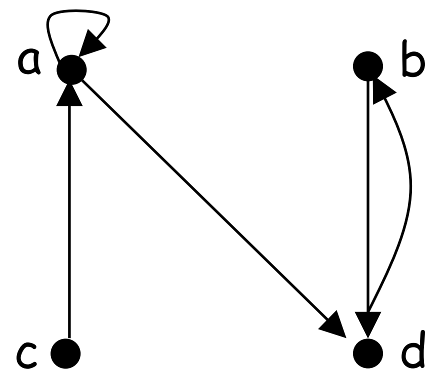
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$W_4 = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c|c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c|c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c|c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

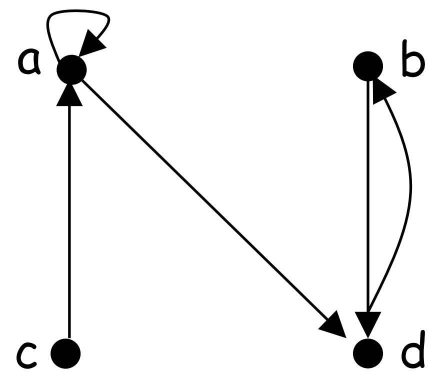
$$\begin{array}{c|c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{c|c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_3 (pivote c)

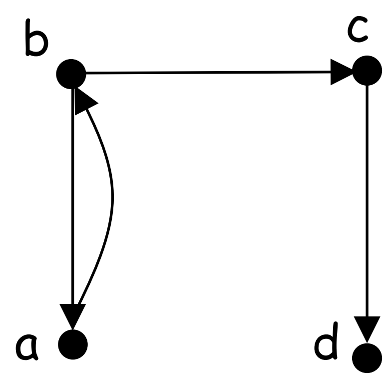
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix} \end{array} = M_R^{\infty}$$

Grafos

Aplicar el algoritmo de Warshall



$$W_{ij}^{k} = \begin{cases} M_R & k = 0 \\ W_{ij}^{k-1} \vee \left(W_{kj}^{k-1} \wedge W_{ik}^{k-1} \right) \end{cases}$$

$$M_R = \begin{array}{c|cccc} & a & b & c & d \\ a & 0 & 1 & 0 & 0 \\ b & 1 & 0 & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array} = W_0$$

$$W^1 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 0 & 1 & 0 & 0 \\ b & 1 & 1 & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

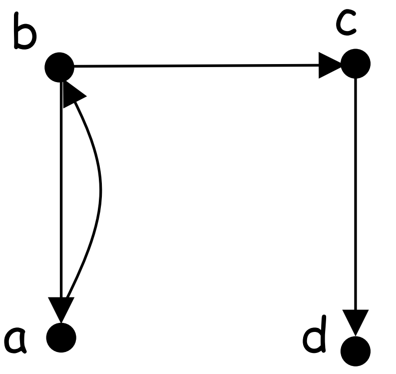
$$W^2 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 1 & 1 & 0 \\ b & 1 & 1 & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

$$W^3 : \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 1 & 1 & 1 \\ b & 1 & 1 & 1 & 1 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

$$W_4 = \begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 1 & 1 & 1 \\ b & 1 & 1 & 1 & 1 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

Grafos

$$W_0 = \quad M_R = \begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

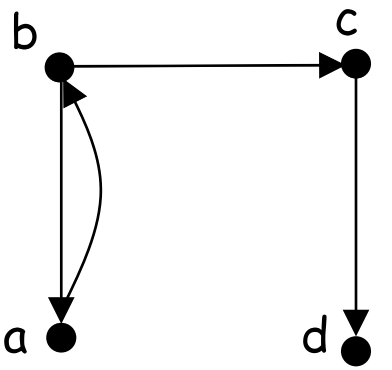


W_1 (pivote a)

$$\begin{array}{c c} & \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & \mathbf{1} & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \quad M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

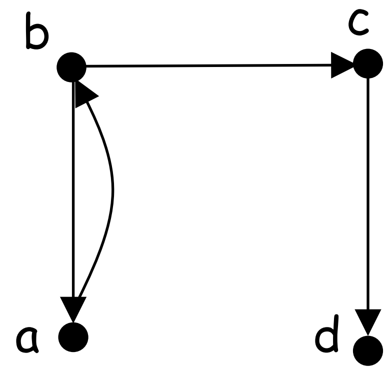
$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 0 & 1 & 0 & 0 \\ b & 1 & \mathbf{1} & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

W_2 (pivote b)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & \mathbf{1} & 1 & \mathbf{1} & 0 \\ b & 1 & 1 & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

Grafos

$$W_0 = \quad M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & \mathbf{1} & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

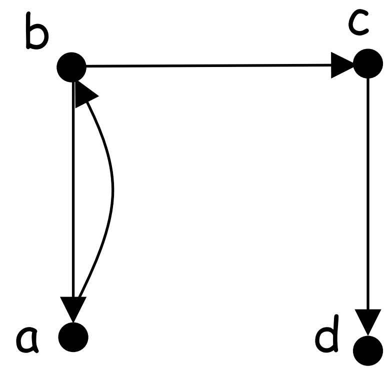
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} \mathbf{1} & 1 & \mathbf{1} & 0 \\ 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & \mathbf{1} \\ 1 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & \mathbf{1} & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} \mathbf{1} & 1 & \mathbf{1} & 0 \\ 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_3 (pivote c)

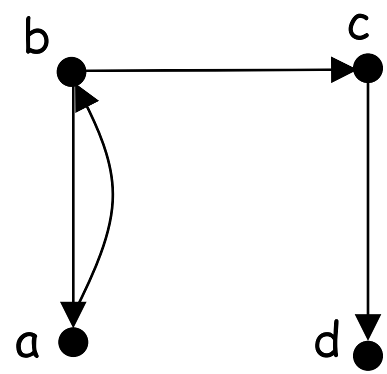
$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & \mathbf{1} \\ 1 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$



W_1 (pivote a)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 0 & 1 & 0 & 0 \\ b & 1 & \mathbf{1} & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

W_2 (pivote b)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & \mathbf{1} & 1 & \mathbf{1} & 0 \\ b & 1 & 1 & 1 & 0 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

W_3 (pivote c)

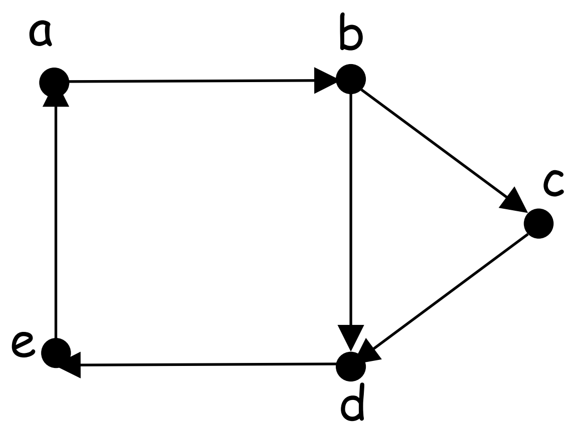
$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 1 & 1 & \mathbf{1} \\ b & 1 & 1 & 1 & \mathbf{1} \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array}$$

W_4 (pivote d)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline a & 1 & 1 & 1 & 1 \\ b & 1 & 1 & 1 & 1 \\ c & 0 & 0 & 0 & 1 \\ d & 0 & 0 & 0 & 0 \end{array} = M_R^{\infty}$$

Matriz de conectividad

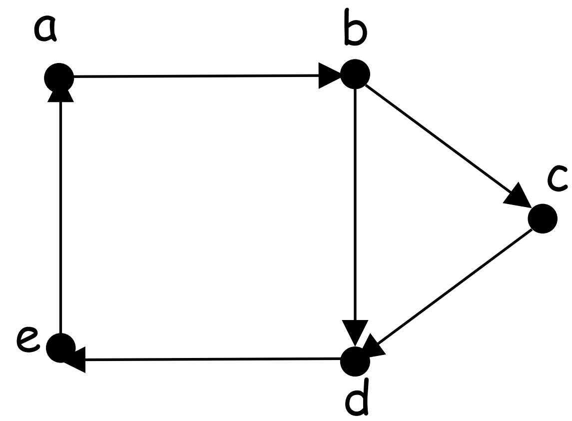
Aplicar el algoritmo de Warshall



$$M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Grafos

$$W_0 = \ M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

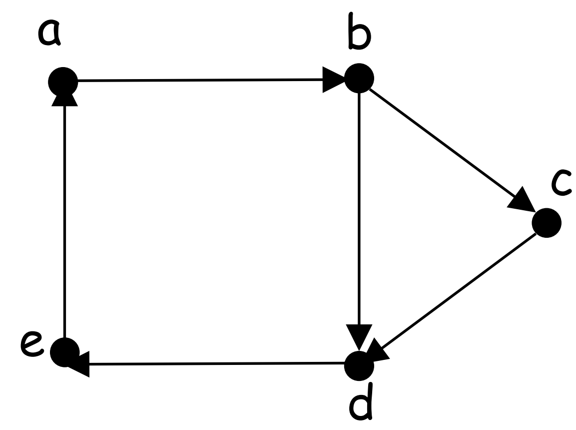


W_1 (pivote a)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & \mathbf{1} & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

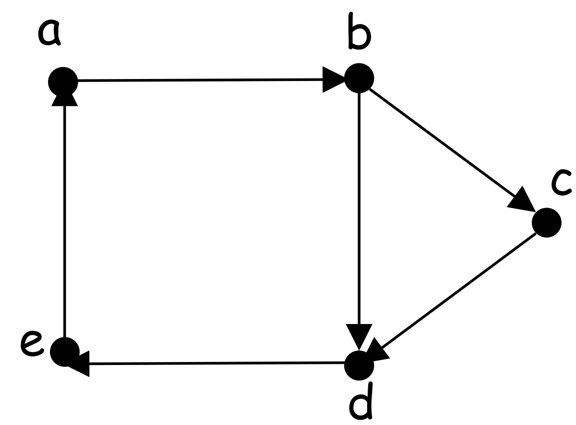
$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & \mathbf{1} & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & \mathbf{1} & \mathbf{1} & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & \mathbf{1} & \mathbf{1} & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & \mathbf{1} & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

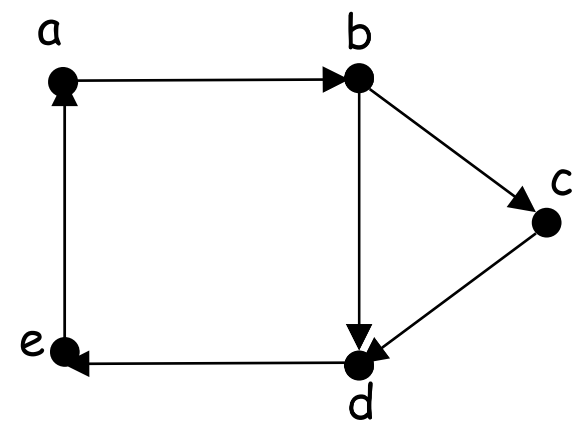
$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & \mathbf{1} & \mathbf{1} & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & \mathbf{1} & \mathbf{1} & 0 \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \ M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & \mathbf{1} & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & \mathbf{1} & \mathbf{1} & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & \mathbf{1} & \mathbf{1} & 0 \end{pmatrix} \end{array}$$

W_3 (pivote c)

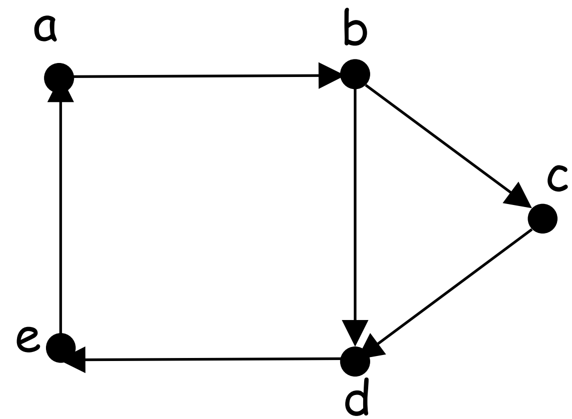
$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & \mathbf{1} \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & \mathbf{1} & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & \mathbf{1} & \mathbf{1} & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & \mathbf{1} & \mathbf{1} & 0 \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

W_4 (pivote d)

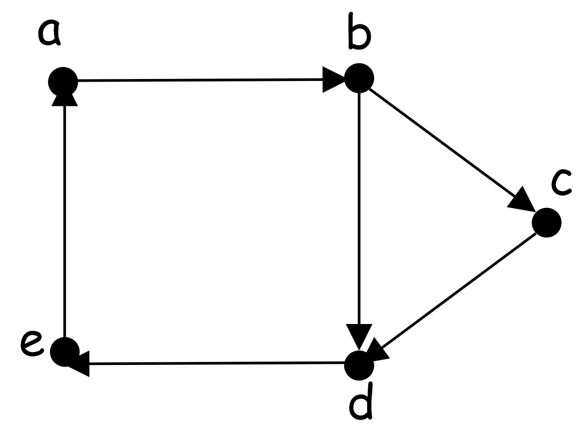
$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & \mathbf{1} \end{pmatrix} \end{array}$$

W_5 (pivote e)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} \mathbf{1} & 1 & 1 & 1 & 1 \\ \mathbf{1} & \mathbf{1} & 1 & 1 & 1 \\ \mathbf{1} & \mathbf{1} & \mathbf{1} & 1 & 1 \\ \mathbf{1} & \mathbf{1} & \mathbf{1} & \mathbf{1} & 1 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \quad M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & \mathbf{1} & 0 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & \mathbf{1} & \mathbf{1} & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & \mathbf{1} & \mathbf{1} & 0 \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 1 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 1 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & \mathbf{1} \end{pmatrix} \end{array}$$

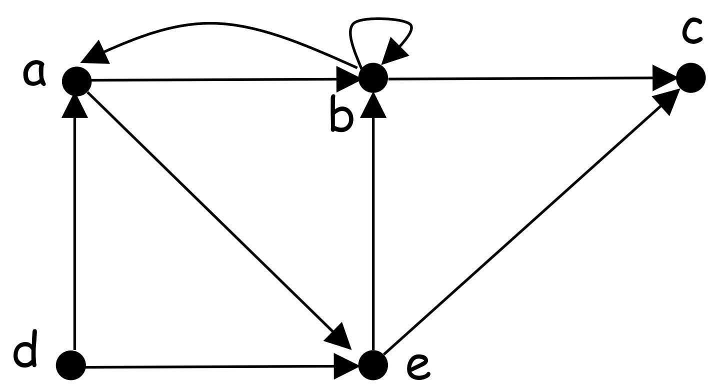
W_5 (pivote e)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \end{array}$$

Matriz de conectividad

Grafos

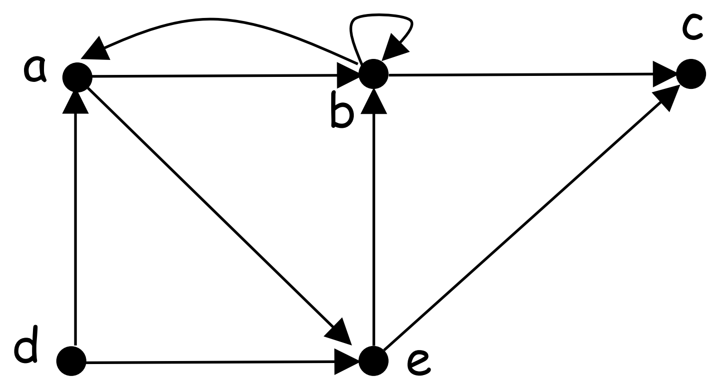
Aplicar el algoritmo de Warshall



$$M_R = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \; M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$

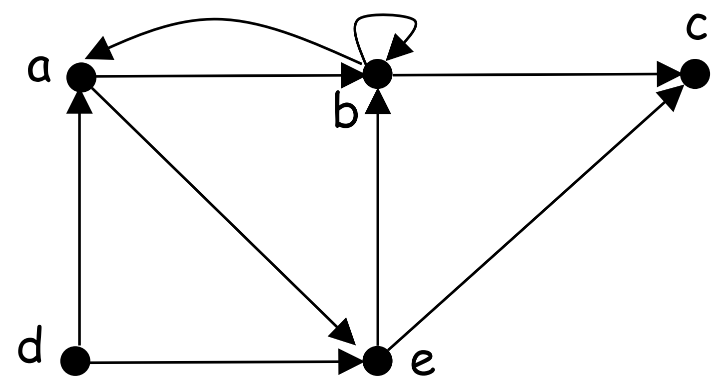


W_1 (pivote a)

$$\begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 0 \\ 1 & \mathbf{1} & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \ M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

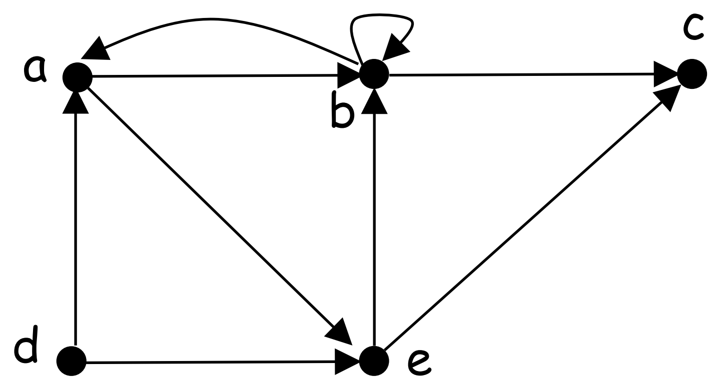
$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 0 \\ 1 & \mathbf{1} & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} \mathbf{1} & 1 & \mathbf{1} & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & \mathbf{1} & 0 & 1 \\ \mathbf{1} & 1 & 1 & 0 & \mathbf{1} \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{c|c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 0 \\ 1 & \mathbf{1} & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

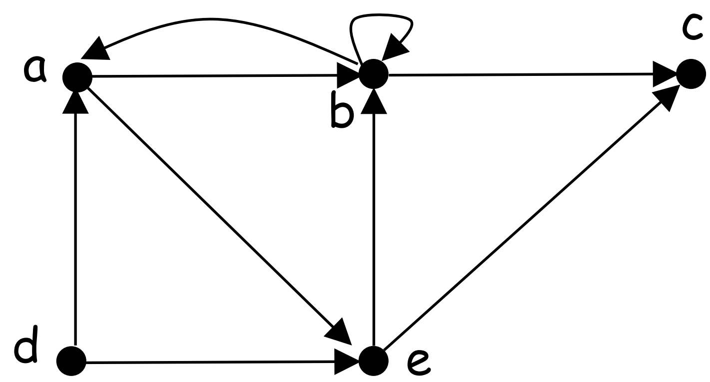
$$\begin{array}{c|c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} \mathbf{1} & 1 & \mathbf{1} & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & \mathbf{1} & 0 & 1 \\ \mathbf{1} & 1 & 1 & 0 & \mathbf{1} \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c|c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \; M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 0 \\ 1 & \mathbf{1} & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} \mathbf{1} & 1 & \mathbf{1} & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & \mathbf{1} & 0 & 1 \\ \mathbf{1} & 1 & 1 & 0 & \mathbf{1} \end{pmatrix} \end{array}$$

W_3 (pivote c)

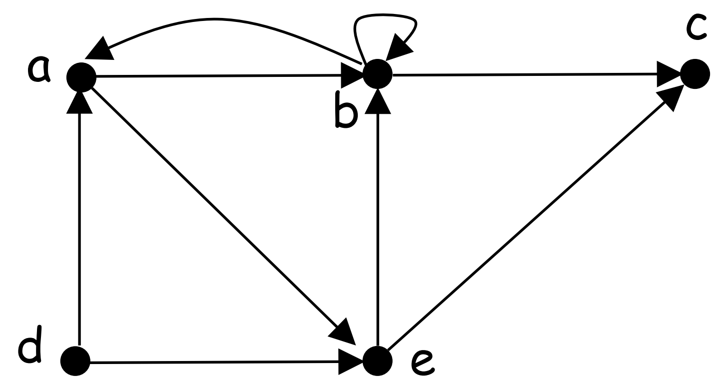
$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{c c} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$



W_1 (pivote a)

$$\begin{array}{cc} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & \mathbf{1} \\ 0 & 0 & 0 & 0 & 0 \\ 1 & \mathbf{1} & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix} \end{array}$$

W_2 (pivote b)

$$\begin{array}{cc} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} \mathbf{1} & 1 & \mathbf{1} & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & \mathbf{1} & 0 & 1 \\ \mathbf{1} & 1 & 1 & 0 & \mathbf{1} \end{pmatrix} \end{array}$$

W_3 (pivote c)

$$\begin{array}{cc} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

W_4 (pivote d)

$$\begin{array}{cc} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

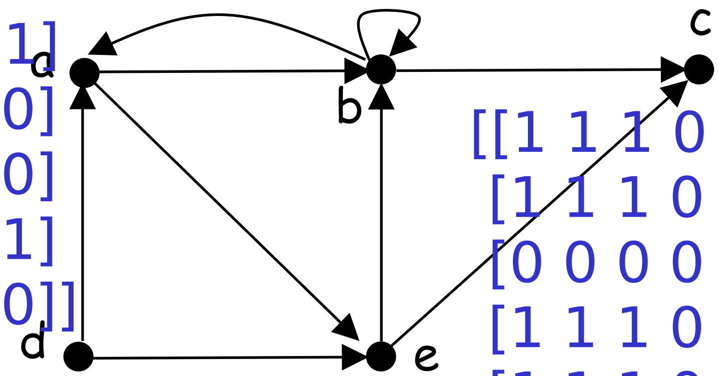
W_5 (pivote e)

$$\begin{array}{cc} & \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \end{array} & \begin{pmatrix} 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Grafos

$$W_0 = \quad M_R = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & \boxed{1} & \boxed{1} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$

[[0 1 0 0 1]
 [1 1 1 0 0]
 [0 0 0 0 0]
 [1 0 0 0 1]
 [0 1 1 0 0]]



[[1 1 1 0 1]
 [1 1 1 0 1]
 [0 0 0 0 0]
 [1 1 1 0 1]
 [1 1 1 0 1]]

$r_1 = 1$

W_1 (pivote a)

$$\begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 0 & 1 & 0 & 0 & 1 \\ b & 1 & \boxed{1} & \boxed{1} & 0 & \boxed{1} \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & \mathbf{1} & 0 & 0 & 1 \\ e & 0 & 1 & 1 & 0 & 0 \end{array}$$

$w^0[k,i] \cap w^0[j,k]$

W_2 (pivote b)

$$\begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & \mathbf{1} & 1 & \mathbf{1} & 0 & 1 \\ b & 1 & 1 & 1 & 0 & 1 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & 1 & \mathbf{1} & 0 & 1 \\ e & \mathbf{1} & 1 & 1 & 0 & \mathbf{1} \end{array}$$

W_3 (pivote c)

$$\begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 1 & 1 & 1 & 0 & 1 \\ b & 1 & 1 & 1 & 0 & 1 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & 1 & 1 & 0 & 1 \\ e & 1 & 1 & 1 & 0 & 1 \end{array}$$

W_4 (pivote d)

$$\begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 1 & 1 & 1 & 0 & 1 \\ b & 1 & 1 & 1 & 0 & 1 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & 1 & 1 & 0 & 1 \\ e & 1 & 1 & 1 & 0 & 1 \end{array}$$

W_5 (pivote e)

$$\begin{array}{c|ccccc} & a & b & c & d & e \\ \hline a & 1 & 1 & 1 & 0 & 1 \\ b & 1 & 1 & 1 & 0 & 1 \\ c & 0 & 0 & 0 & 0 & 0 \\ d & 1 & 1 & 1 & 0 & 1 \\ e & 1 & 1 & 1 & 0 & 1 \end{array}$$

Matriz de conectividad