

TP N° 6: Crowd Simulation

Grupo N° 5

A black silhouette of a crowd of five people holding a large banner. The banner is a solid black rectangle with a wavy top and bottom edge, and the names 'Daniel Lobo | Agustín Golmar' are written on it in white. The crowd consists of five stylized human figures, also in black silhouette, holding the banner from below.

Daniel Lobo | Agustín Golmar

A decorative network diagram in the top-left corner, featuring a complex web of interconnected nodes and lines. Some nodes are highlighted with blue circles, and others with blue dots. The diagram is rendered in a light gray color.

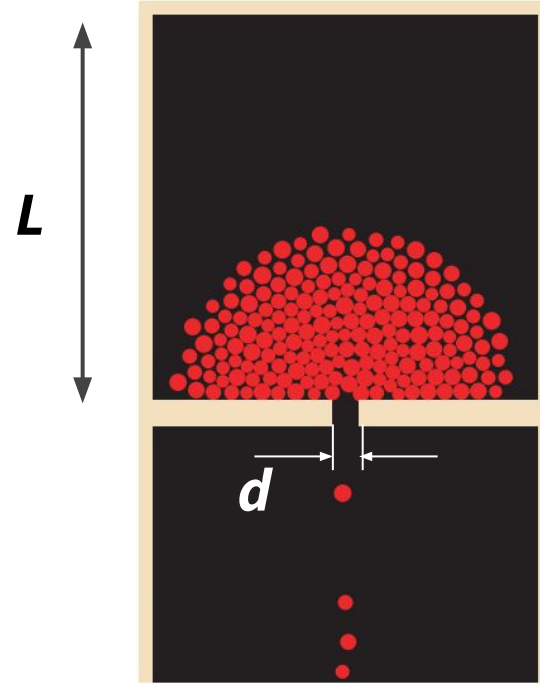
Fundamentos

A decorative network diagram in the bottom-right corner, similar to the one in the top-left, featuring a complex web of interconnected nodes and lines. Some nodes are highlighted with blue circles, and others with blue dots. The diagram is rendered in a light gray color.

Sistema Físico

*“Comportamiento de una **multitud** intentando evacuar una sala cuadrada.”*

*“La sala posee lado **L**, y una puerta de ancho **d**.”*



Modelo Matemático

(Social Force Model)

$$\bar{F}_{flow} = \bar{F}_{driven} + \sum \bar{F}_{social} + \sum \bar{F}_{normal} + \sum \bar{F}_{friction}$$

- Fuerza de **Deseo**

$$\bar{F}_{driven} = \frac{m}{\tau} (v_d \hat{n}_0 - \bar{v})$$

- Fuerza **Social**

$$\bar{F}_{social} = -A e^{\frac{\xi_0}{B}} \hat{n}$$

- Fuerza **Normal** (choque), y de **Fricción**

$$\bar{F}_{normal} = (-k_n \xi_0 - \gamma \xi_1) \hat{n} \qquad \bar{F}_{friction} = -k_t \xi_0 \langle r_1^\Delta, \hat{t} \rangle \hat{t}$$

Modelo Matemático

$$\bar{F}_{normal} = (-k_n \xi_0 - \gamma \xi_1) \hat{n} \quad \bar{F}_{friction} = -k_t \xi_0 \langle r_1^\Delta, \hat{t} \rangle \hat{t}$$

- Dirección **normal** y **tangencial**

$$\hat{n} = \frac{r_0^j - r_0^i}{\|r_0^j - r_0^i\|} \quad \hat{t} = (-\hat{n}_y, \hat{n}_x)$$

- Superposición

$$\xi_0 = R_i + R_j - \|r_0^j - r_0^i\|$$

- Velocidad de superposición y relativa

$$\xi_1 = \frac{\langle r_0^j - r_0^i, r_1^\Delta \rangle}{\|r_0^j - r_0^i\|} \quad r_1^\Delta = r_1^i - r_1^j$$

Modelo Matemático

$$\bar{F}_{driven} = \frac{m}{\tau} (v_d \hat{n}_0 - \bar{v})$$

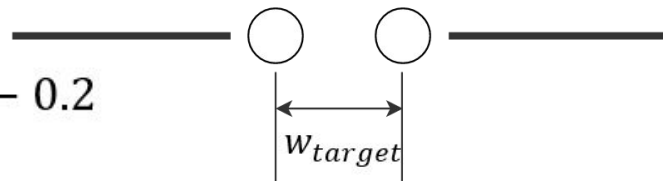
- Dirección **normal** hacia el objetivo (*target*) $\hat{n}_0 = \frac{\bar{t}_0 - r_0^i}{\|\bar{t}_0 - r_0^i\|}$

- Target **ancho**

$$w_{target} = d - 2R_{max} - 0.2$$

- Target **dinámico**

$$r_{0,y}^i < 0 \rightarrow \bar{t}_0 = (r_{0,x}^i, r_{0,y}^i - 1)$$



Modelo Matemático

$$\bar{F}_{social} = -A e^{\frac{\xi_0}{B}} \hat{n}$$

- Dirección **normal**
- Radio de acción (**2.5 m**, máximo)

$$A = 2000 \text{ N}, B = 0.08 \text{ m}, \xi_0 < -2.5 \text{ m} \rightarrow F_{social} < 6 \times 10^{-11}$$

A decorative background featuring a network diagram with nodes and connecting lines. Some nodes are highlighted with blue circles or dots. The diagram is composed of grey lines and dots, with blue highlights scattered throughout.

Implementación

Modelo Computacional

- Java 8 SE Release

- JSON

(<https://www.json.org/>)

- Jackson 2.9.5

(<https://github.com/FasterXML/jackson>)

- Ovito

(<https://ovito.org/>)

- Microsoft Excel

(<https://products.office.com/en/excel>)

- Draw.io

(<https://www.draw.io/>)

- Reutilización de:

- Todo el **TP N° 5 !!!**

- Integrador **Beeman**

- Doble caché (*Cell Index*)

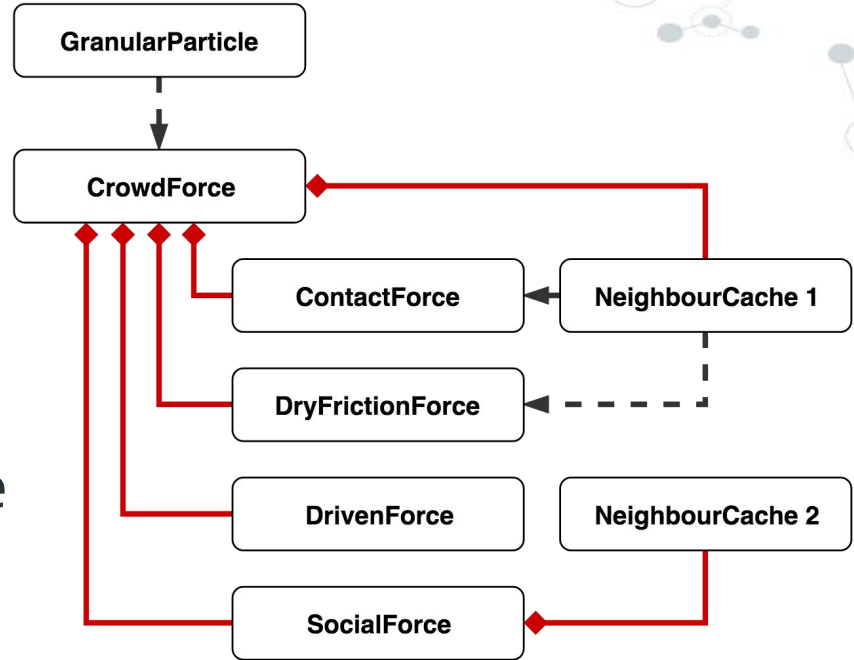
- Solo se agregan 2 fuerzas:

- DrivenForce
- SocialForce

Campos de Fuerza

(ForceField<T> Interface)

- **CrowdForce**
 - DrivenForce
 - SocialForce
 - ContactForce
 - DryFrictionForce



Configuración

(JSON Input)

- Paso temporal (10^{-4})

$$\Delta t < \sqrt{\frac{m}{100 k_n}}$$

- Paper de Vicsek¹ *et. al.*
- Amortiguación **crítica**

$$\gamma_{critic} = 2\sqrt{mk_n}$$

```
{
  "output"      : "res/data/output",
  "delta"       : "0.0001",
  "time"        : "120.0",
  "fps"         : "50",
  "playbackSpeed" : "1.0",
  "samplesPerSecond" : "200",
  "integrator"  : "BeemanIntegrator",
  "reportEnergy" : "false",
  "reportTime"  : "true",
  "radius"      : ["0.25", "0.29"],
  "mass"        : "80.0",
  "elasticNormal" : "1.2E+5",
  "elasticTangent" : "2.4E+5",
  "viscousDamping" : "6196.773354",
  "siloDamping"  : "6196.773354",

  "a"           : "2000.0",
  "b"           : "0.08",
  "tau"         : "0.5",
  "desiredSpeed" : "5.0",
  "breakRange"  : "2.5",
  "target"      : ["10.0", "0.0"],
  "targetWidth" : "0.42",

  "generator"   : "73604268647601935",
  "n"           : "200",
  "height"      : "20.0",
  "width"       : "20.0",
  "drain"       : "1.2",
  "window"      : "5.0",
  "flowRate"    : "0.01"
}
```

¹ "Simulating Dynamical Features of Escape Panic". Dirk Helbing, Illés Farkas and Tamás Vicsek. *Nature*, Vol. 407. 28th September, 2000. Macmillan Magazine.

Formato de Archivos

(Output)

- Formato **.static*, propiedades estáticas del sistema:
`<radius> <mass>`
- Formato **.state*, para el estado del sistema (propiedades dinámicas):
`<x> <y> <vx> <vy>`
- Formato **.pressure*, para almacenar la presión:
`<pressure>`
- Formato **.xyz* (para Ovito):
`<n>`
`<time>`
`<x> <y> <radius> <speed> <pressure>`
- Formato **.drain* (eventos de egreso):
`<time> <id>`
- Formato **.flow* (caudal, con **sliding-window**):
`<time> <flow>`

A decorative network diagram in the top-left corner of the slide. It features a complex web of interconnected nodes and edges. The nodes are represented by small circles, some of which are solid blue, some are solid grey, and some are outlined in blue. The edges are thin grey lines connecting the nodes. The overall structure is dense and organic, resembling a molecular or biological network.

Simulación

Consideraciones

- Se colorean las partículas según la **presión**:

$$P = \frac{1}{2\pi R_i} \left\| \sum \bar{F}_{normal} + \bar{F}_{social} \right\|$$

- La fuerza social **no aplica contra las paredes**, como en *Vicsek et. al.*
- No hay reingreso de partículas.
- Todos los *peatones* poseen la misma masa (**80 kg**).
- Se utiliza **sliding-window** para computar la evolución del caudal (ventana de **5 s** y *sliding* de **0.01 s**).
- El valor promediado en la ventana (T_n, T_{n+1}), se asigna a **T_{n+1}** .

Sliding-window

(Cálculo del Caudal)

- Sea $E = T(0), \dots, T(n)$ una lista de tiempos de egreso.
- Sea W el ancho de la ventana.
- Sea S el *sliding*.
- Sea T el tiempo máximo muestreado.
- Sea $Q(e) = e/W$ el caudal, siendo e los egresos en el tiempo t .
- Aplicar el siguiente algoritmo:
 1. Sea k entero entre 0 y $\text{ceil}((T - W)/S)$ (ambos, inclusive).
 2. Sea $\Delta t = kS$ y $t = W + \Delta t$.
 3. Definir $e = \#\{t' \text{ en } E \mid \Delta t \leq t' < t\}$.
 4. Definir el caudal en el tiempo t como $Q(e)$.
 5. Repetir para el siguiente k .

Simulación - 1

(50 FPS | Speed x1.0 | 720p)

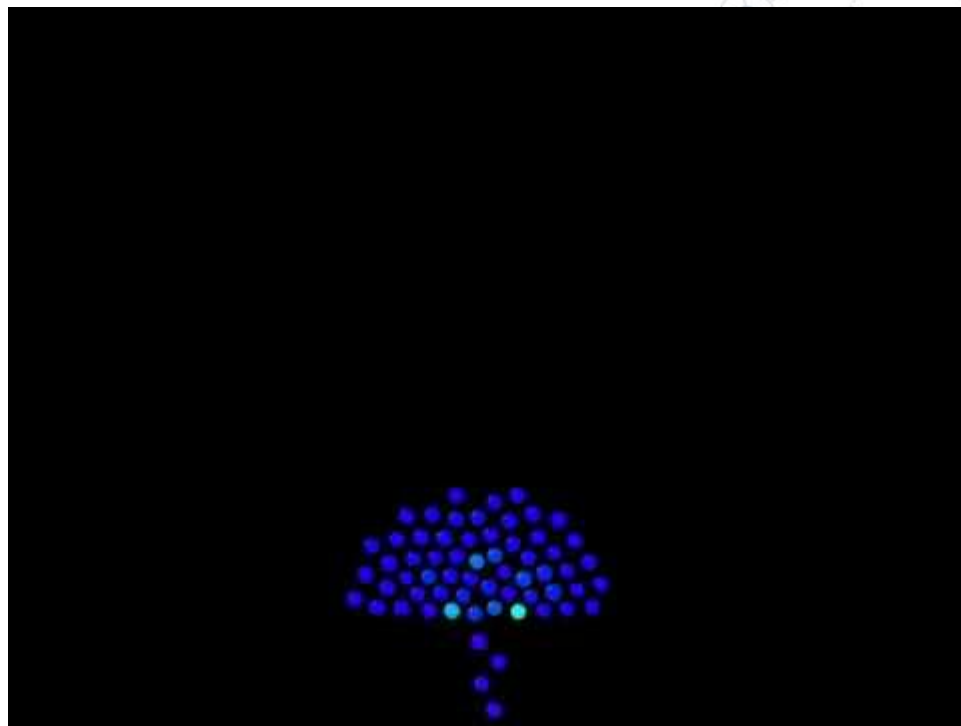
```
{  
  ...  
  "time"      : "180",  
  "n"         : "100",  
  "deltat"    : "0.002",  
  "desiredSpeed" : "0.5",  
  ...  
}
```



Simulación - 2

(50 FPS | Speed x1.0 | 720p)

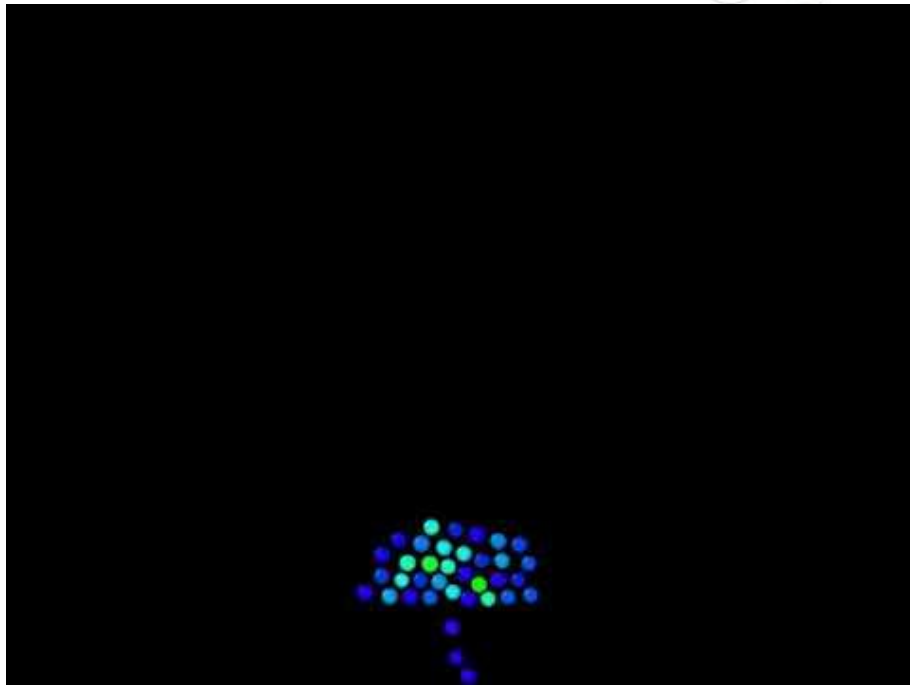
```
{  
  ...  
  "time"      : "75",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "1.0",  
  ...  
}
```



Simulación - 3

(50 FPS | Speed x1.0 | 720p)

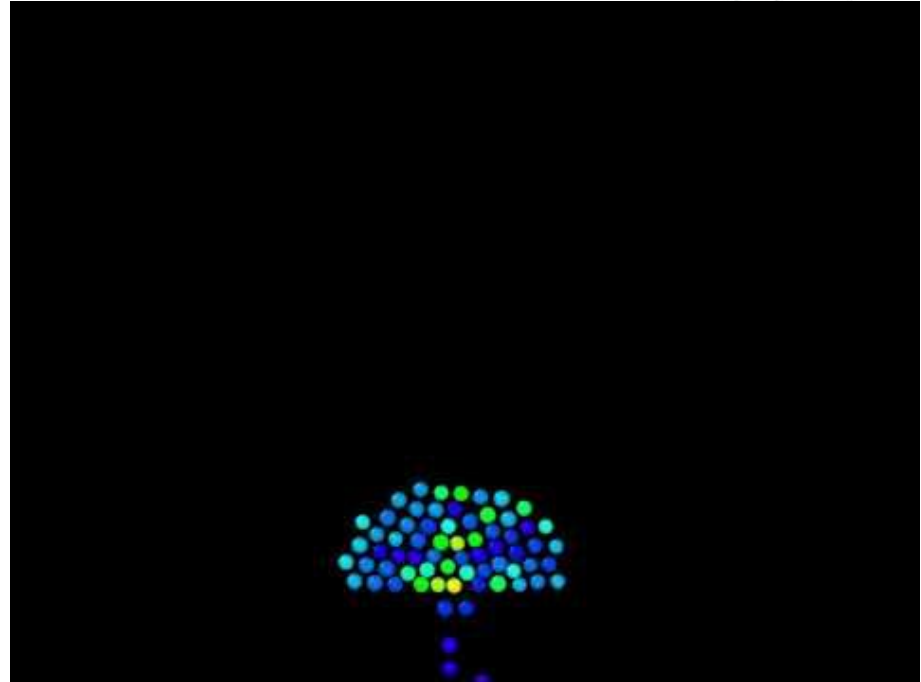
```
{  
  ...  
  "time"      : "40",  
  "n"         : "100",  
  "deltat"    : "0.0003",  
  "desiredSpeed" : "2.0",  
  ...  
}
```



Simulación - 4

(50 FPS | Speed x1.0 | 720p)

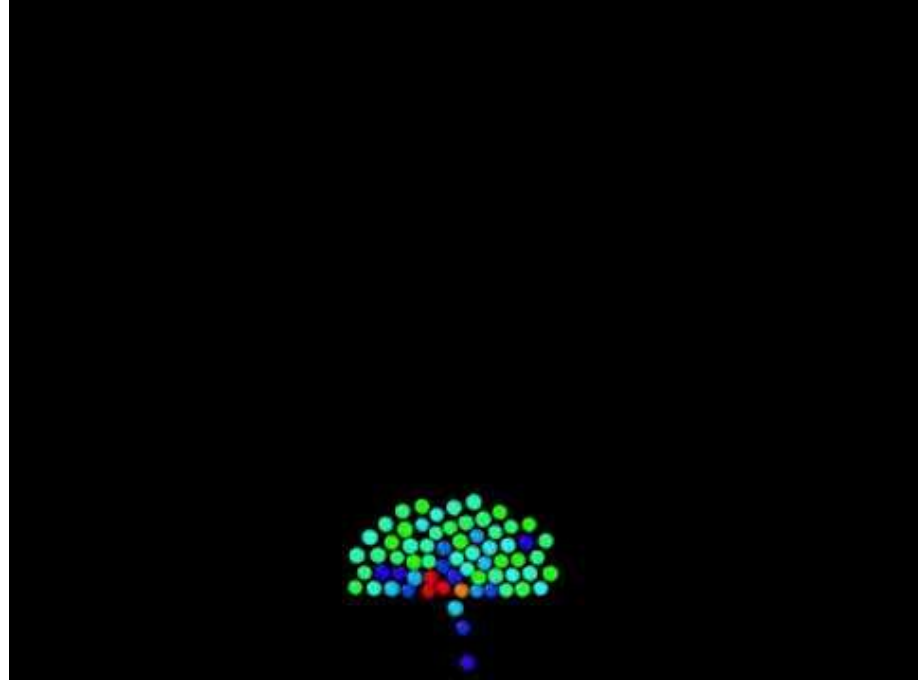
```
{  
  ...  
  "time"      : "30",  
  "n"         : "100",  
  "deltat"    : "0.0001",  
  "desiredSpeed" : "3.0",  
  ...  
}
```



Simulación - 5

(50 FPS | Speed x1.0 | 720p)

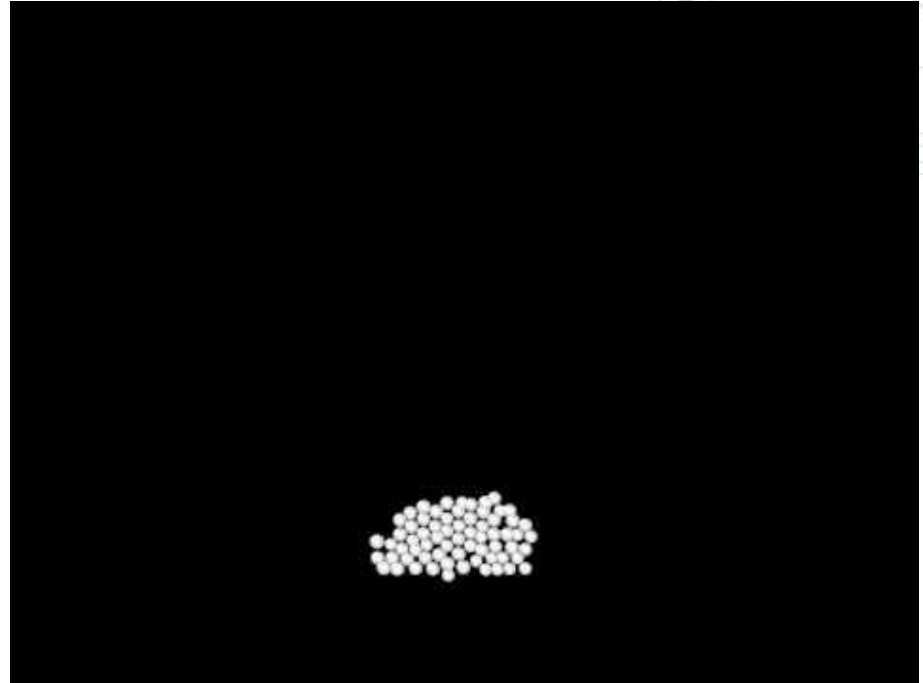
```
{  
  ...  
  "time"      : "80",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "4.0",  
  ...  
}
```



Simulación - 6

(50 FPS | Speed x1.0 | 720p)

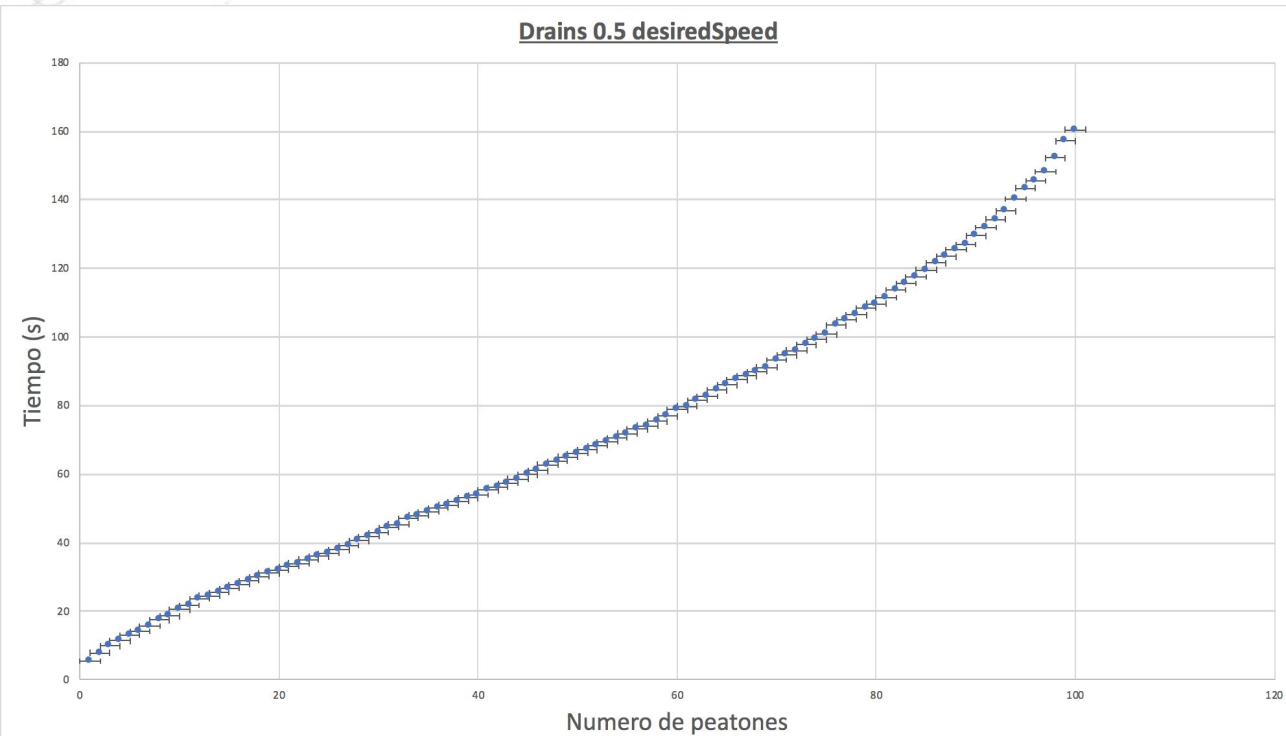
```
{  
  ...  
  "time"      : "80",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "4.0",  
  "A"         : "0",  
  ...  
}
```



A decorative network diagram in the top-left corner of the slide. It features a complex web of interconnected nodes and edges. The nodes are represented by small circles, some of which are solid blue, some are solid grey, and some are hollow blue. The edges are thin grey lines connecting the nodes. The overall shape of the network is roughly triangular, pointing towards the top-left corner.

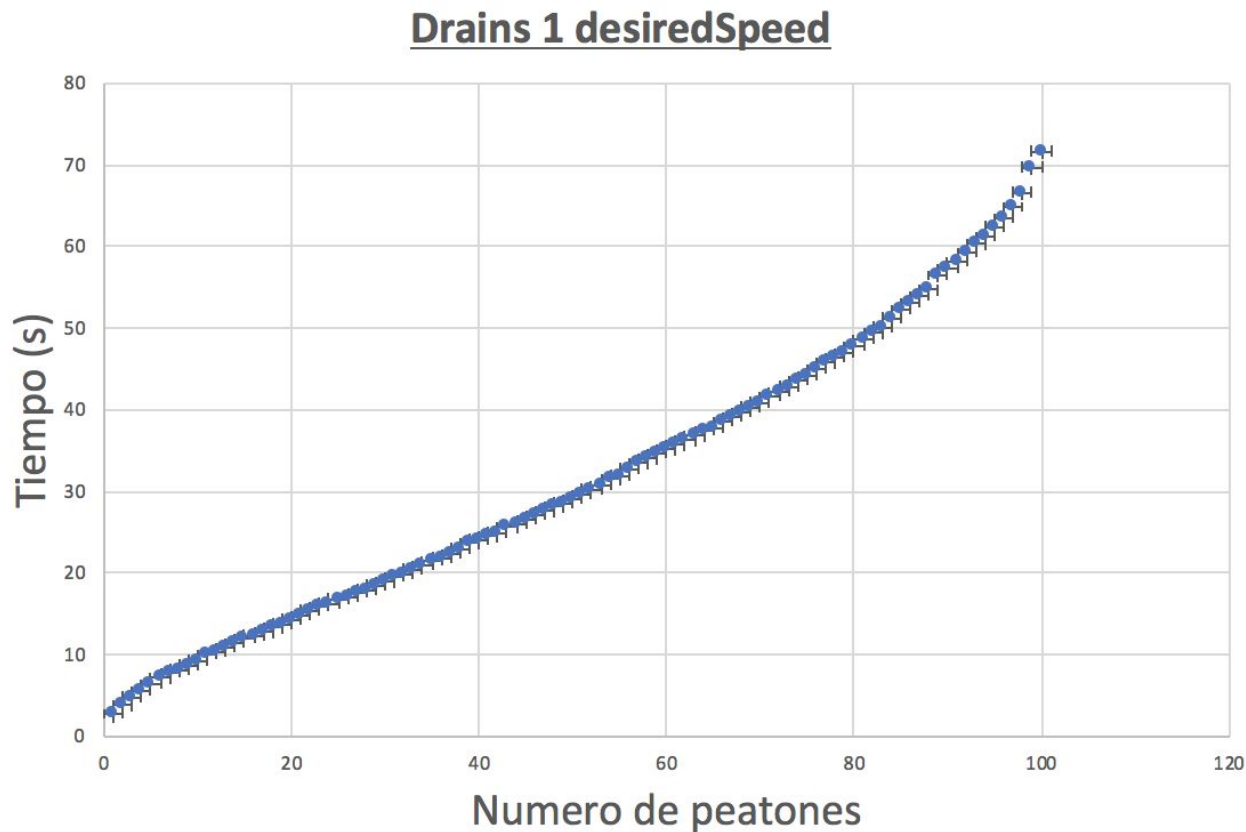
Resultados

Tiempo en f. Del número de peatones



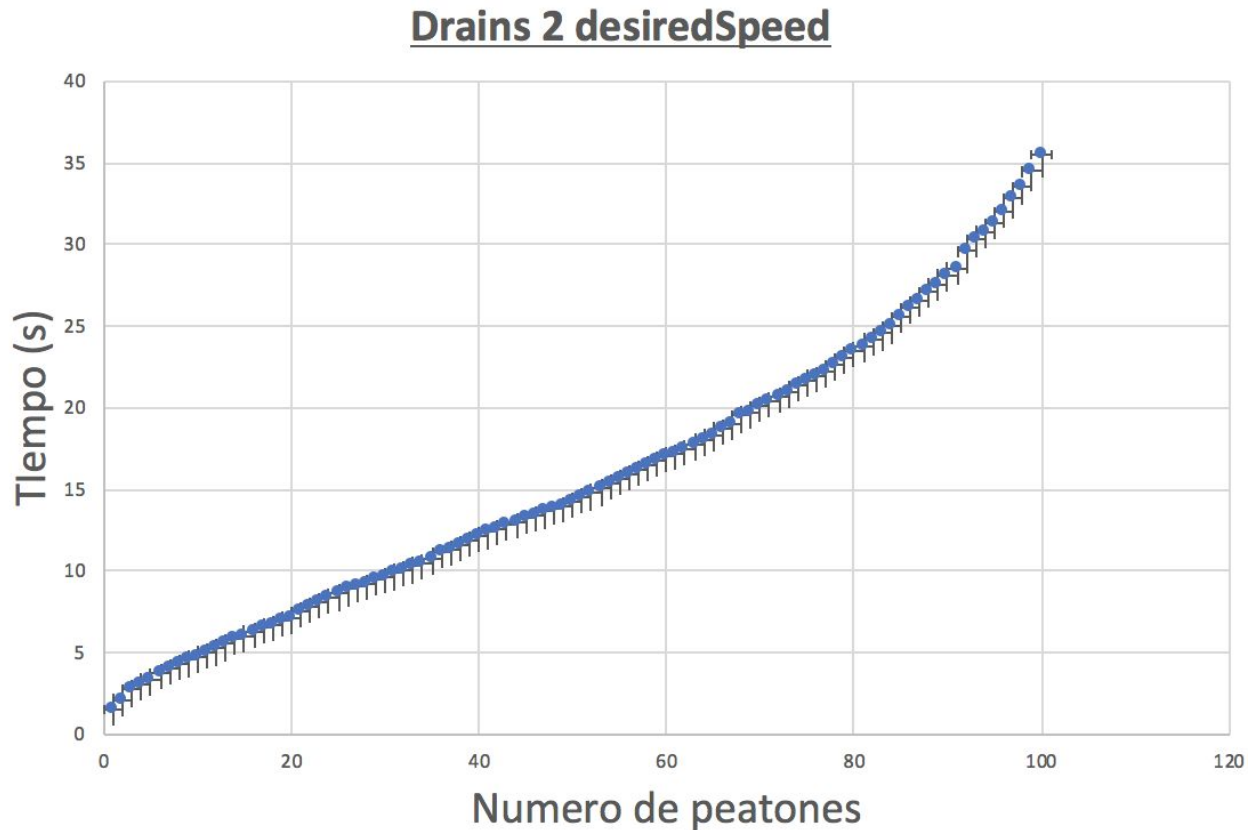
```
{  
  ...  
  "time"      : "180",  
  "n"         : "100",  
  "deltat"    : "0.002",  
  "desiredSpeed" : "0.5",  
  ...  
}
```

Tiempo en f. Del número de peatones



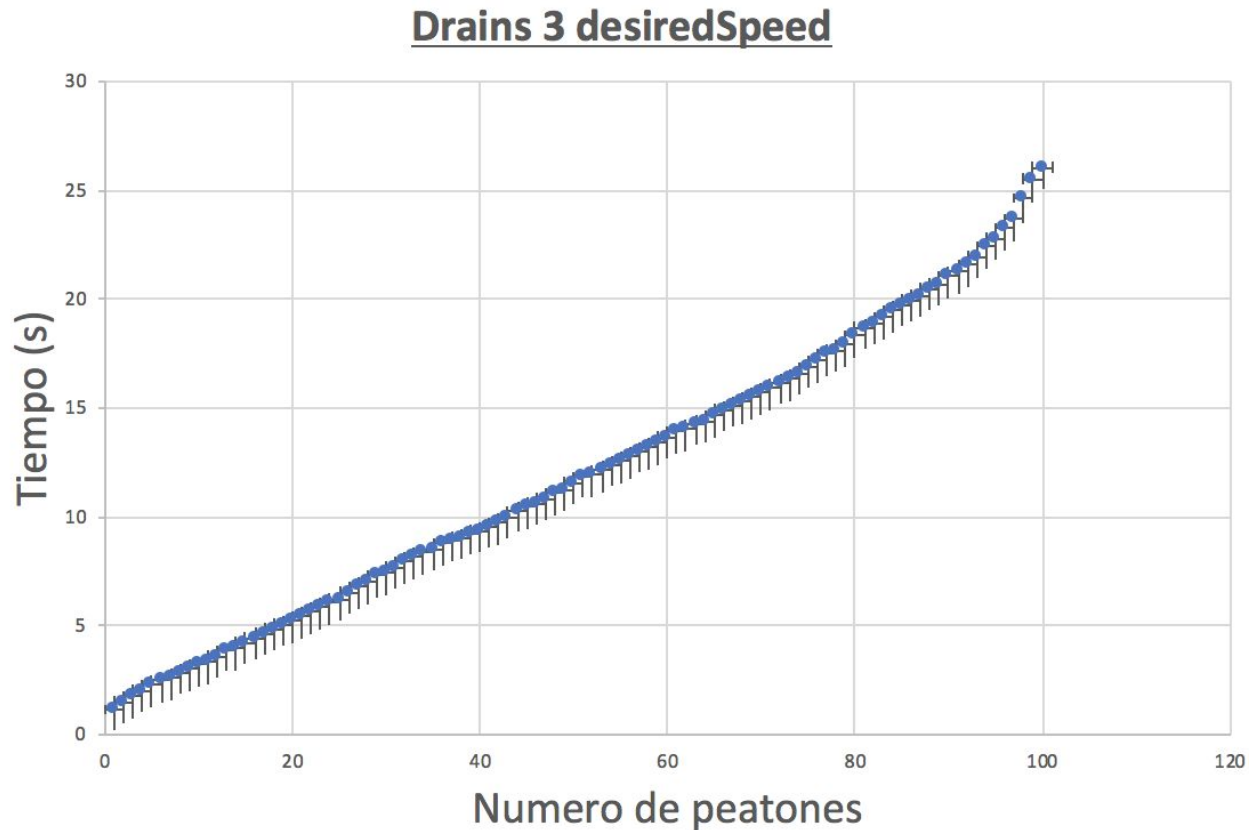
```
{  
  ...  
  "time"      : "75",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "1.0",  
  ...  
}
```


Tiempo en f. Del número de peatones



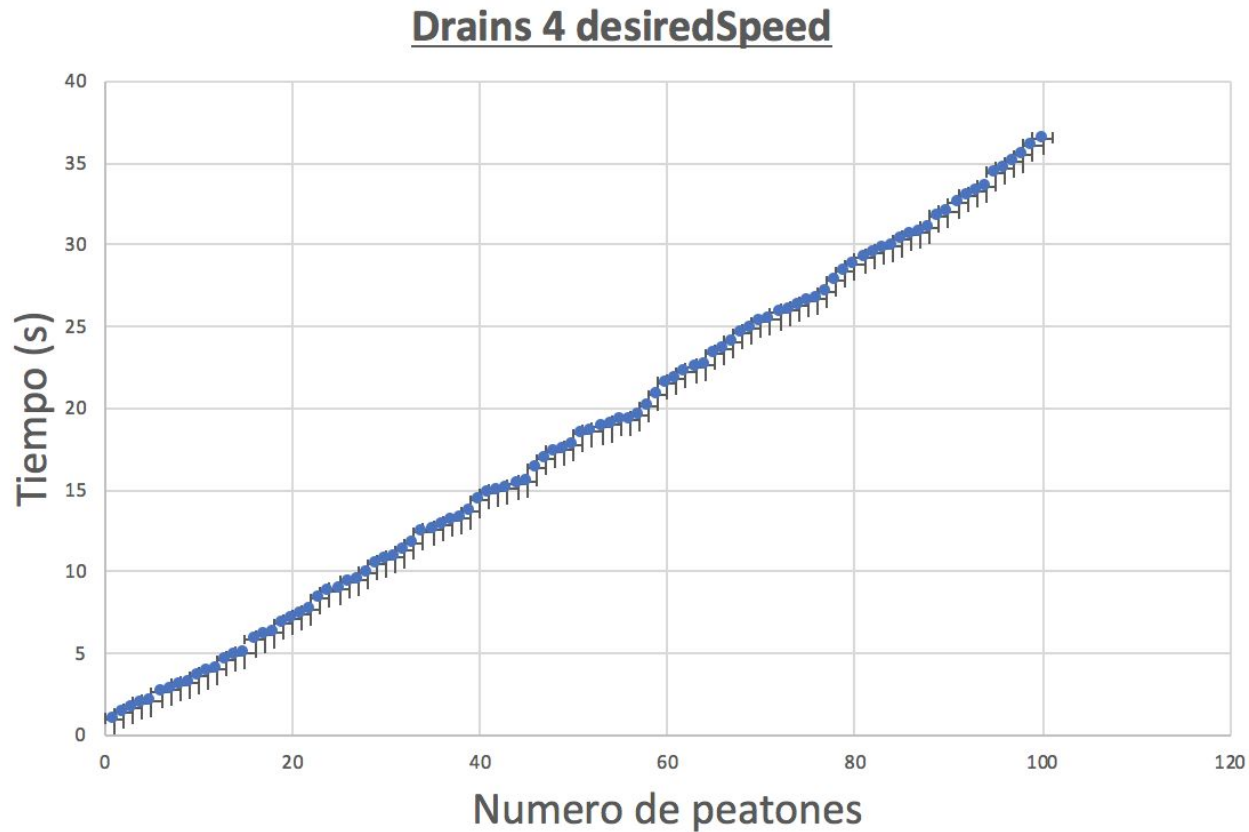
```
{  
  ...  
  "time"      : "40",  
  "n"         : "100",  
  "deltat"    : "0.0003",  
  "desiredSpeed" : "2.0",  
  ...  
}
```

Tiempo en f. Del número de peatones



```
{  
  ...  
  "time"      : "30",  
  "n"         : "100",  
  "deltat"    : "0.0001",  
  "desiredSpeed" : "3.0",  
  ...  
}
```

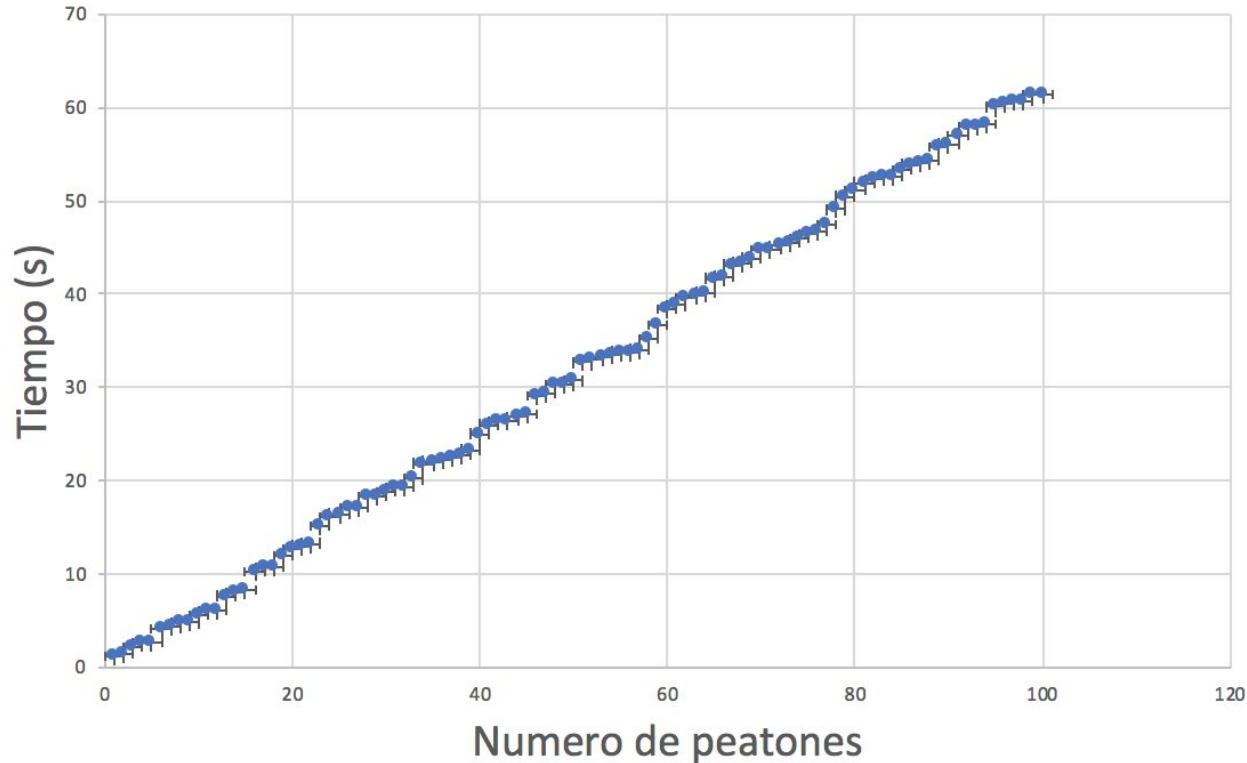
Tiempo en f. Del número de peatones



```
{  
  ...  
  "time"      : "80",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "4.0",  
  ...  
}
```

Tiempo en f. Del número de peatones

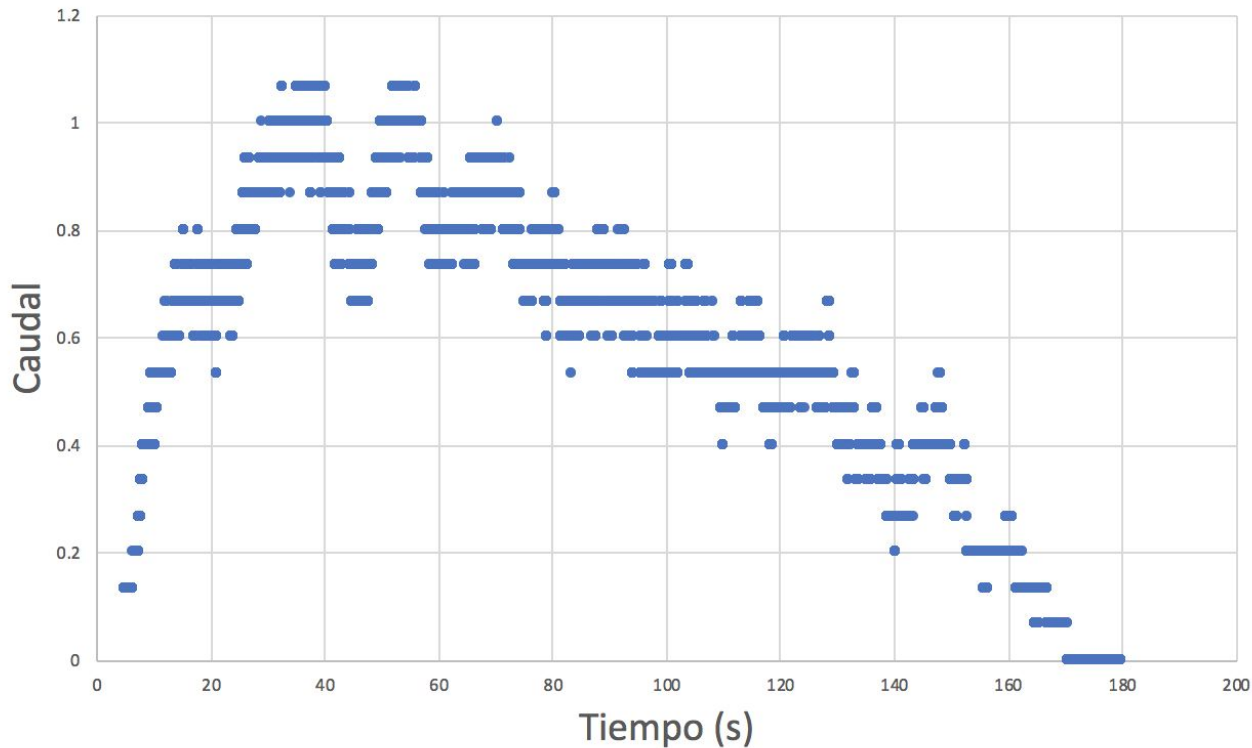
Drains 4 desiredSpeed - A = 0



```
{  
  ...  
  "time"      : "80",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "4.0",  
  "A"         : "0",  
  ...  
}
```

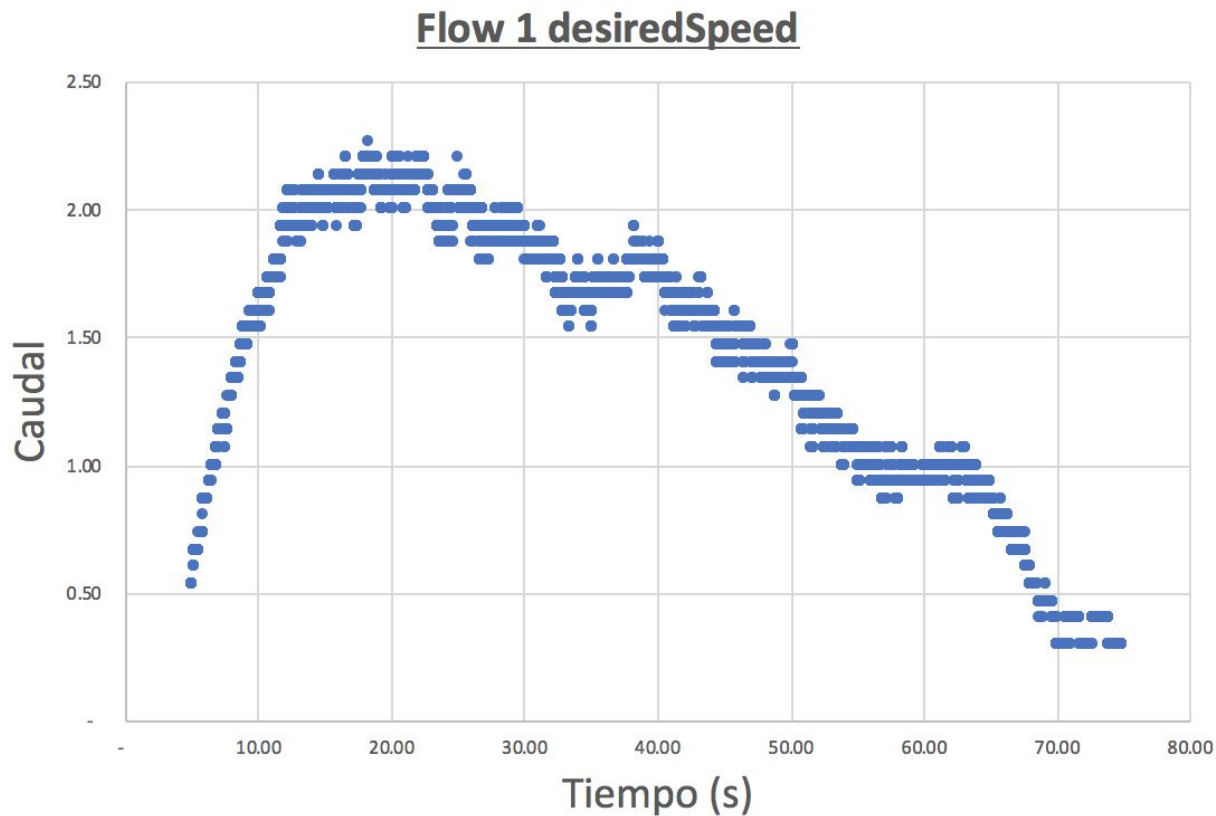
Caudal en función del tiempo

Flow 0.5 desiredSpeed



```
{  
  ...  
  "time"      : "180",  
  "n"         : "100",  
  "deltat"    : "0.002",  
  "desiredSpeed" : "0.5",  
  ...  
}
```

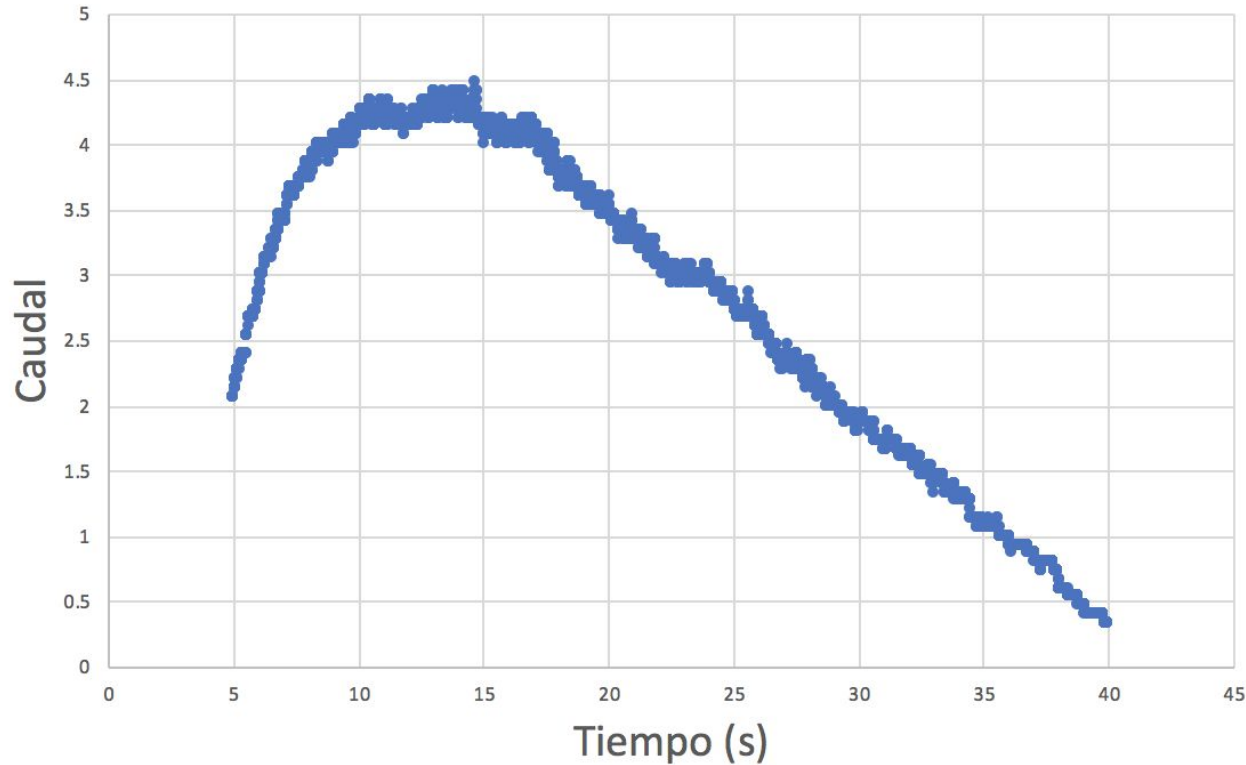
Caudal en función del tiempo



```
{  
  ...  
  "time"      : "75",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "1.0",  
  ...  
}
```

Caudal en función del tiempo

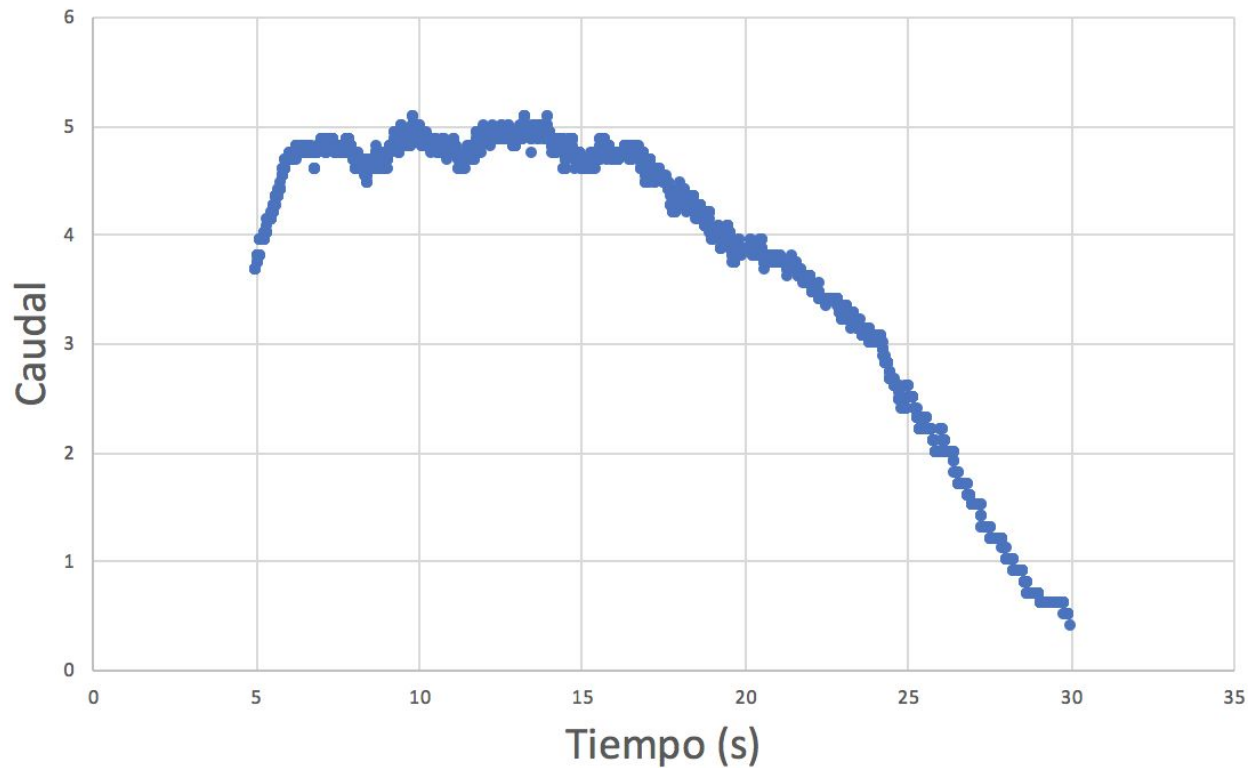
Flow 2 desiredSpeed



```
{  
  ...  
  "time"      : "40",  
  "n"         : "100",  
  "deltat"    : "0.0003",  
  "desiredSpeed" : "2.0",  
  ...  
}
```

Caudal en función del tiempo

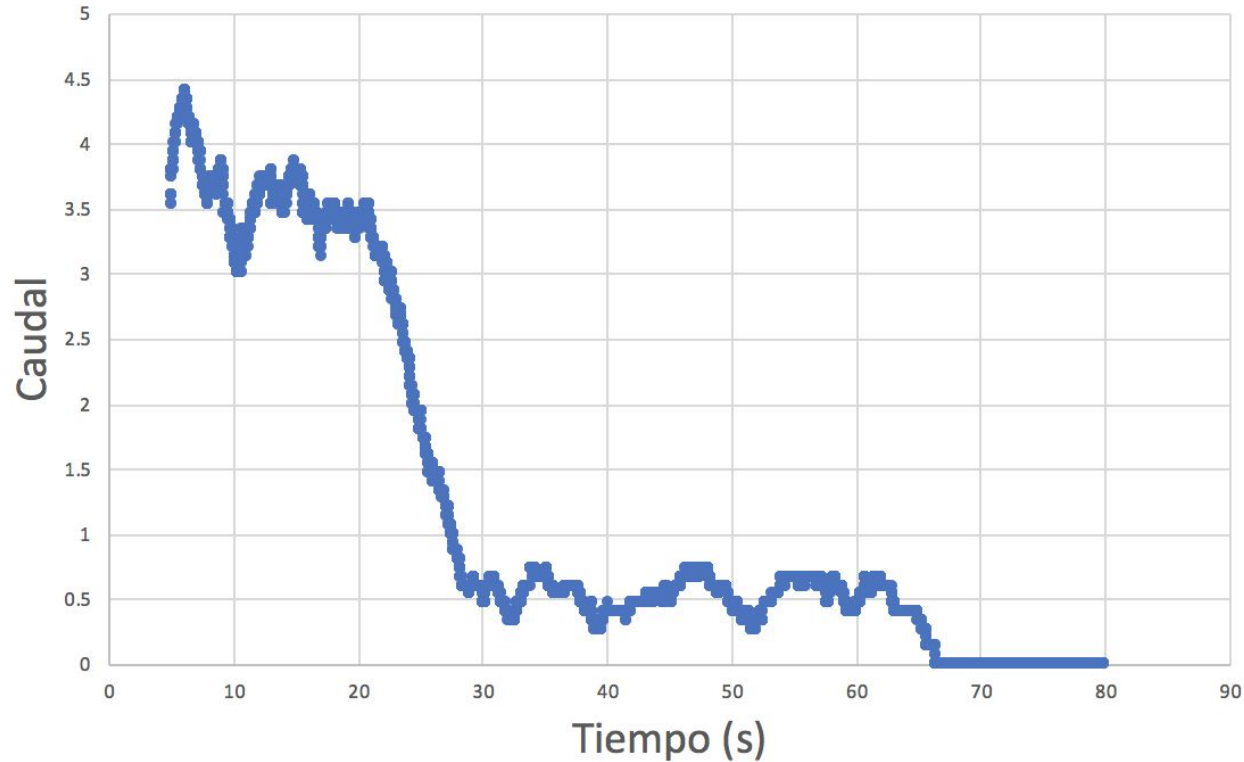
Flow 3 desiredSpeed



```
{  
  ...  
  "time"      : "30",  
  "n"         : "100",  
  "deltat"    : "0.0001",  
  "desiredSpeed" : "3.0",  
  ...  
}
```


Caudal en función del tiempo

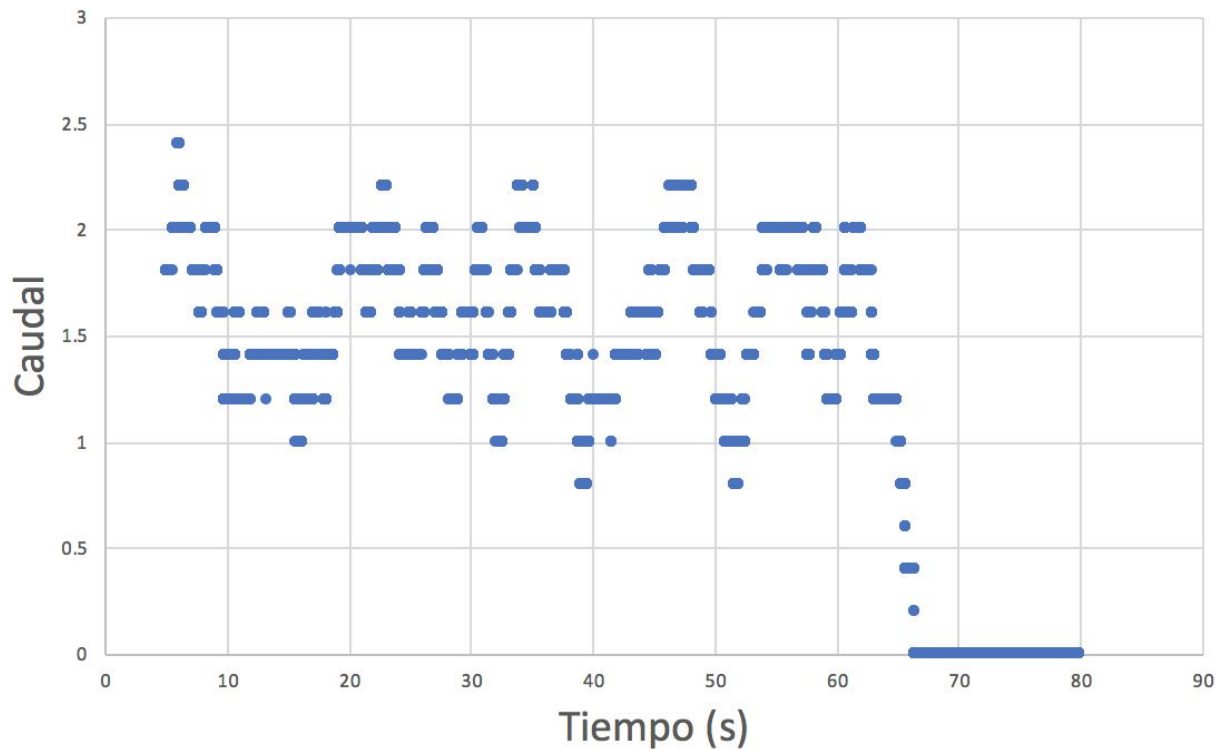
Flow 4 desiredSpeed



```
{  
  ...  
  "time"      : "80",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "4.0",  
  ...  
}
```

Caudal en función del tiempo

Flow 4 desiredSpeed - A = 0



```
{  
  ...  
  "time"      : "80",  
  "n"         : "100",  
  "deltat"    : "0.0005",  
  "desiredSpeed" : "4.0",  
  "A"         : "0",  
  ...  
}
```

Tiempo de evacuación

<u>deltat (s)</u>	<u>Generator</u>	<u>N</u>	<u>desiredSpeed (m/s)</u>	<u>Total time (s)</u>	<u>Tiempo de última partícula (s)</u>	<u>Promedio de tiempos de última partícula</u>
0.0005	12304268647601935	100	4	30	22.76	23.66
	73604261247601935				23.23	
	73604268647601935				25.01	
0.0001	12304268647601935	100	3	30	26.05	25.37
	73604261247601935				26.05	
	73604268647601935				24.02	

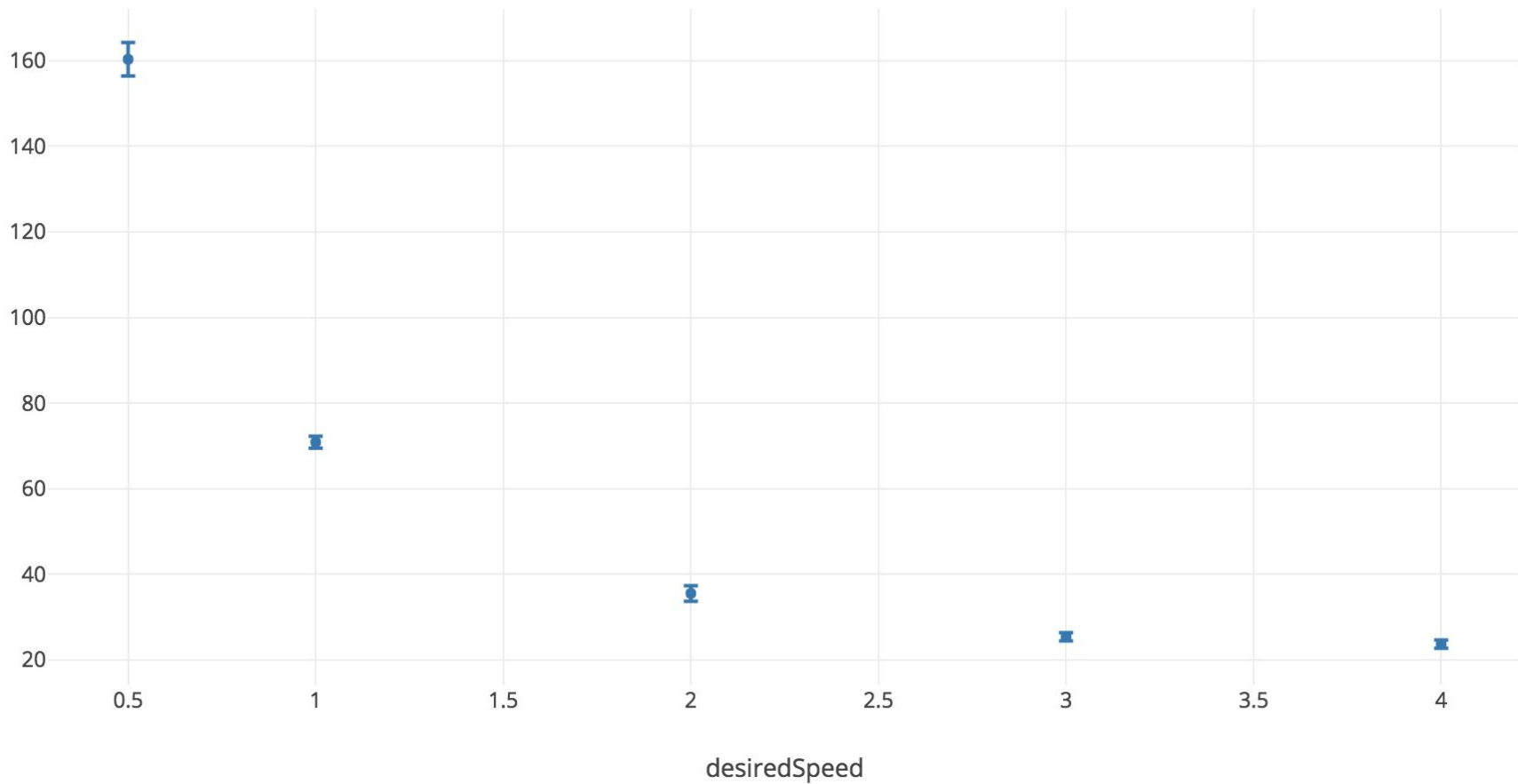
Tiempo de evacuación

<u>deltat</u>	<u>Generator</u>	<u>N</u>	<u>desiredSpeed</u>	<u>Total time</u>	<u>Tiempo de última partícula</u>	<u>Promedio de tiempos de última partícula</u>
0.0003	12304268647601935	100	2	40	33.04	35.53
	73604261247601935				36.22	
	73604268647601935				37.33	
0.0005	12304268647601935	100	1	75	72.68	70.87
	73604261247601935				70.76	
	73604268647601935				69.19	
0.002	12304268647601935	100	0.5	180	165.44	160.37
	73604261247601935				155.89	
	73604268647601935				159.8	

Tiempo de evacuación

Tiempo de evacuación

Promedio de tiempos de última partícula



A decorative network diagram in the top-left corner of the slide. It features a complex web of interconnected nodes and edges. The nodes are represented by small circles, some of which are solid blue, some are solid grey, and some are hollow with a blue outline. The edges are thin grey lines connecting the nodes. The overall shape of the network is roughly triangular, pointing towards the top-left corner.

Conclusiones

Conclusiones

- A mayor *desiredSpeed*, menor es el tiempo de evacuación.
- $A = 0$ hace que aumente el tiempo de evacuación.

Gracias!

Grupo N° 5

Daniel Lobo | Agustín Golmar

