Optimal Routing of Pipelines in Naval Designs

Advances on data analysis, logistics and transportation problems on complex networks

Sevilla, 21 de Diciembre 2021
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Autores del trabajo (https://arxiv.org/abs/2108.00416)

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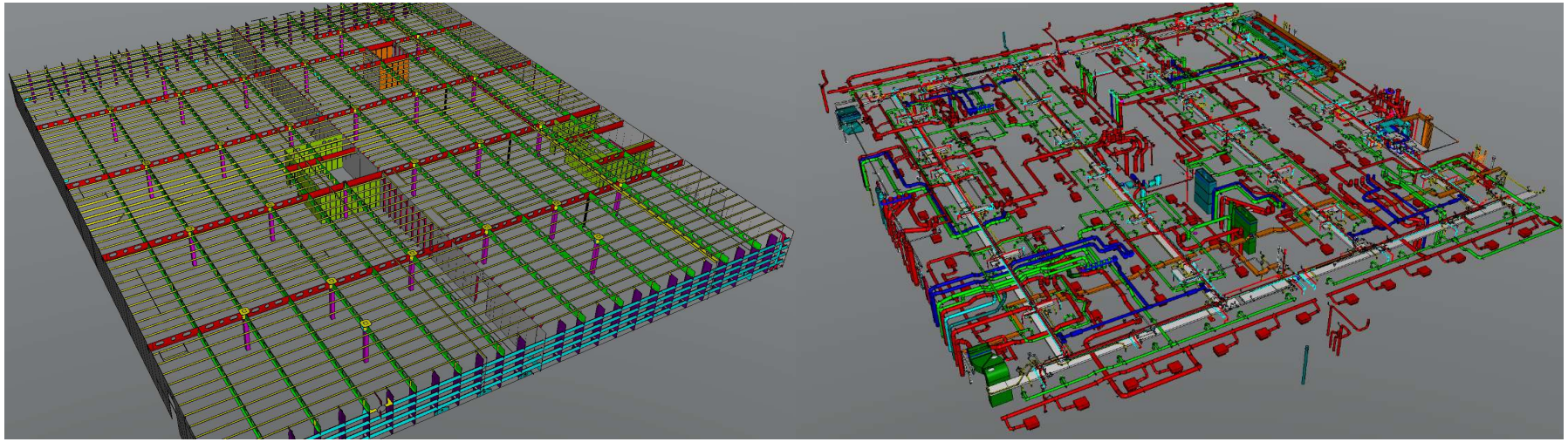
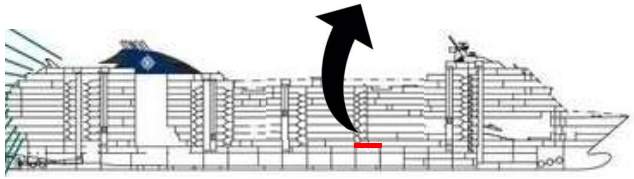
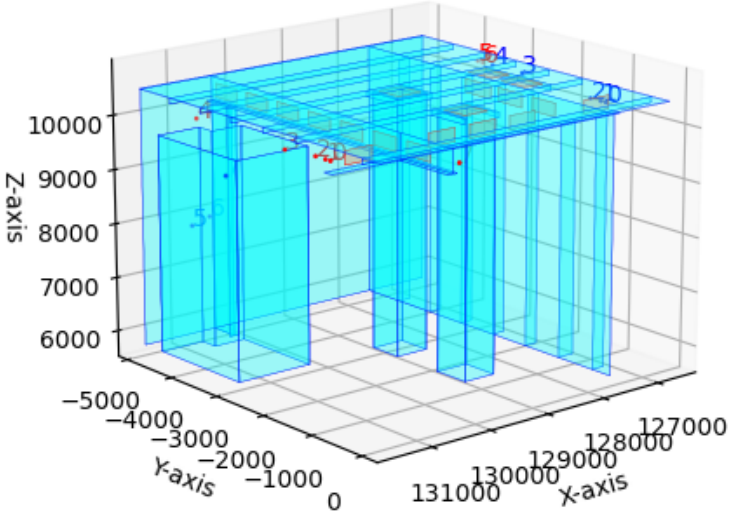
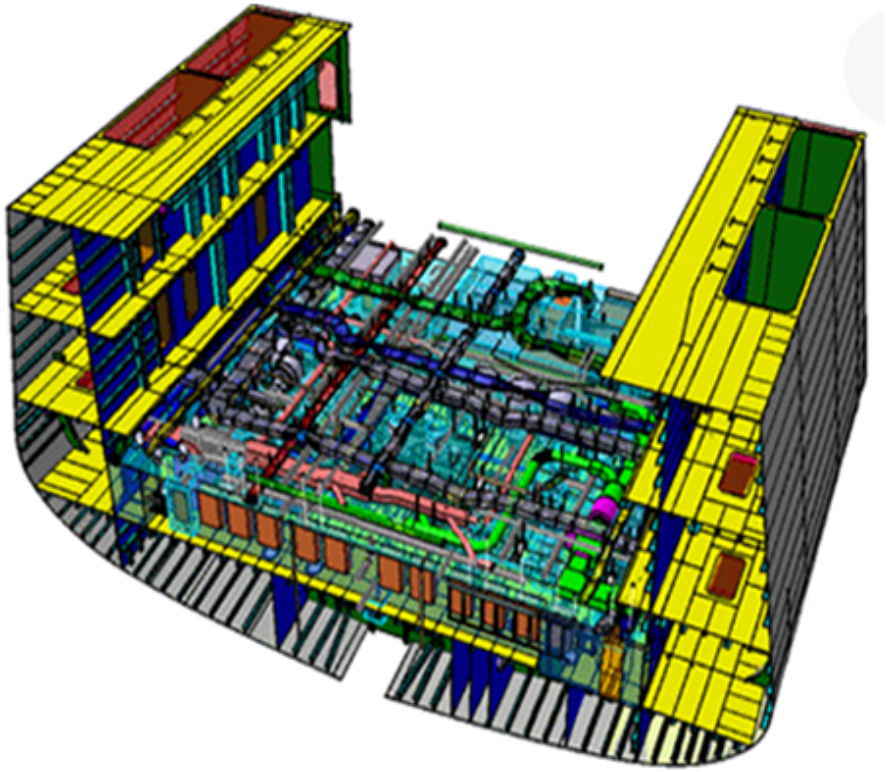
Canalizaciones en diseños navales

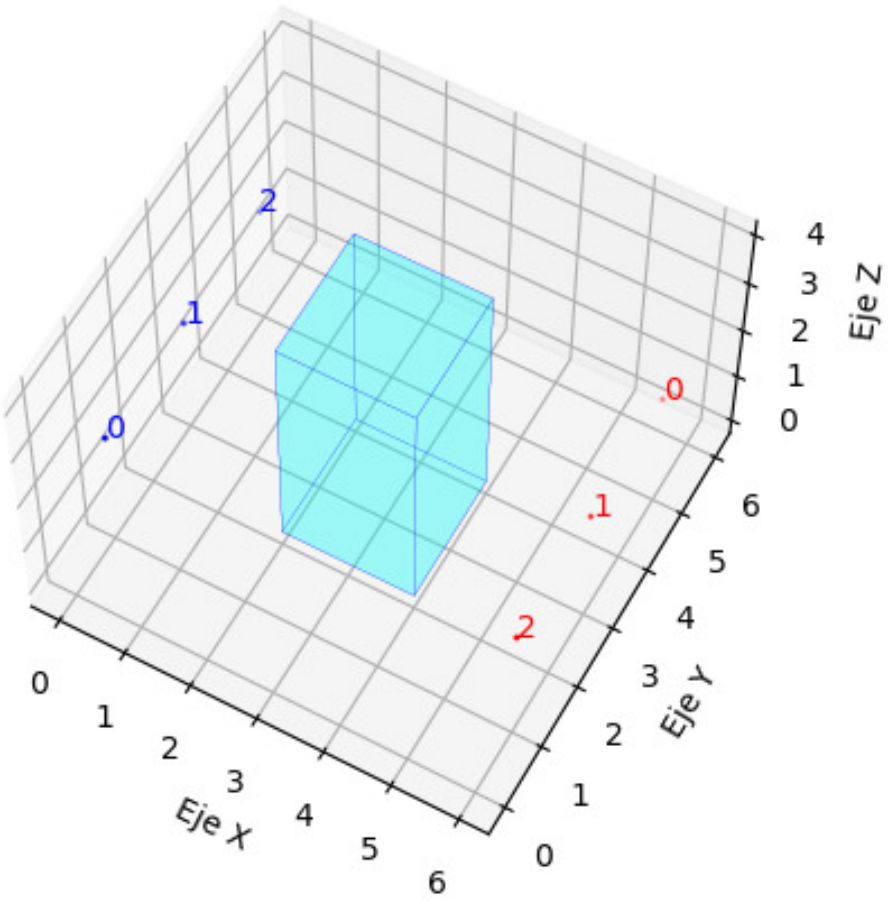


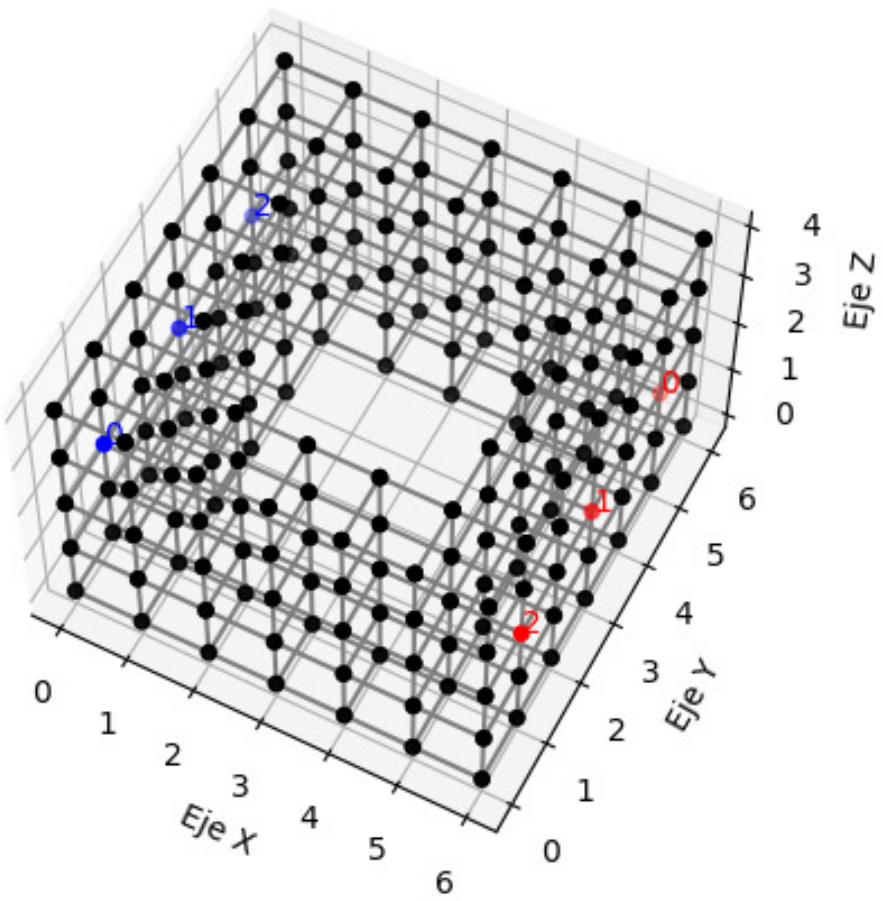




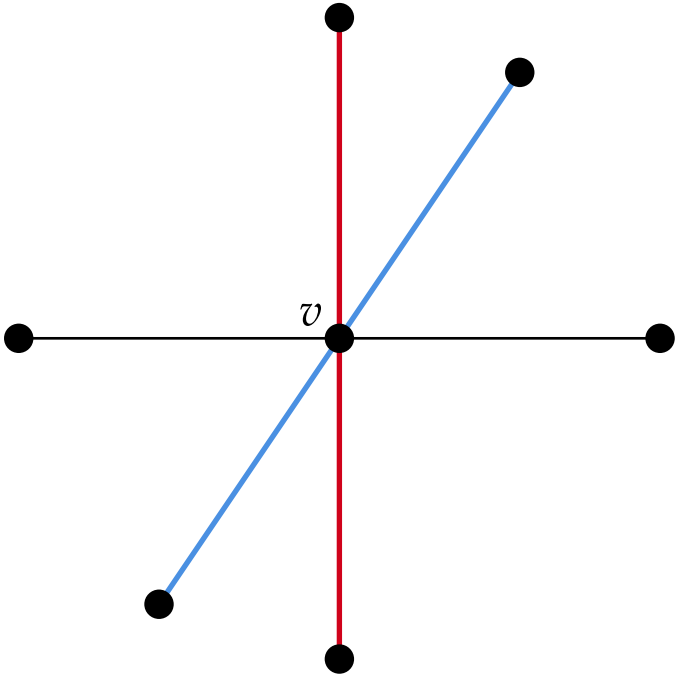


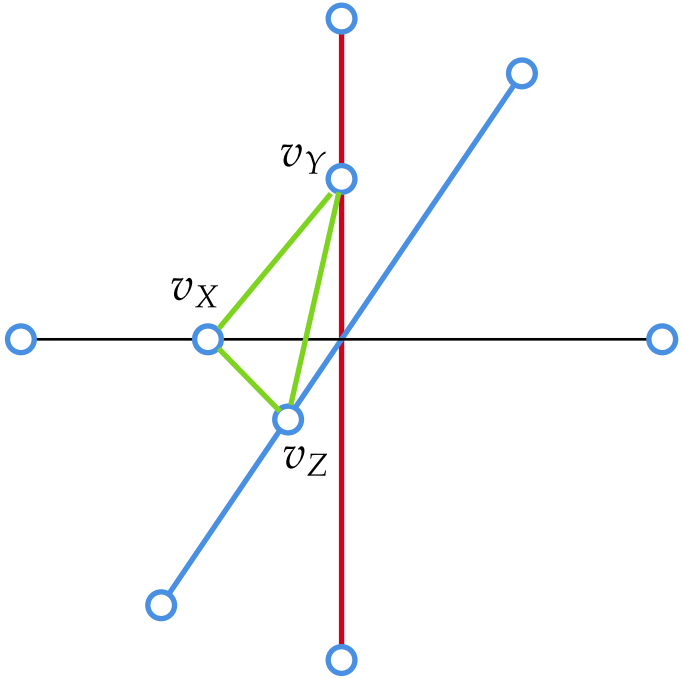
Discretización del espacio

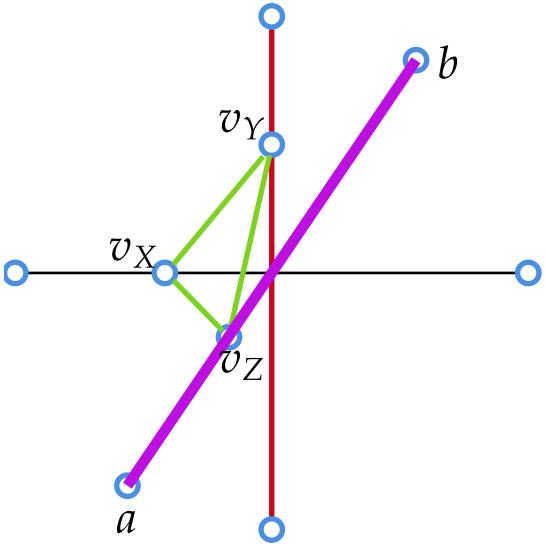


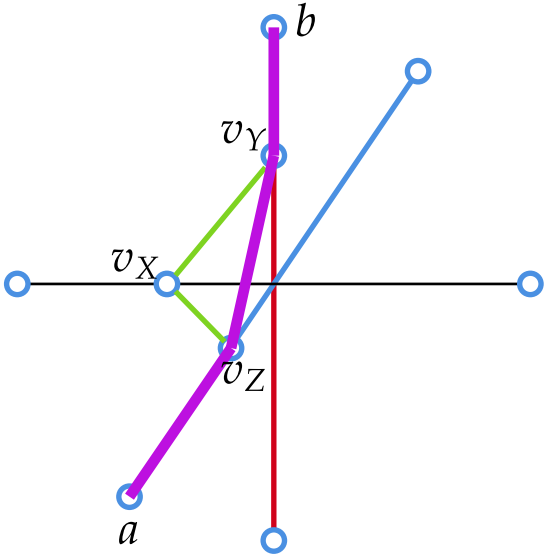


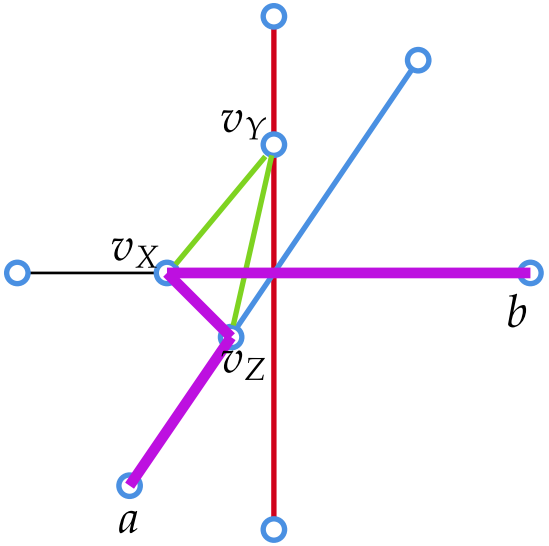
Explosión de nodos











Función de costes

$$C_{ij} = (\alpha_1 + \alpha_5)d_{ij} + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_6 + \alpha_7$$

- d_{ij} distancia entre el nodo i y el nodo j (longitud de la arista).
- α_1 peso asociado a la longitud de la arista (ponderación relativa de la longitud).
- α_2 coste de un codo de 90º.
- α_3 penalización para alejar el trazado del techo (su valor será mayor cuanto más lejos esté del techo).
- α_4 penalización por cambiar el trazado en altura.
- α_5 bonificación por trazar en zona preferente ($\alpha_5 < 0;\ \alpha_1 + \alpha_5 \geq 0$).
- α_6 coste por entrar en una zona penetrable.
- α_7 penalización por poner un codo cerca de un punto de entrada o salida.

Modelo

$$\min \sum_{(i,j)\in A} \sum_{k\in K} c_{ij}^k x_{ij}^k.$$

$$\text{s. a} \sum_{k\in K} \sum_{j\in V} x_{ij}^k \leq 1, \qquad \forall i \in V,$$

$$\sum_{j\in V} x_{ij}^k - \sum_{j\in V} x_{ji}^k = 0, \qquad \forall k \in K, i \in V(i \neq s^k, t^k),$$

$$\sum_{j\in V} x_{s^k,j}^k = 1, \qquad \forall k \in K,$$

$$\sum_{i\in V} x_{i,t^k}^k = 1, \qquad \forall k \in K,$$

$$\sum_{k'\in K:k'\neq k} \sum_{\substack{a'\in A \\ d_{aa'}<R^{kk'}}} x_{a'}^{k'} \leq M_a^k(1 - x_a^k), \qquad \forall a \in A \setminus A^v, k \in K,$$

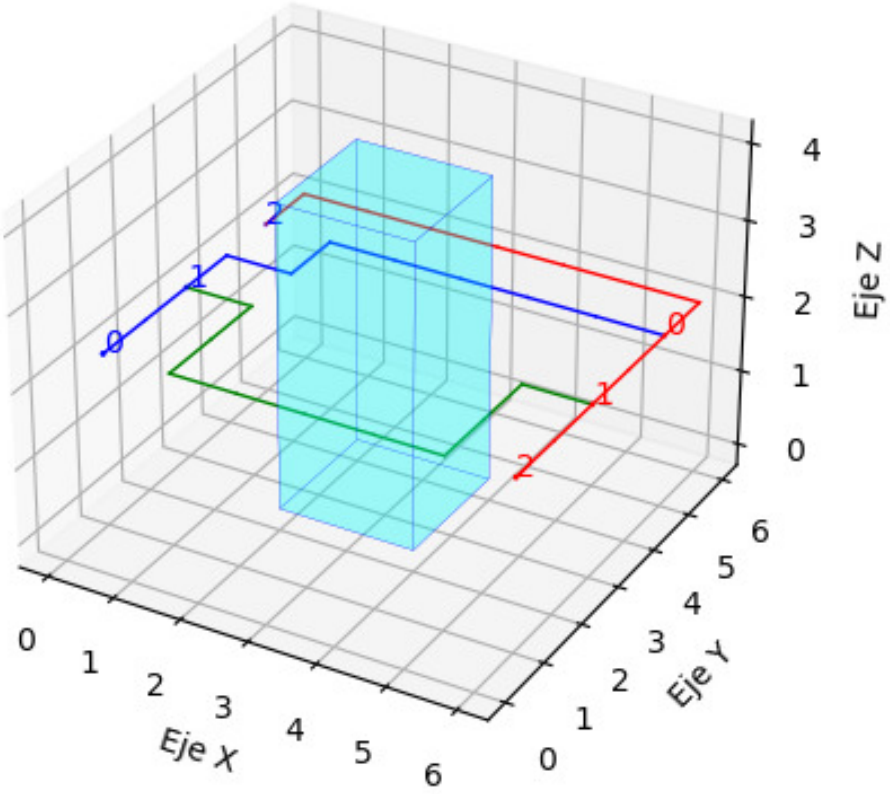
$$\sum_{\tilde{a}\in RE(a)} x_{\tilde{a}}^k + \sum_{\bar{a}\in RE(a')} x_{\bar{a}}^k \leq 1, \qquad \forall a, a' \in A^v : d_{aa'} \leq D^k, a \neq a', k \in K,$$

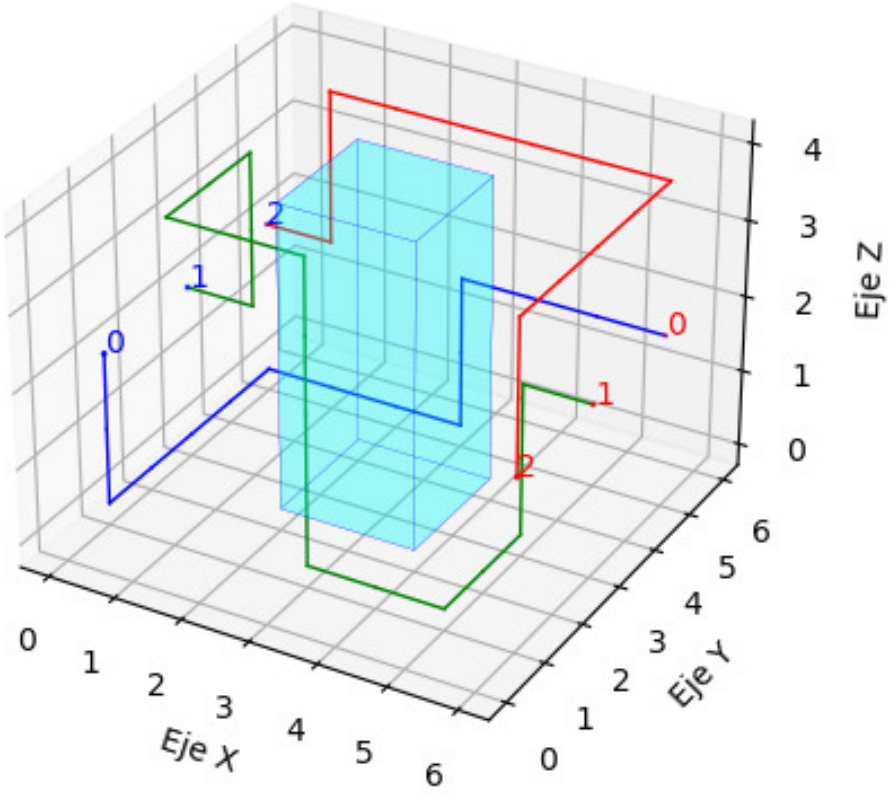
$$x_{ij}^k \in \{0, 1\}, \qquad \forall (i,j) \in A, k \in K.$$

Restricciones perezosas

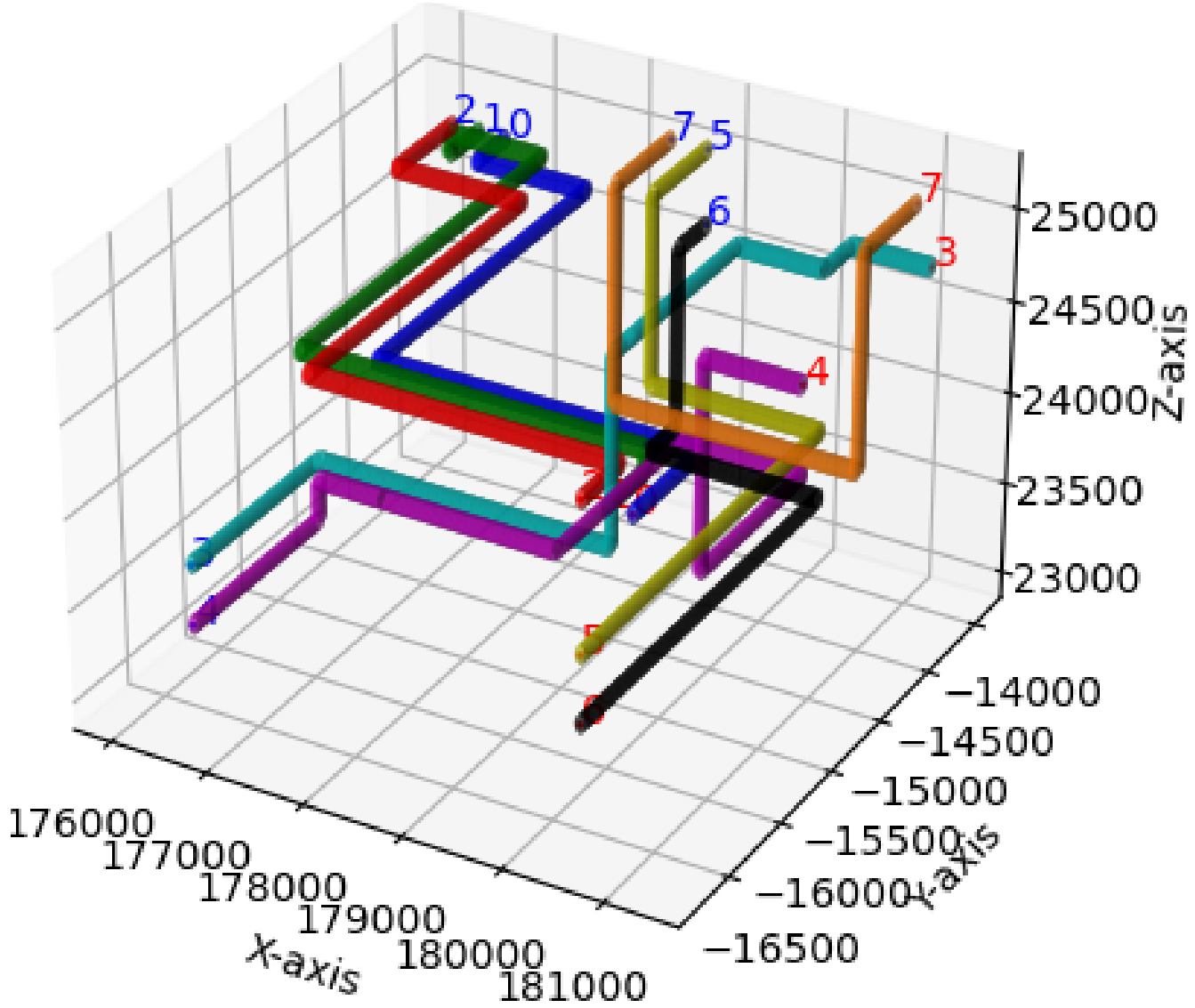
$$\sum_{k' \in K : k' \neq k} \sum_{\substack{a' \in A \\ d_{aa'} < R^{kk'}}} x_{a'}^{k'} \leq M_a^k (1 - x_a^k), \qquad \forall a \in A \setminus A^v, k \in K$$

$$\sum_{\tilde{a} \in RE(a)} x_{\tilde{a}}^k + \sum_{\bar{a} \in RE(a')} x_{\bar{a}}^k \leq 1, \qquad \forall a, a' \in A^v : d_{aa'} \leq D^k, a \neq a', k \in K$$



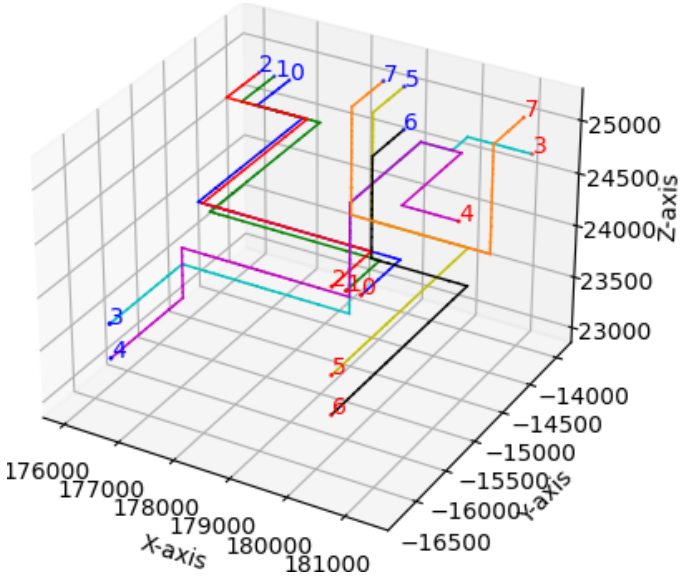


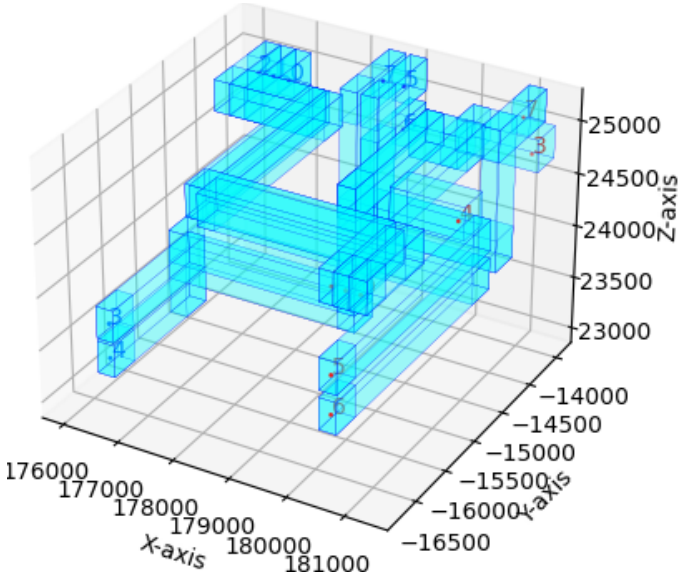
Escenario real resuelto a optimalidad

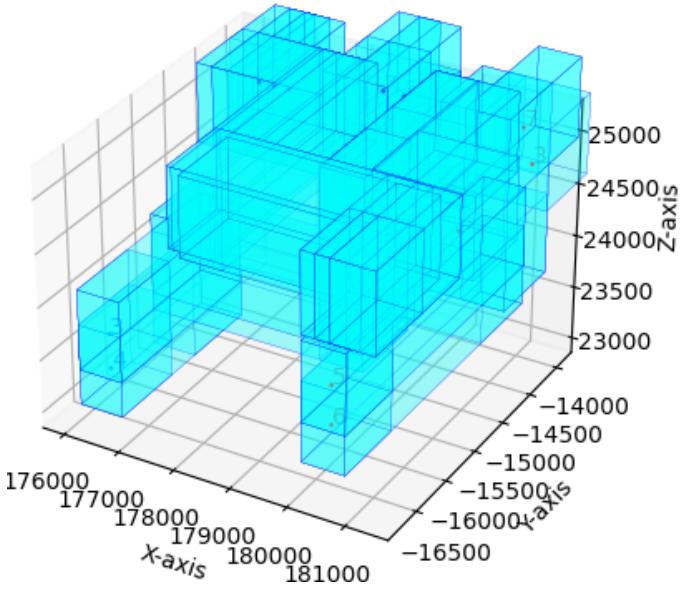


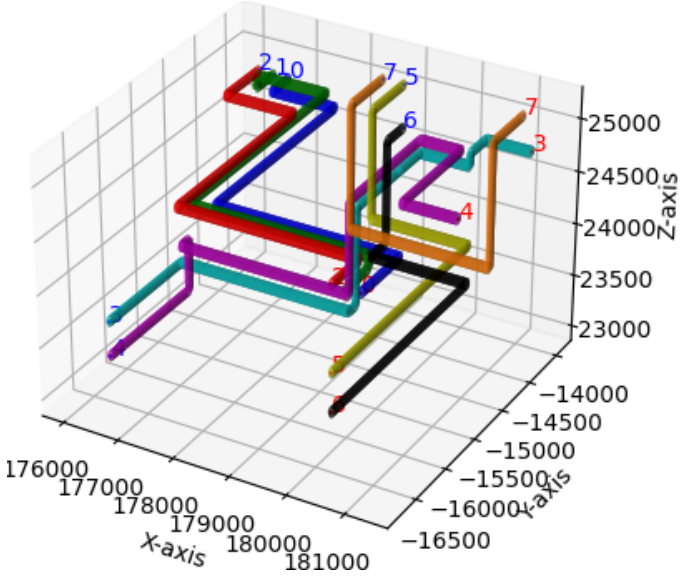
- Variables: 2,341,952
- Restricciones: 757,597
- Tiempo: 1 hora y 5 minutos

Heurística



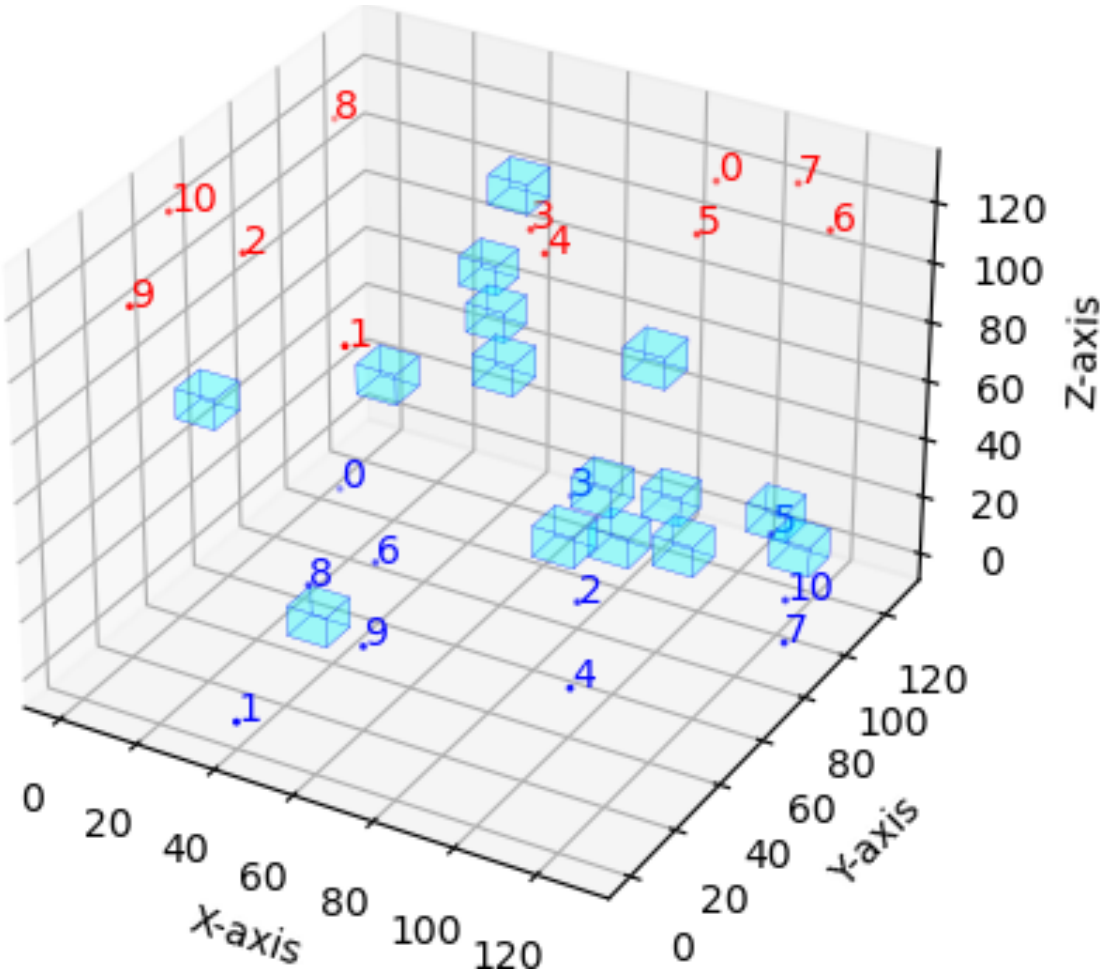






- Variables: 362,838 (antes 2,341,952)
- Tiempo: 14 minutos y 45 segundos

Instancias aleatorias



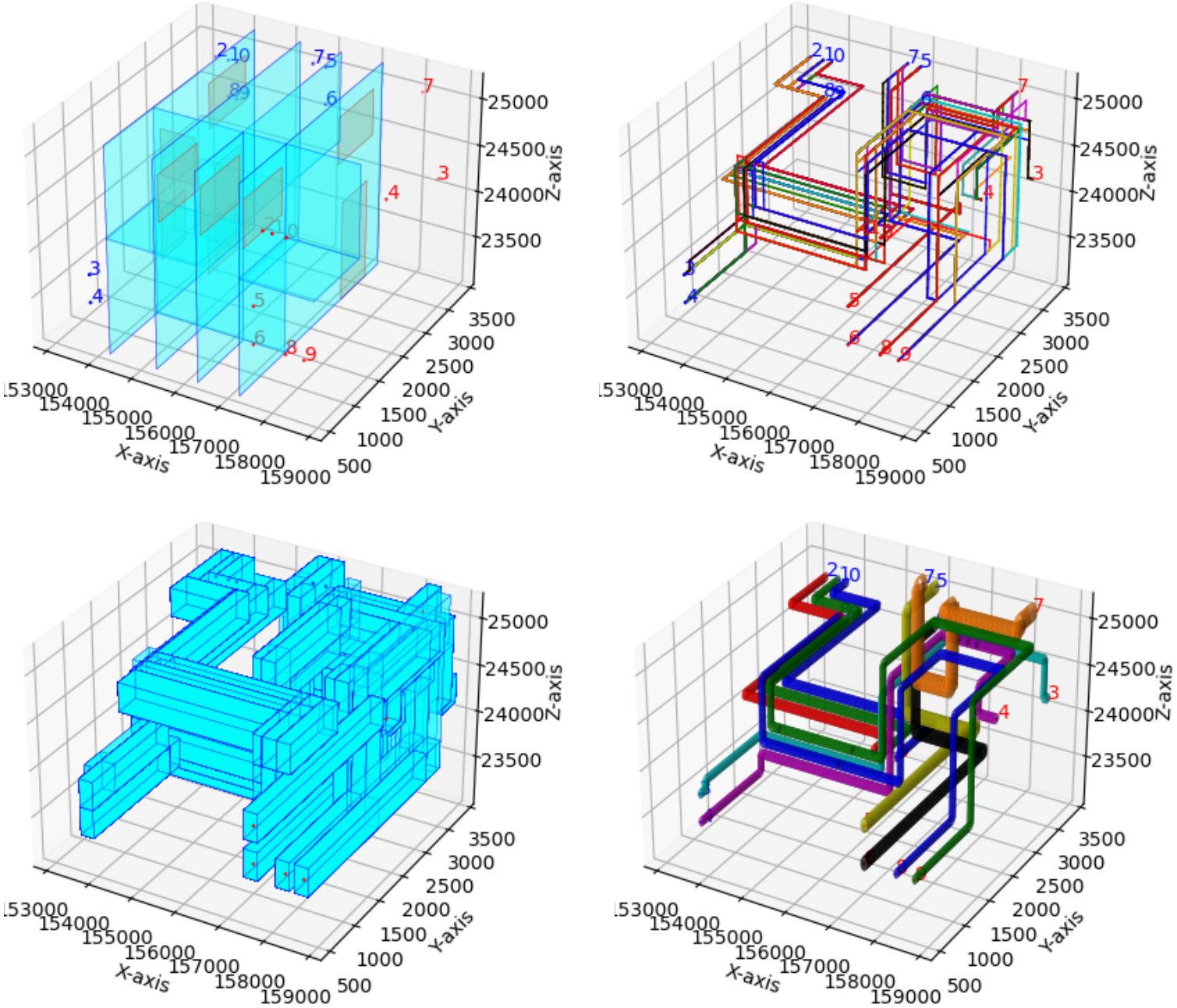
$$c_e^k = \alpha_1^k(d_e + 10El_e + 2Ch_e)$$

- α_1^k toma valores enteros aleatorios en $[1, 9]$.
- d_e longitud de la arista.
- El_e vale 1 si la arista es un codo y 0 si no.
- Ch_e vale 1 si la arista es paralela al eje Y.

Experiencia computacional

d	s	o	Vars	Cons	Solved	GAP		Time	
						Ex	H	Ex	H
17	5	5	228,232	73,572	5	0,00	0,10	11,15	6,26
		10	227,421	73,386	5	0,00	0,32	11,51	7,80
		15	226,736	73,230	5	0,00	2,01	12,21	9,73
	8	5	399,406	117,761	5	0,00	0,31	400,17	396,38
		10	397,986	117,463	5	0,00	1,96	339,85	240,53
		15	396,788	117,214	5	0,00	5,73	347,41	482,09
	12	5	627,638	176,735	5	0,00	0,61	4216,11	1824,99
		10	625,407	176,289	5	0,00	2,64	3367,94	2159,86
		15	623,524	175,914	5	0,00	4,93	2596,96	2215,58
17			**417,015**	**122,396**	**45**	**0,00**	**2,07**	**1225,45**	**1149,25**
33	5	5	1,694,166	537,852	5	0,00	0,10	163,20	3,31
		10	1,689,282	536,568	5	0,00	0,16	152,20	5,43
		15	1,684,880	535,407	5	0,00	0,69	176,34	9,82
	8	5	2,964,791	860,609	3	0,06	0,24	5100,74	62,58
		10	2,956,243	858,554	4	0,16	1,26	4393,18	247,27
		15	2,948,540	856,697	4	0,16	3,07	3484,85	1546,39
	12	5	4,658,958	1,291,007	0	1,26	0,45	7200.05	236,02
		10	4,645,524	1,287,926	0	1,48	1,32	7200.05	1214,57
		15	4,633,420	1,285,139	0	1,38	3,68	7200.05	4278,22
33			**3,097,312**	**894,418**	**26**	**0,50**	**1,22**	**3896,75**	**844,85**
Total			**1,757,163**	**508,4007**	**71**	**0,25**	**1,64**	**2576,11**	**997,05**

Caso de Estudio. Heurística un paso más allá



- Variables: 3,104,222

Conclusiones

- Metodología flexible para el trazado óptimo de canalizaciones capaz de adaptarse a distintos criterios de constructibilidad.
- Heurística capaz de abordar escenarios de mayor tamaño.

Muchas gracias por su atención