

Informe Proyecto I CI-5437

1. Introducción.

En el presente informe se presentan las decisiones de diseño tomadas y los resultados obtenidos en el proyecto 1 del curso CI-5437 Inteligencia Artificial I. Las especificaciones en donde se realizaron las pruebas fueron las siguientes.

- Computadora 1: i3 6ta generación, 12Gb de RAM y SO Ubuntu 23.04
- Computadora 2: i3 4ta generación, 4Gb de RAM y SO Mint 21

2. Representación.

2.1. N-Puzzle.

Para representar los estados se definió un dominio llamado `tile` el cual define los diferentes valores que puede tomar una pieza en el puzzle. El estado está representado por un vector de 16 `tiles` para 15-Puzzle y uno de 25 para 24-Puzzle. Estos `tiles` pueden tomar valores entre $[1 \dots n]$, siendo n la cantidad total de casillas numeradas en el puzzle, así como el valor de `b` para representar la casilla en blanco o `blank`. El vector tiene el siguiente formato:

<code>b</code>	—	—	—
<code>X</code>	—	—	—
—	—	—	—
—	—	—	—

$\langle v_1, v_2, v_3, v_4, \dots, v_n \rangle$

En donde cada índice corresponde a una de las $n+1$ casillas en el tablero.

En sí, la función de transición se define como el movimiento del `blank` `b` hacia la izquierda, derecha, arriba o abajo. El conjunto de los estados objetivos sólo posee un estado, y es aquel donde en la posición 0 del tablero se encuentra el `blank` y en las n posiciones siguientes los n números arreglados en forma ascendente.

2.2. Torres de Hanoi.

Los estados están representados por vectores de 42, 56 y 68 posiciones. Cada posición de los vectores puede tomar valores entre $[0 \dots 2]$. Esté vector tiene el siguiente formato:

$\langle v_{11}, v_{12}, v_{13}, v_{14}, v_{21}, v_{22}, v_{23}, v_{24}, \dots, v_{i1}, v_{i2}, v_{i3}, v_{i4}, \dots, v_{n1}, v_{n2}, v_{n3}, v_{n4} \rangle$

En donde el primer índice corresponde al número de un disco y el segundo corresponde al hasta en donde se encuentra el disco. Si $v_{ij} = 1$, entonces que el disco i se encuentra en el asta j . Si $v_{ij} = 0$, entonces el disco i no se encuentra en el asta j .

La función de transición se define como el movimiento de un disco i desde un asta hacia otra distinta y se definió como estado objetivo el estado en donde todos los discos están en el asta 1.

2.3. Topspin.

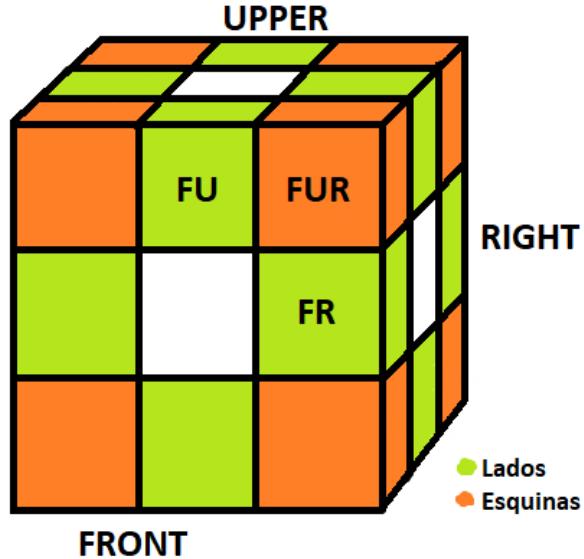
Los estados están representados por vectores de 12, 14 y 17 posiciones. Cada posición de los vectores pueden tomar valores entre $[0 \dots n]$, siendo $n =$ cantidad de números del `topspin`. La función de transición se definió como todas las posibles rotaciones de segmentos consecutivos de longitud 4 del vector. Estas rotaciones incluyen los bordes del vector que se completan tomando el inicio del mismo.

Para cada variación del `topspin`, se definieron n estados objetivos. Los estados objetivos son las rotaciones ordenadas del vector de estado.

2.4. Cubo de Rubik 3x3x3

Los estados están representados por un dominio denominado colour, el cual puede poseer los valores *RED*, *GREEN*, *BLUE*, *YELLOW*, *ORANGE* y *WHITE* que representan los seis colores que se hallan en un cubo de rubik. El estado está representado por un vector de 48 variables colour donde cada una de ellas es una de las 48 piezas móviles del cubo.

Cada una de las caras del cubo tiene un nombre distinto dependiendo de la posición en la que están ubicadas: *Upper*, *Down*, *Left*, *Right*, *Front*, *Back*. Ahora, para explicar los posibles valores que puede tener una variable, se debe recordar que en las piezas móviles de un cubo de rubik existen los *lados* y las *esquinas*. Las esquinas tienen tres colores mientras que los lados tienen dos. Así, el valor de cada variable es una combinación de 2 o 3 letras que representan la posición actual de esa casilla y la posición (o las dos posiciones) adyacentes a la misma. Luego, el vector tiene el siguiente formato:



```
<v1_1, v1_2, v1_3, v1_4, v1_5,  
v1_6, v1_7, v1_8, v2_1, ..., v2_1, ..., v6_1, v6_2, v6_3, v6_4, v6_5,  
v6_6, v6_7, v6_8>
```

Donde cada ocho casillas corresponden a las piezas de lado o esquina de una de las caras del cubo hasta completar las seis caras.

La función de transición se define como la rotación de una de las caras en un giro de 180 grados o de 90 grados a cada una de las dos caras adyacentes.

Existe sólo un estado objetivo, el cual tiene los lados y esquinas de cada cara siendo del mismo color que la ficha central de la misma.

3. Abstracciones

3.1. N Puzzle

En el caso del N-Puzzle, se crearon abstracciones por el método de proyección, en el cual por cada una de las abstracciones se considera un número de casillas en el tablero y a las demás se les realiza un *mapping* para convertirlas en *blank*. Así, juntando todas las abstracciones, las N casillas están nuevamente llenas y ninguna se sobreponen a la otra.

Para el 15-Puzzle, se decidió utilizar tres abstracciones, cada una considerando cinco casillas. Con el 24-puzzle, se tuvo una idea inicial de dividirlo en cuatro abstracciones de cuatro casillas cada una. Sin embargo, resultó ser muy pesado para poder correr los algoritmos, por lo que finalmente se optó por una división en cinco abstracciones, considerando cuatro casillas en una abstracción y cinco casillas en las demás.

Las divisiones finales de las abstracciones de los N-Puzzle se pueden detallar en las figuras a continuación.

	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

15- Puzzle

- abst1.txt
- abst2.txt
- abst3.txt

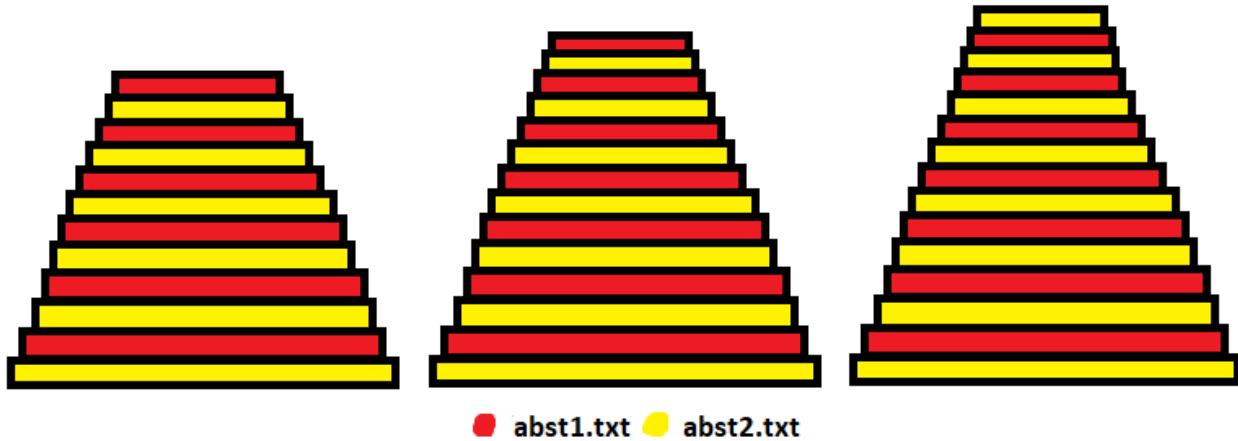
	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19
20	21	22	23	24

24-Puzzle

- abst1.txt
- abst2.txt
- abst3.txt
- abst4.txt
- abst5.txt

3.2. Torres de Hanoi

Para todos los casos de las torres de Hanoi se crearon dos abstracciones. Una de estas proyecta los discos pares y la otra proyecta los discos impares. Dada la representación usada para este puzzle, las abstracciones proyectan las 4 posiciones del vector de cada disco. De esta manera, la abstracción genera torres de Hanoi considerando la mitad de discos que el puzzle original.



3.3. Topspin

Para los casos de 12 y 17 números se crearon 3 abstracciones, mientras que para el topspin de 14 números se crearon 4 abstracciones. En estas abstracciones se mapean varios números del dominio 12 a 0. De esta manera, se reduce la cantidad de números de cada puzzle. Las abstracciones creadas se encuentran a continuación:

Topspin 12

0	0	0	0	0	0	7	8	9	10	11
0	1	2	0	0	0	0	0	0	0	0
0	1	2	3	4	0	0	0	0	0	0

Topspin 14

0	1	2	3	0	0	0	0	0	0	0
0	0	0	3	4	5	6	0	0	0	0
0	0	0	0	0	0	6	7	8	9	0
0	0	0	0	0	0	0	0	9	10	11

Topspin 17

0	0	0	0	0	0	0	0	0	0	12	13	14	15	16
0	1	2	3	4	5	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	6	7	8	9	10	11	0	0	0

3.4. Cubo de Rubik 3x3x3

A manera de obtener abstracciones para el cubo de Rubik 3x3x3, se tomó la idea ilustrada en el paper *Finding Optimal Solutions to Rubik's Cube Using Data Pattern Databases* de Richard Korf de tener tres PDBs distintas: Una para las esquinas y otras dos para los lados, lo cual significa tener tres abstracciones. Sin embargo, el enfoque que le fue dado al cubo en este proyecto tuvo consigo cuatro abstracciones distintas: Dos para las esquinas y otras dos para los lados.

4. Resultados obtenidos.

4.1. Árboles de Búsqueda.

En esta parte se recorren los árboles de búsqueda para conocer la cantidad de nodos generados y el factor de ramificación en cada profundidad del árbol. Para obtener estos valores, se implementó una versión modificada del algoritmo Breadth First Search (BFS). Por limitaciones de hardware no se podía ejecutar el algoritmo durante más de un minuto y 30 segundos aproximadamente. A parte de este algoritmo, se implementó Iterative Deepening Depth First Search (IDDFS). Sin embargo, por problemas en la implementación, no se logró ser preciso en la cantidad de nodos generados y el factor de ramificación.

4.1.1. Sin realizar poda parcial de duplicados.

15 puzzle			24 puzzle		
Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor
0	1	2	0	1	2
1	2	3	1	2	3
2	6	3	2	6	3
3	18	3,22	3	18	3,33
4	58	3,21	4	60	3,3
5	186	3,24	5	198	3,45
6	602	4,23	6	684	3,39
7	1946	3,24	7	2322	3,49
8	6298	3,24	8	9100	3,42
9	20378	3,24	9	27702	3,5
10	65946	3,24	10	96876	3,43
11	213402	3,24	11	331938	3,5
12	690586	3,24	12	1161540	3,43
13	2234778	3,24	13	3981798	3,5
14	7231898	3,24	14	13935564	3,43
15	23402906	3,24	15	47777202	3,5
16	75733402	3,24			

hanoi4_12			hanoi4_14			hanoi4_17		
Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor
0	1	3	0	1	3	0	1	3
1	3	5	1	3	5	1	3	5
2	15	5	2	15	5	2	15	5
3	75	5,24	3	75	5,24	3	75	5,24
4	393	5,37	4	393	5,37	4	393	5,37
5	2109	5,45	5	2109	5,45	5	2109	5,45
6	11487	5,52	6	11487	5,52	6	11487	5,52
7	63375	5,57	7	63375	5,57	7	63375	5,57
8	352755	5,61	8	352755	5,61	8	352755	5,61
9	1978341	5,64	9	1978341	5,64	9	1978341	5,64
10	11161197	5,67	10	11161197	5,67	10	11161197	5,67

topspin12_4			topspin14_4			topspin17_4		
Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor
0	1	12	0	1	14	0	1	17
1	12	12	1	14	14	1	17	17
2	144	12	2	196	14	2	289	17
3	1728	12	3	2744	14	3	4913	17
4	20736	12	4	38416	14	4	83521	17
5	248832	12	5	537824	14	5	1419857	17

6	2985984	12		6	7529536	14		6	24137569	17
7	35831808	12								

rubik3		
Depth	Nodos generados	Branching Factor
0	1	18
1	18	18
2	324	18
3	5832	18
4	104976	18
5	1889568	18

Con respecto a los factores de ramificación, se puede confirmar que el resultado obtenido corresponde a lo esperado. Por ejemplo, para el cubo de rubik y topspin, en cualquier estado se pueden realizar todos los movimientos posibles. En el caso de los n puzzles la cantidad de movimientos disponibles de un estado depende de la posición del blank. En el caso de las torres de Hanoi se puede observar que el árbol de búsqueda tiene la misma cantidad de nodos para las tres variaciones del puzzle; esto se debe a que la cantidad de movimientos disponibles depende de la cantidad de astas mas no de la cantidad de discos.

4.1.2. Realizando poda parcial de duplicados.

15 puzzle			24_puzzle		
Profundidad	Nodos generados	Branching Factor	Profundidad	Nodos generados	Branching Factor
0	1	2	0	1	2
1	2	2	1	2	2
2	4	2,5	2	4	2,5
3	10	2,4	3	10	2,6
4	24	2,25	4	26	2,46
5	54	2	5	64	2,5
6	108	2,02	6	160	2,33
7	218	2,17	7	372	2,39
8	472	2,18	8	888	2,25
9	1030	2,14	9	1996	2,44
10	2204	2,12	10	4872	2,32
11	4666	2,12	11	11324	2,44
12	9880	2,13	12	27608	2,3
13	21046	2,14	13	63524	2,43
14	44972	2,13	14	154560	2,3
15	95930	2,13	15	355836	2,43
16	204216	2,13	16	866008	2,3
17	434694	2,13	17	1993748	2,43
18	925980	2,13	18	4854112	2,3
19	1973338	2,13	19	11181004	2,43
20	4204856	2,13	20	27216632	2,3
21	8957558	2,13	21	62666404	2,43
22	19080940	2,13			

23	40648730	2,13					
24	86600984	2,13					

hanoi4_12			hanoi4_14			hanoi4_17		
Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor
0	1	3	0	1	3	0	1	3
1	3	5	1	3	5	1	3	5
2	15	4,6	2	15	4,6	2	15	4,6
3	69	4,74	3	69	4,74	3	69	4,74
4	327	4,87	4	327	4,87	4	327	4,87
5	1593	4,94	5	1593	4,94	5	1593	4,94
6	7863	5	6	7863	5	6	7863	5
7	39333	5,05	7	39333	5,05	7	39333	5,05
8	198591	5,09	8	198591	5,09	8	198591	5,09
9	1010517	5,12	9	1010517	5,12	9	1010517	5,12
10	5174019	5,15	10	5174019	5,15	10	5174019	5,15

topspin12_4			topspin14_4			topspin17_4		
Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor	Depth	Nodos generados	Branching Factor
0	1	12	0	1	14	0	1	17
1	12	8,5	1	14	9,5	1	17	11
2	102	7,96	2	133	8,63	2	187	9,61
3	812	7,88	3	1148	8,46	3	1797	9,25
4	6402	7,87	4	9711	8,43	4	16622	9,17
5	50412	7,87	5	81864	8,43	5	152503	9,17
6	396902	7,87	6	689800	8,43	6	1398011	9,17
7	3124812	7,87	7	5812144	8,43	7	12819040	9,17
8	24601602	7,87						

rubik3			
Depth	Nodos generados	Branching Factor	
0	1	18	
1	18	13,5	
2	243	13,33	
3	3240	13,35	
4	43254	13,35	
5	577368	13,35	
6	7706988	13,35	

En esta parte se usó un historial de longitud 1 para determinar si un movimiento era o no válido. Como se puede observar, los factores de ramificación son menores que en el caso anterior. Además de esto, se logró explorar el árbol de búsqueda a mayor profundidad.

4.2. Heurísticas.

Las heurísticas utilizadas fueron el máximo de varias PDBs, PDBs aditivas y distancia Manhattan. La cantidad de estados que contienen las PDBs y el espacio que ocupa cada una fueron las siguientes:

- **15 puzzle:** Distancia Manhattan y PDBs aditivas. Se usaron 3 PDBs. Dos de estas contienen 524160 estados y pesan 21 MB cada una. La otra contiene 43680 estados y pesa 1,3 MB.
- **24 puzzle:** PDBs aditivas. Se usaron 5 PDBs. 4 de estas contienen 6375600 estados y pesan 539,9 MB cada una. la otra contiene 303600 estados y pesa 16,8 MB.
- **Hanoi12_12:** Se usó al máximo de dos PDBs. Estas contienen 4096 estados cada una y pesan 426 kB cada una.
- **Hanoi14_14:** Se usó el máximo de dos PDBs. Estas contienen 16384 estados en total y pesan 2 MB cada una.
- **Hanoi14_17:** Se usó el máximo de dos PDBs. Estas contienen 65536 y 262144 estados, y pesan 9,4 MB y 37,7 MB.
- **Topspin12_4:** Se usó el máximo de 3 PDBs. Dos de estas contienen 95040 estados y la otra contiene 11880 estados. Esas pesan 2,1 MB y 262,2 kB.
- **Topspin14_4:** Se usó el máximo de 4 PDBs. Tres de estas contienen 2666664 estados y pesan 83,9 MB. La otra contiene 279552 y pesa 10,5 MB.
- **Topspin17_4:** Se usó el máximo de 3 PDBs. Dos de estas contienen 742560 estados y pesan 25,2 MB. Y la otra contiene 8910720 estados y pesa 402,2 MB

Estas PDBs fueron creadas usando las abstracciones que se mencionaron anteriormente. Para el caso del cubo de rubik, no se lograron generar sus PDBs correspondientes.

4.3. Algoritmos Informados

Se implementaron los algoritmos A* y IDA* para resolver diferentes instancias de los puzzles. Los casos de prueba se generaron usando el archivo `generator.c`. Para cada puzzle se generaron varios archivos de 10 casos de prueba con profundidad y semilla distinta. Los resultados obtenidos fueron los siguientes:

15_puzzle				
	A*		IDA*	
Profundidad	Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados
5	3	4	3	5,5 ~ 6
10	3,4 ~ 3	4,4 ~ 4	3,4 ~ 3	5,9 ~ 6
15	4,8 ~ 5	5,8 ~ 6	4,8 ~ 5	9,6 ~ 10
20	8,8 ~ 9	15,2 ~ 15	8,8 ~ 9	41,3 ~ 41
30	11	113,6 ~ 114	11	203,7 ~ 204
50	14,4 ~ 14	41,6 ~ 42	14,4 ~ 14	110,9 ~ 111
75	25,2 ~ 25	189261,8 ~ 189262	23,1 ~ 23	642584
100	28,4 ~ 28	460848,9 ~ 460849	28,4 ~ 28	20146576

15_puzzle_manhattan				
	A*		IDA*	
Profundidad	Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados
5	3	147,8 ~ 148	3	215
10	3,4 ~ 3	155,1 ~ 155	3,4 ~ 3	409,8 ~ 410

15	4,8 ~ 5	1999,5 ~ 2000	4,8 ~ 5	10532,9 ~ 10533
20	8,8 ~ 9	7383964	8,8 ~ 9	18336056
30	-	-	-	-
50	*13,33 ~ 13	12395853	13,33 ~ 13	36725595
75	-	-	-	-
100	-	-	-	-

Profundidad	24_puzzle			
	A*		IDA*	
ad	Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados
5	3,4 ~ 3	4,4 ~ 4	3,4 ~ 3	6,2 ~ 6
10	4,6 ~ 5	5,6 ~ 6	4,6 ~ 5	8,8 ~ 9
15	7,2 ~ 7	9,2 ~ 9	7,2 ~ 7	18,6 ~ 19
20	9	26	9	83,8 ~ 84
30	12	69,8	12,2 ~ 12	178,1 ~ 178
50	18	484,3 ~ 484	18	2317,9 ~ 2318
75	30,2 ~ 30	1186985,9 ~ 1186986	30,2 ~ 30	1834826,8 ~ 1635827
100	31,2 ~ 31	64957,7 ~ 64958	31,2 ~ 31	250423,6 ~ 250724

Profundidad	Hanoi_4_12			
	A*		IDA*	
ad	Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados
5	2,1 ~ 2	4,69 ~ 5	2,1 ~ 2	24,3 ~ 24
10	2,9 ~ 3	13,4 ~ 13	2,9 ~ 3	84,5 ~ 85
15	3,4 ~ 3	23	3,4 ~ 3	188,2 ~ 188
20	4,2 ~ 4	264,1 ~ 264	4,2 ~ 4	2458,5 ~ 2459
30	5	231,6 ~ 232	5	1252,7 ~ 1253
50	5,7	7560,8 ~ 7561	6,3 ~ 6	48018,2 ~ 48018
75	8	22467,9 ~ 22468	8	155278,5 ~ 155279
90	8	22467,9 ~ 22468	8	155278,5 ~ 155279

Profundidad	Hanoi_4_14			
	A*		IDA*	
ad	Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados
5	2,7 ~ 3	12,2 ~ 12	2,7 ~ 3	66
10	3,1 ~ 3	59,5 ~ 60	3,1 ~ 3	756,2 ~ 756
15	3,6 ~ 4	296,9 ~ 297	3,6 ~ 4	949,2 ~ 949
20	4,5 ~ 5	175,1 ~ 175	4,5 ~ 5	874,4 ~ 874
30	6,1 ~ 6	4982,8 ~ 4983	6,1 ~ 6	19673,7 ~ 196738
50	5,4 ~ 5	14781	5,4 ~ 5	57327
75	7,1 ~ 7	7534,2 ~ 7534	7,1 ~ 7	33079,1 ~ 33079
90	-	-	-	-
100	8	92143,5 ~ 92144	8	693825,5

	Hanoi_4_17

Profundidad	A*		IDA*	
	Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados
5	2,5 ~ 3	8,2 ~ 8	2,2 ~ 2	37,1 ~ 37
10	2	5,9 ~ 6	2,2 ~ 2	33,4 ~ 33
15	4,9 ~ 5	743,9 ~ 744	4,9 ~ 5	2671,4 ~ 2671
20	4,4 ~ 5	2554	4,4 ~ 5	2615,4 ~ 2615
30	6,5 ~ 7	3445	6,5 ~ 7	14288,1 ~ 14288
50	-	-	7,6 ~ 8	1199982,8 ~ 1199983
75	8,2 ~ 8	240697,5 ~ 240698	9,4 ~ 9	1485812,6 ~ 1485813
90	7,6 ~ 8	11670	7,6 ~ 8	69882
100	7,2 ~ 7	9502,5 ~ 9503	9,7 ~ 10	100128,2 ~ 100129

Profundidad	Topspin_12_4			
	A*		IDA*	
Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados	
5	5	7,3 ~ 7	5	71,8 ~ 72
10	7,3 ~ 7	4106,4 ~ 4106	7,3 ~ 7	15102,1 ~ 15102
15	8,8 ~ 9	15371,4 ~ 15371	8,8 ~ 9	175919,7 ~ 175920
20	9,2 ~ 9	26123	9,2 ~ 9	206473,1 ~ 206473
30	9,1 ~ 9	11967,5 ~ 11968	9,1 ~ 9	108305,1 ~ 108305
50	9,6 ~ 10	291892,8 ~ 291893	9,6 ~ 10	902409,7 ~ 902410
75	7,9 ~ 8	11129,5 ~ 11130	8,8 ~ 9	51953,9 ~ 51954
90	9,2 ~ 9	141253	9,2 ~ 9	1026806,4 ~ 1026806
100	9,1 ~ 9	25860,8 ~ 25861	9,1 ~ 9	346678,1 ~ 346679

Profundidad	Topspin_14_4			
	A*		IDA*	
Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados	
5	5,4 ~ 5	3821,7 ~ 3822	5,4 ~ 5	69783,4 ~ 69783
10	8,3 ~ 8	203915,7 ~ 203916	9,3 ~ 9	2989191,4 ~ 2989191
15	11	2846098	11	8399989
20	11,16 ~ 11	631048,7 ~ 631049	-	-

Profundidad	Topspin_17_4			
	A*		IDA*	
Promedio profundidad	Promedio nodos generados	Promedio profundidad	Promedio nodos generados	
5	4,8 ~ 5	12,1 ~ 12	5,4 ~ 5	293,6 ~ 294
10	9,5 ~ 10	27477	9,5 ~ 10	527109,1 ~ 527109

En las tablas se puede observar las diferencias de los resultados de los algoritmos distintos. Es claro que ambos algoritmos encuentran las soluciones en profundidades iguales o muy parecidas. La diferencia de la ejecución de estos algoritmos se hace notoria en la cantidad de nodos generados, siendo IDA* el que genera más nodos. Esto se debe al tipo de búsqueda que realiza cada algoritmo. En el peor caso, IDA* tiene que recorrer todo el árbol de búsqueda hasta cierta profundidad, mientras que A* no recorre el árbol completo.

En el caso del 15_puzzle, podemos ver que ambas heurísticas encuentran las soluciones a la misma profundidad. Sin embargo, usando PDBs aditivas se generan muchos menos nodos para encontrar la solución que usando distancia Manhattan como heurística. Por limitaciones de hardware, no se lograron ejecutar los casos de prueba completos para el topspin. En los anexos se muestran las ejecuciones individuales de cada caso de prueba en cada puzzle.

Se puede conseguir que la cantidad mínima de movimientos necesarios para resolver las torres de Hanoi es $2^n - 1$. Sin embargo, estas soluciones tienen como configuración inicial a todos los discos en un asta distinta al asta objetivo. Los casos pruebas que se generaron son casos en donde, partiendo del estado objetivo, se realiza cierta cantidad de movimientos aleatorios. Por esta razón, los resultados son menores a $2^n - 1$ movimientos.

Para algunas variaciones del topspin del topspin no se lograron ejecutar la mayoría de los casos pruebas y esto se debe a la gran cantidad de nodos que se generan. Como no se lograron generar las PDBs para el cubo de rubik, tampoco se logró ejecutar ningún caso prueba del mismo.

5. Conclusiones.

Se pudo observar la diferencia en la cantidad de nodos y el factor de ramificación del árbol de búsqueda y se mostró que los árboles de búsqueda que se generaron realizando poda parcial de duplicado tienen menos nodos y un menor factor de ramificación.

Se vió el desempeño de estos algoritmos y concluimos que A* tiene mejor desempeño que IDA*. Ambos algoritmos encuentran soluciones óptimas a los puzzles, pero A* genera menos nodos que IDA*. Se logró observar las diferencias de ejecución usando distintas heurísticas para el caso del 15_puzzle.

A pesar de las limitaciones en memoria RAM y de que IDA* genera mayor cantidad de nodos, ambos algoritmos lograron ejecutar la misma cantidad de casos prueba. Tomando en cuenta los resultados obtenidos para los casos de prueba de mayor profundidad podemos concluir que la cantidad de movimientos óptimas para cada puzzle son las siguientes:

- 15_puzzle: 23 ~ 28 movimientos.
- 24_puzzle: 30 movimientos aproximadamente.
- Torres de hanoi: 8 ~ 10 movimientos para cualquier variación.
- Topsin: 8 ~ 10 movimientos aproximadamente

6. Anexos.

Corridas A*:

15-Puzzle

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../benchmarks/15-puzzle/15_puzzle.d\=005
puzzle name: 15_puzzle
goal reached at depth 3 - nodes generated 4
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 4
goal reached at depth 5 - nodes generated 6
goal reached at depth 3 - nodes generated 4
goal reached at depth 3 - nodes generated 4
goal reached at depth 1 - nodes generated 2
goal reached at depth 5 - nodes generated 6
goal reached at depth 1 - nodes generated 2
goal reached at depth 5 - nodes generated 6
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../benchmarks/15-puzzle/15_puzzle.d\=010
puzzle name: 15_puzzle
goal reached at depth 4 - nodes generated 5
goal reached at depth 2 - nodes generated 3
goal reached at depth 2 - nodes generated 3
goal reached at depth 4 - nodes generated 5
goal reached at depth 0 - nodes generated 1
goal reached at depth 6 - nodes generated 7
goal reached at depth 4 - nodes generated 5
goal reached at depth 4 - nodes generated 5
goal reached at depth 4 - nodes generated 5
goal reached at depth 4 - nodes generated 5
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../benchmarks/15-puzzle/15_puzzle.d\=015
puzzle name: 15_puzzle
goal reached at depth 1 - nodes generated 2
goal reached at depth 9 - nodes generated 10
goal reached at depth 5 - nodes generated 6
goal reached at depth 7 - nodes generated 8
goal reached at depth 1 - nodes generated 2
goal reached at depth 5 - nodes generated 6
goal reached at depth 7 - nodes generated 8
goal reached at depth 5 - nodes generated 6
goal reached at depth 3 - nodes generated 4
goal reached at depth 5 - nodes generated 6
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../benchmarks/15-puzzle/15_puzzle.d\=020
puzzle name: 15_puzzle
goal reached at depth 6 - nodes generated 7
goal reached at depth 14 - nodes generated 22
goal reached at depth 6 - nodes generated 7
goal reached at depth 6 - nodes generated 7
goal reached at depth 8 - nodes generated 9
goal reached at depth 16 - nodes generated 51
goal reached at depth 14 - nodes generated 28
goal reached at depth 6 - nodes generated 7
goal reached at depth 6 - nodes generated 7
goal reached at depth 6 - nodes generated 7
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../ben
chmarks/15-puzzle/15_puzzle.d\=030
puzzle name: 15_puzzle
goal reached at depth 18 - nodes generated 47
goal reached at depth 10 - nodes generated 11
goal reached at depth 14 - nodes generated 15
goal reached at depth 10 - nodes generated 11
goal reached at depth 16 - nodes generated 1005
goal reached at depth 6 - nodes generated 7
goal reached at depth 8 - nodes generated 9
goal reached at depth 10 - nodes generated 11
goal reached at depth 12 - nodes generated 13
goal reached at depth 6 - nodes generated 7
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../ben
chmarks/15-puzzle/15_puzzle.d\=050
puzzle name: 15_puzzle
goal reached at depth 12 - nodes generated 13
goal reached at depth 12 - nodes generated 18
goal reached at depth 16 - nodes generated 17
goal reached at depth 22 - nodes generated 216
goal reached at depth 8 - nodes generated 9
goal reached at depth 12 - nodes generated 13
goal reached at depth 18 - nodes generated 32
goal reached at depth 10 - nodes generated 11
goal reached at depth 20 - nodes generated 72
goal reached at depth 14 - nodes generated 15
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../ben
chmarks/15-puzzle/15_puzzle.d\=075
puzzle name: 15_puzzle
goal reached at depth 27 - nodes generated 23112
goal reached at depth 31 - nodes generated 1741795
goal reached at depth 23 - nodes generated 772
goal reached at depth 25 - nodes generated 5156
goal reached at depth 33 - nodes generated 976
goal reached at depth 27 - nodes generated 8684
goal reached at depth 23 - nodes generated 109037
goal reached at depth 21 - nodes generated 31
goal reached at depth 21 - nodes generated 2921
goal reached at depth 21 - nodes generated 134
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.a_star < ../ben
chmarks/15-puzzle/15_puzzle.d\=100
puzzle name: 15_puzzle
goal reached at depth 34 - nodes generated 165585
goal reached at depth 30 - nodes generated 16262
goal reached at depth 32 - nodes generated 1860300
goal reached at depth 34 - nodes generated 634027
goal reached at depth 30 - nodes generated 261141
goal reached at depth 26 - nodes generated 1560485
goal reached at depth 32 - nodes generated 102649
goal reached at depth 24 - nodes generated 7231
goal reached at depth 24 - nodes generated 687
goal reached at depth 18 - nodes generated 122
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

15 Puzzle - Manhattan

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
r < ../benchmarks/15-puzzle/15_puzzle.d\=005
puzzle name: 15_puzzle_manhattan
goal reached at depth 3 - nodes generated 36
goal reached at depth 1 - nodes generated 3
goal reached at depth 3 - nodes generated 38
goal reached at depth 5 - nodes generated 374
goal reached at depth 3 - nodes generated 36
goal reached at depth 3 - nodes generated 61
goal reached at depth 1 - nodes generated 3
goal reached at depth 5 - nodes generated 679
goal reached at depth 1 - nodes generated 4
goal reached at depth 5 - nodes generated 244
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle_manhattan.a sta
r < ../benchmarks/15-puzzle/15_puzzle.d\=010
puzzle name: 15_puzzle_manhattan
goal reached at depth 4 - nodes generated 123
goal reached at depth 2 - nodes generated 7
goal reached at depth 2 - nodes generated 15
goal reached at depth 4 - nodes generated 111
goal reached at depth 0 - nodes generated 1
goal reached at depth 6 - nodes generated 1017
goal reached at depth 4 - nodes generated 123
goal reached at depth 4 - nodes generated 53
goal reached at depth 4 - nodes generated 48
goal reached at depth 4 - nodes generated 53
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle_manhattan.a sta
r < ../benchmarks/15-puzzle/15_puzzle.d\=015
puzzle name: 15_puzzle_manhattan
goal reached at depth 1 - nodes generated 4
goal reached at depth 9 - nodes generated 15331
goal reached at depth 5 - nodes generated 374
goal reached at depth 7 - nodes generated 1683
goal reached at depth 1 - nodes generated 4
goal reached at depth 5 - nodes generated 282
goal reached at depth 7 - nodes generated 1548
goal reached at depth 5 - nodes generated 181
goal reached at depth 3 - nodes generated 21
goal reached at depth 5 - nodes generated 567
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle_manhattan.a sta
r < ../benchmarks/15-puzzle/15_puzzle.d\=020
puzzle name: 15_puzzle_manhattan
goal reached at depth 6 - nodes generated 482
goal reached at depth 14 - nodes generated 9408700
goal reached at depth 6 - nodes generated 1287
goal reached at depth 6 - nodes generated 1224
goal reached at depth 8 - nodes generated 7574
goal reached at depth 16 - nodes generated 57152893
goal reached at depth 14 - nodes generated 7264079
goal reached at depth 6 - nodes generated 796
goal reached at depth 6 - nodes generated 2188
goal reached at depth 6 - nodes generated 418
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

24 Puzzle

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=005
puzzle name: 24_puzzle
goal reached at depth 3 - nodes generated 4
goal reached at depth 3 - nodes generated 4
goal reached at depth 3 - nodes generated 4
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 4
goal reached at depth 5 - nodes generated 6
goal reached at depth 3 - nodes generated 4
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 6
goal reached at depth 3 - nodes generated 4
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=010
puzzle name: 24_puzzle
goal reached at depth 8 - nodes generated 9
goal reached at depth 4 - nodes generated 5
goal reached at depth 6 - nodes generated 7
goal reached at depth 2 - nodes generated 3
goal reached at depth 6 - nodes generated 7
goal reached at depth 4 - nodes generated 5
goal reached at depth 6 - nodes generated 7
goal reached at depth 6 - nodes generated 7
goal reached at depth 4 - nodes generated 5
goal reached at depth 0 - nodes generated 1
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=015
puzzle name: 24_puzzle
goal reached at depth 3 - nodes generated 4
goal reached at depth 9 - nodes generated 10
goal reached at depth 13 - nodes generated 14
goal reached at depth 7 - nodes generated 8
goal reached at depth 9 - nodes generated 10
goal reached at depth 3 - nodes generated 4
goal reached at depth 5 - nodes generated 6
goal reached at depth 13 - nodes generated 24
goal reached at depth 3 - nodes generated 4
goal reached at depth 7 - nodes generated 8
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=020
puzzle name: 24_puzzle
goal reached at depth 6 - nodes generated 7
goal reached at depth 6 - nodes generated 7
goal reached at depth 10 - nodes generated 11
goal reached at depth 8 - nodes generated 9
goal reached at depth 10 - nodes generated 11
goal reached at depth 10 - nodes generated 11
goal reached at depth 8 - nodes generated 9
goal reached at depth 10 - nodes generated 101
goal reached at depth 8 - nodes generated 9
goal reached at depth 14 - nodes generated 85
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=030
puzzle name: 24_puzzle
goal reached at depth 14 - nodes generated 15
goal reached at depth 20 - nodes generated 511
goal reached at depth 18 - nodes generated 97
goal reached at depth 10 - nodes generated 11
goal reached at depth 14 - nodes generated 20
goal reached at depth 8 - nodes generated 9
goal reached at depth 10 - nodes generated 11
goal reached at depth 8 - nodes generated 9
goal reached at depth 14 - nodes generated 15
goal reached at depth 8 - nodes generated 9
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=050
puzzle name: 24_puzzle
goal reached at depth 18 - nodes generated 19
goal reached at depth 24 - nodes generated 49
goal reached at depth 14 - nodes generated 15
goal reached at depth 18 - nodes generated 1045
goal reached at depth 22 - nodes generated 32
goal reached at depth 14 - nodes generated 15
goal reached at depth 14 - nodes generated 103
goal reached at depth 20 - nodes generated 3379
goal reached at depth 12 - nodes generated 29
goal reached at depth 24 - nodes generated 157
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=075
puzzle name: 24_puzzle
goal reached at depth 33 - nodes generated 4977599
goal reached at depth 25 - nodes generated 177
goal reached at depth 27 - nodes generated 68820
goal reached at depth 39 - nodes generated 712588
goal reached at depth 31 - nodes generated 2895760
goal reached at depth 33 - nodes generated 6047
goal reached at depth 23 - nodes generated 11597
goal reached at depth 37 - nodes generated 3180185
goal reached at depth 23 - nodes generated 1842
goal reached at depth 31 - nodes generated 15244
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.a_star < ../benchmarks/24-puzzle/24_puzzle.d\=100
puzzle name: 24_puzzle
goal reached at depth 24 - nodes generated 46
goal reached at depth 38 - nodes generated 177949
goal reached at depth 24 - nodes generated 25
goal reached at depth 32 - nodes generated 311957
goal reached at depth 24 - nodes generated 73
goal reached at depth 34 - nodes generated 1770
goal reached at depth 28 - nodes generated 86
goal reached at depth 42 - nodes generated 75805
goal reached at depth 26 - nodes generated 3042
goal reached at depth 40 - nodes generated 78824
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ make clean
```

Hanoi 4_12

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=005
puzzle name: hanoi4_12
goal reached at depth 3 - nodes generated 5
goal reached at depth 1 - nodes generated 2
goal reached at depth 2 - nodes generated 4
goal reached at depth 3 - nodes generated 9
goal reached at depth 1 - nodes generated 2
goal reached at depth 2 - nodes generated 4
goal reached at depth 3 - nodes generated 5
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 12
goal reached at depth 2 - nodes generated 4
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=010
puzzle name: hanoi4_12
goal reached at depth 2 - nodes generated 4
goal reached at depth 5 - nodes generated 56
goal reached at depth 1 - nodes generated 2
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 12
goal reached at depth 1 - nodes generated 2
goal reached at depth 4 - nodes generated 13
goal reached at depth 4 - nodes generated 16
goal reached at depth 4 - nodes generated 14
goal reached at depth 4 - nodes generated 13
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=015
puzzle name: hanoi4_12
goal reached at depth 3 - nodes generated 12
goal reached at depth 5 - nodes generated 69
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 4 - nodes generated 13
goal reached at depth 4 - nodes generated 19
goal reached at depth 3 - nodes generated 12
goal reached at depth 2 - nodes generated 4
goal reached at depth 5 - nodes generated 80
goal reached at depth 4 - nodes generated 13
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=020
puzzle name: hanoi4_12
goal reached at depth 1 - nodes generated 2
goal reached at depth 8 - nodes generated 2233
goal reached at depth 4 - nodes generated 19
goal reached at depth 4 - nodes generated 8
goal reached at depth 2 - nodes generated 4
goal reached at depth 6 - nodes generated 209
goal reached at depth 4 - nodes generated 8
goal reached at depth 6 - nodes generated 133
goal reached at depth 4 - nodes generated 13
goal reached at depth 3 - nodes generated 12
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../ben
chmarks/hanoi_4p12d/hanoi_4p12d.d\=030
puzzle name: hanoi4_12
goal reached at depth 3 - nodes generated 12
goal reached at depth 6 - nodes generated 141
goal reached at depth 7 - nodes generated 1358
goal reached at depth 6 - nodes generated 209
goal reached at depth 6 - nodes generated 238
goal reached at depth 4 - nodes generated 13
goal reached at depth 3 - nodes generated 5
goal reached at depth 5 - nodes generated 96
goal reached at depth 6 - nodes generated 228
goal reached at depth 4 - nodes generated 16
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../ben
chmarks/hanoi_4p12d/hanoi_4p12d.d\=050
puzzle name: hanoi4_12
goal reached at depth 6 - nodes generated 213
goal reached at depth 8 - nodes generated 5329
goal reached at depth 10 - nodes generated 55570
goal reached at depth 4 - nodes generated 19
goal reached at depth 6 - nodes generated 261
goal reached at depth 4 - nodes generated 13
goal reached at depth 6 - nodes generated 228
goal reached at depth 3 - nodes generated 12
goal reached at depth 7 - nodes generated 1422
goal reached at depth 9 - nodes generated 12541
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../ben
chmarks/hanoi_4p12d/hanoi_4p12d.d\=075
puzzle name: hanoi4_12
goal reached at depth 6 - nodes generated 369
goal reached at depth 10 - nodes generated 46537
goal reached at depth 9 - nodes generated 15135
goal reached at depth 8 - nodes generated 6616
goal reached at depth 4 - nodes generated 19
goal reached at depth 10 - nodes generated 45488
goal reached at depth 6 - nodes generated 250
goal reached at depth 10 - nodes generated 47327
goal reached at depth 10 - nodes generated 58732
goal reached at depth 7 - nodes generated 4206
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.a_star < ../ben
chmarks/hanoi_4p12d/hanoi_4p12d.d\=090
puzzle name: hanoi4_12
goal reached at depth 6 - nodes generated 369
goal reached at depth 10 - nodes generated 46537
goal reached at depth 9 - nodes generated 15135
goal reached at depth 8 - nodes generated 6616
goal reached at depth 4 - nodes generated 19
goal reached at depth 10 - nodes generated 45488
goal reached at depth 6 - nodes generated 250
goal reached at depth 10 - nodes generated 47327
goal reached at depth 10 - nodes generated 58732
goal reached at depth 7 - nodes generated 4206
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

Hanoi 4 14

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=005
puzzle name: hanoi4_14
goal reached at depth 4 - nodes generated 13
goal reached at depth 5 - nodes generated 56
goal reached at depth 3 - nodes generated 12
goal reached at depth 1 - nodes generated 2
goal reached at depth 4 - nodes generated 13
goal reached at depth 1 - nodes generated 2
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 3 - nodes generated 12
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=010
puzzle name: hanoi4_14
goal reached at depth 7 - nodes generated 495
goal reached at depth 5 - nodes generated 56
goal reached at depth 1 - nodes generated 2
goal reached at depth 2 - nodes generated 4
goal reached at depth 4 - nodes generated 14
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 4 - nodes generated 8
goal reached at depth 2 - nodes generated 4
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=015
puzzle name: hanoi4_14
goal reached at depth 7 - nodes generated 2756
goal reached at depth 5 - nodes generated 71
goal reached at depth 3 - nodes generated 12
goal reached at depth 3 - nodes generated 5
goal reached at depth 3 - nodes generated 12
goal reached at depth 1 - nodes generated 2
goal reached at depth 4 - nodes generated 13
goal reached at depth 4 - nodes generated 16
goal reached at depth 5 - nodes generated 80
goal reached at depth 1 - nodes generated 2
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=020
puzzle name: hanoi4_14
goal reached at depth 6 - nodes generated 139
goal reached at depth 3 - nodes generated 9
goal reached at depth 2 - nodes generated 4
goal reached at depth 5 - nodes generated 84
goal reached at depth 4 - nodes generated 16
goal reached at depth 4 - nodes generated 13
goal reached at depth 5 - nodes generated 56
goal reached at depth 5 - nodes generated 56
goal reached at depth 4 - nodes generated 16
goal reached at depth 7 - nodes generated 1358
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
chmarks/hanoi_4p14d/hanoi_4p14d.d\=030
puzzle name: hanoi4_14
goal reached at depth 7 - nodes generated 1358
goal reached at depth 2 - nodes generated 4
goal reached at depth 6 - nodes generated 209
goal reached at depth 6 - nodes generated 125
goal reached at depth 5 - nodes generated 91
goal reached at depth 7 - nodes generated 1889
goal reached at depth 7 - nodes generated 1262
goal reached at depth 10 - nodes generated 42951
goal reached at depth 4 - nodes generated 13
goal reached at depth 7 - nodes generated 1926
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../ben
chmarks/hanoi_4p14d/hanoi_4p14d.d\=050
puzzle name: hanoi4_14
goal reached at depth 6 - nodes generated 208
goal reached at depth 4 - nodes generated 13
goal reached at depth 5 - nodes generated 91
goal reached at depth 7 - nodes generated 1889
goal reached at depth 1 - nodes generated 2
goal reached at depth 4 - nodes generated 8
goal reached at depth 5 - nodes generated 84
goal reached at depth 5 - nodes generated 80
goal reached at depth 11 - nodes generated 145197
goal reached at depth 6 - nodes generated 238
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../ben
chmarks/hanoi_4p14d/hanoi_4p14d.d\=075
puzzle name: hanoi4_14
goal reached at depth 9 - nodes generated 25487
goal reached at depth 5 - nodes generated 91
goal reached at depth 9 - nodes generated 10654
goal reached at depth 4 - nodes generated 8
goal reached at depth 5 - nodes generated 71
goal reached at depth 8 - nodes generated 3513
goal reached at depth 10 - nodes generated 30599
goal reached at depth 8 - nodes generated 2532
goal reached at depth 5 - nodes generated 91
goal reached at depth 8 - nodes generated 2296
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../ben
chmarks/hanoi_4p14d/hanoi_4p14d.d\=090
puzzle name: hanoi4_14
goal reached at depth 8 - nodes generated 5980
goal reached at depth 10 - nodes generated 57950
^C
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.a_star < ../ben
chmarks/hanoi_4p14d/hanoi_4p14d.d\=100
puzzle name: hanoi4_14
goal reached at depth 5 - nodes generated 71
goal reached at depth 11 - nodes generated 205790
goal reached at depth 4 - nodes generated 8
goal reached at depth 4 - nodes generated 14
goal reached at depth 8 - nodes generated 2232
goal reached at depth 8 - nodes generated 2532
goal reached at depth 9 - nodes generated 16612
goal reached at depth 12 - nodes generated 600387
goal reached at depth 11 - nodes generated 88937
goal reached at depth 8 - nodes generated 4852
```

Hanoi 4 17

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=005
puzzle name: hanoi4_17
goal reached at depth 3 - nodes generated 12
goal reached at depth 4 - nodes generated 19
goal reached at depth 3 - nodes generated 9
goal reached at depth 2 - nodes generated 4
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 9
goal reached at depth 3 - nodes generated 9
goal reached at depth 2 - nodes generated 4
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 12
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=010
puzzle name: hanoi4_17
goal reached at depth 4 - nodes generated 13
goal reached at depth 0 - nodes generated 1
goal reached at depth 1 - nodes generated 2
goal reached at depth 4 - nodes generated 8
goal reached at depth 3 - nodes generated 9
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 2 - nodes generated 4
goal reached at depth 1 - nodes generated 2
goal reached at depth 3 - nodes generated 12
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=015
puzzle name: hanoi4_17
goal reached at depth 8 - nodes generated 4990
goal reached at depth 5 - nodes generated 56
goal reached at depth 6 - nodes generated 238
goal reached at depth 5 - nodes generated 96
goal reached at depth 5 - nodes generated 96
goal reached at depth 4 - nodes generated 8
goal reached at depth 3 - nodes generated 12
goal reached at depth 3 - nodes generated 5
goal reached at depth 7 - nodes generated 1926
goal reached at depth 3 - nodes generated 12
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=020
puzzle name: hanoi4_17
goal reached at depth 3 - nodes generated 5
goal reached at depth 7 - nodes generated 3340
goal reached at depth 4 - nodes generated 8
goal reached at depth 4 - nodes generated 8
goal reached at depth 3 - nodes generated 12
goal reached at depth 8 - nodes generated 2112
goal reached at depth 3 - nodes generated 9
goal reached at depth 4 - nodes generated 8
goal reached at depth 4 - nodes generated 19
goal reached at depth 4 - nodes generated 19
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help

waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=030
puzzle name: hanoi4_17
goal reached at depth 7 - nodes generated 3123
goal reached at depth 6 - nodes generated 141
goal reached at depth 6 - nodes generated 125
goal reached at depth 6 - nodes generated 238
goal reached at depth 4 - nodes generated 16
goal reached at depth 7 - nodes generated 1736
goal reached at depth 6 - nodes generated 139
goal reached at depth 7 - nodes generated 452
goal reached at depth 9 - nodes generated 25933
goal reached at depth 7 - nodes generated 2547
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=050
puzzle name: hanoi4_17
^C
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=075
puzzle name: hanoi4_17
goal reached at depth 12 - nodes generated 1945238
goal reached at depth 9 - nodes generated 9987
goal reached at depth 11 - nodes generated 222815
goal reached at depth 8 - nodes generated 6561
goal reached at depth 2 - nodes generated 4
goal reached at depth 11 - nodes generated 206130
goal reached at depth 5 - nodes generated 56
goal reached at depth 6 - nodes generated 133
goal reached at depth 9 - nodes generated 7430
goal reached at depth 9 - nodes generated 8621
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=090
puzzle name: hanoi4_17
goal reached at depth 4 - nodes generated 16
goal reached at depth 9 - nodes generated 8499
goal reached at depth 10 - nodes generated 26495
^C
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.a_star < ../ben
chmarks/hanoi_4p17d/hanoi_4p17d.d\=100
puzzle name: hanoi4_17
goal reached at depth 6 - nodes generated 238
goal reached at depth 5 - nodes generated 56
goal reached at depth 10 - nodes generated 30617
goal reached at depth 8 - nodes generated 7099
^C
```

Topspin 12-4

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=005
puzzle name: topspin12_4
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 10
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 10
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 8
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=010
puzzle name: topspin12_4
goal reached at depth 9 - nodes generated 31827
goal reached at depth 4 - nodes generated 5
goal reached at depth 8 - nodes generated 2896
goal reached at depth 8 - nodes generated 2183
goal reached at depth 8 - nodes generated 1007
goal reached at depth 8 - nodes generated 1346
goal reached at depth 4 - nodes generated 5
goal reached at depth 8 - nodes generated 240
goal reached at depth 8 - nodes generated 748
goal reached at depth 8 - nodes generated 807
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=015
puzzle name: topspin12_4
goal reached at depth 8 - nodes generated 775
goal reached at depth 8 - nodes generated 1099
goal reached at depth 8 - nodes generated 4225
goal reached at depth 10 - nodes generated 21542
goal reached at depth 10 - nodes generated 74692
goal reached at depth 8 - nodes generated 750
goal reached at depth 9 - nodes generated 31933
goal reached at depth 10 - nodes generated 85244
goal reached at depth 9 - nodes generated 5247
goal reached at depth 8 - nodes generated 2899
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=020
puzzle name: topspin12_4
goal reached at depth 10 - nodes generated 80684
goal reached at depth 10 - nodes generated 42287
goal reached at depth 10 - nodes generated 41960
goal reached at depth 8 - nodes generated 3184
goal reached at depth 9 - nodes generated 18282
goal reached at depth 10 - nodes generated 39789
goal reached at depth 9 - nodes generated 6498
goal reached at depth 8 - nodes generated 735
goal reached at depth 8 - nodes generated 2998
goal reached at depth 10 - nodes generated 24813
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=030
puzzle name: topspin12_4
goal reached at depth 8 - nodes generated 1470
goal reached at depth 9 - nodes generated 10881
goal reached at depth 9 - nodes generated 3951
goal reached at depth 9 - nodes generated 6482
goal reached at depth 9 - nodes generated 7154
goal reached at depth 9 - nodes generated 2780
goal reached at depth 10 - nodes generated 36199
goal reached at depth 10 - nodes generated 20838
goal reached at depth 9 - nodes generated 15449
goal reached at depth 9 - nodes generated 14471
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=050
puzzle name: topspin12_4
goal reached at depth 12 - nodes generated 2585387
goal reached at depth 9 - nodes generated 5636
goal reached at depth 9 - nodes generated 4284
goal reached at depth 10 - nodes generated 57835
goal reached at depth 10 - nodes generated 39987
goal reached at depth 9 - nodes generated 10917
goal reached at depth 10 - nodes generated 110079
goal reached at depth 9 - nodes generated 10268
goal reached at depth 10 - nodes generated 88725
goal reached at depth 8 - nodes generated 5810
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=075
puzzle name: topspin12_4
goal reached at depth 9 - nodes generated 21684
goal reached at depth 9 - nodes generated 26403
goal reached at depth 9 - nodes generated 23683
goal reached at depth 8 - nodes generated 236
goal reached at depth 9 - nodes generated 6870
goal reached at depth 10 - nodes generated 21326
goal reached at depth 9 - nodes generated 5012
goal reached at depth 8 - nodes generated 3880
goal reached at depth 8 - nodes generated 757
goal reached at depth 9 - nodes generated 14444
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=090
puzzle name: topspin12_4
goal reached at depth 10 - nodes generated 56058
goal reached at depth 8 - nodes generated 1449
goal reached at depth 10 - nodes generated 33150
goal reached at depth 9 - nodes generated 5877
goal reached at depth 10 - nodes generated 43678
goal reached at depth 8 - nodes generated 218
goal reached at depth 11 - nodes generated 1167853
goal reached at depth 7 - nodes generated 219
goal reached at depth 9 - nodes generated 11242
goal reached at depth 10 - nodes generated 92786
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=100
puzzle name: topspin12_4
goal reached at depth 9 - nodes generated 10517
goal reached at depth 10 - nodes generated 30030
goal reached at depth 9 - nodes generated 4032
goal reached at depth 10 - nodes generated 47791
goal reached at depth 10 - nodes generated 27592
goal reached at depth 8 - nodes generated 1717
goal reached at depth 7 - nodes generated 87
goal reached at depth 9 - nodes generated 4541
goal reached at depth 10 - nodes generated 125858
goal reached at depth 9 - nodes generated 6443
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=2000
puzzle name: topspin12_4
goal reached at depth 9 - nodes generated 8654
goal reached at depth 7 - nodes generated 571
goal reached at depth 10 - nodes generated 92957
goal reached at depth 9 - nodes generated 12380
goal reached at depth 9 - nodes generated 19064
goal reached at depth 11 - nodes generated 239349
goal reached at depth 7 - nodes generated 58
goal reached at depth 8 - nodes generated 76
goal reached at depth 10 - nodes generated 13034
goal reached at depth 9 - nodes generated 3868
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin12_4.a_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=2000000
puzzle name: topspin12_4
goal reached at depth 9 - nodes generated 5944
goal reached at depth 10 - nodes generated 30403
goal reached at depth 9 - nodes generated 5225
goal reached at depth 11 - nodes generated 322501
goal reached at depth 9 - nodes generated 24600
goal reached at depth 9 - nodes generated 9531
goal reached at depth 7 - nodes generated 103
goal reached at depth 8 - nodes generated 1301
goal reached at depth 9 - nodes generated 34411
goal reached at depth 10 - nodes generated 17820
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

Topspin 14-4

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin14_4.a_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=005
puzzle name: topspin14_4
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 7
goal reached at depth 9 - nodes generated 38140
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 10
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 22
goal reached at depth 5 - nodes generated 6
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin14_4.a_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=010
puzzle name: topspin14_4
goal reached at depth 10 - nodes generated 88301
goal reached at depth 10 - nodes generated 131723
goal reached at depth 8 - nodes generated 2397
goal reached at depth 10 - nodes generated 218510
goal reached at depth 10 - nodes generated 674444
goal reached at depth 10 - nodes generated 101447
goal reached at depth 11 - nodes generated 681272
goal reached at depth 6 - nodes generated 41
goal reached at depth 8 - nodes generated 407
goal reached at depth 10 - nodes generated 140615
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin14_4.a_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=015
puzzle name: topspin14_4
goal reached at depth 10 - nodes generated 92331
goal reached at depth 12 - nodes generated 5599865
Killed
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin14_4.a_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=020
puzzle name: topspin14_4
goal reached at depth 12 - nodes generated 1169531
goal reached at depth 10 - nodes generated 16950
goal reached at depth 11 - nodes generated 470882
goal reached at depth 11 - nodes generated 327727
goal reached at depth 12 - nodes generated 4133769
goal reached at depth 11 - nodes generated 191628
Killed
```

Topspin 17-4

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin17_4.a_star < ../benchmarks/topspin_17_4/topspin_17_4.d\=005
puzzle name: topspin17_4
goal reached at depth 5 - nodes generated 14
goal reached at depth 5 - nodes generated 21
goal reached at depth 5 - nodes generated 16
goal reached at depth 5 - nodes generated 18
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 20
goal reached at depth 3 - nodes generated 4
goal reached at depth 5 - nodes generated 7
goal reached at depth 5 - nodes generated 6
goal reached at depth 5 - nodes generated 8
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin17_4.a_star < ../benchmarks/topspin_17_4/topspin_17_4.d\=010
puzzle name: topspin17_4
goal reached at depth 10 - nodes generated 15349
goal reached at depth 8 - nodes generated 282
goal reached at depth 9 - nodes generated 15937
goal reached at depth 10 - nodes generated 13757
goal reached at depth 10 - nodes generated 19631
goal reached at depth 8 - nodes generated 190
goal reached at depth 10 - nodes generated 19417
goal reached at depth 10 - nodes generated 4611
goal reached at depth 10 - nodes generated 51628
goal reached at depth 10 - nodes generated 133968
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin17_4.a_star < ../benchmarks/topspin_17_4/topspin_17_4.d\=015
puzzle name: topspin17_4
goal reached at depth 10 - nodes generated 15349
goal reached at depth 8 - nodes generated 282
goal reached at depth 9 - nodes generated 15937
goal reached at depth 10 - nodes generated 13757
goal reached at depth 10 - nodes generated 19631
goal reached at depth 8 - nodes generated 190
goal reached at depth 10 - nodes generated 19417
goal reached at depth 10 - nodes generated 4611
goal reached at depth 10 - nodes generated 51628
goal reached at depth 10 - nodes generated 133968
```

Corridas IDA*

15-Puzzle

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.ida_star < ../benchmarks/15-puzzle/15_puzzle.d\=005
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 1 - nodes generated: 2
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 5 - nodes generated: 12
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 1 - nodes generated: 2
goal reached at depth: 5 - nodes generated: 8
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 5 - nodes generated: 10
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.ida_star < ../benchmarks/15-puzzle/15_puzzle.d\=010
goal reached at depth: 4 - nodes generated: 7
goal reached at depth: 2 - nodes generated: 2
goal reached at depth: 2 - nodes generated: 4
goal reached at depth: 4 - nodes generated: 7
goal reached at depth: 0 - nodes generated: 0
goal reached at depth: 6 - nodes generated: 11
goal reached at depth: 4 - nodes generated: 7
goal reached at depth: 4 - nodes generated: 7
goal reached at depth: 4 - nodes generated: 7
goal reached at depth: 4 - nodes generated: 7
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.ida_star < ../benchmarks/15-puzzle/15_puzzle.d\=015
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 9 - nodes generated: 19
goal reached at depth: 5 - nodes generated: 12
goal reached at depth: 7 - nodes generated: 15
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 5 - nodes generated: 12
goal reached at depth: 7 - nodes generated: 14
goal reached at depth: 5 - nodes generated: 10
goal reached at depth: 3 - nodes generated: 3
goal reached at depth: 5 - nodes generated: 9
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle.ida_star < ../benchmarks/15-puzzle/15_puzzle.d\=020
goal reached at depth: 6 - nodes generated: 11
goal reached at depth: 14 - nodes generated: 27
goal reached at depth: 6 - nodes generated: 10
goal reached at depth: 6 - nodes generated: 10
goal reached at depth: 8 - nodes generated: 27
goal reached at depth: 16 - nodes generated: 209
goal reached at depth: 14 - nodes generated: 84
goal reached at depth: 6 - nodes generated: 10
goal reached at depth: 6 - nodes generated: 12
goal reached at depth: 6 - nodes generated: 13
```

15 Puzzle Manhattan

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms
File Edit View Search Terminal Help
tar < ../benchmarks/15-puzzle/15_puzzle.d\=005
puzzle name: 15_puzzle_manhattan
goal reached at depth: 3 - nodes generated: 110
goal reached at depth: 1 - nodes generated: 6
goal reached at depth: 3 - nodes generated: 35
goal reached at depth: 5 - nodes generated: 528
goal reached at depth: 3 - nodes generated: 110
goal reached at depth: 3 - nodes generated: 35
goal reached at depth: 1 - nodes generated: 6
goal reached at depth: 5 - nodes generated: 252
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 5 - nodes generated: 1067
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle_manhattan.ida_s
tar < ../benchmarks/15-puzzle/15_puzzle.d\=010
puzzle name: 15_puzzle_manhattan
goal reached at depth: 4 - nodes generated: 229
goal reached at depth: 2 - nodes generated: 2
goal reached at depth: 2 - nodes generated: 34
goal reached at depth: 4 - nodes generated: 246
goal reached at depth: 0 - nodes generated: 0
goal reached at depth: 6 - nodes generated: 3056
goal reached at depth: 4 - nodes generated: 229
goal reached at depth: 4 - nodes generated: 116
goal reached at depth: 4 - nodes generated: 70
goal reached at depth: 4 - nodes generated: 116
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle_manhattan.ida_s
tar < ../benchmarks/15-puzzle/15_puzzle.d\=015
puzzle name: 15_puzzle_manhattan
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 9 - nodes generated: 80169
goal reached at depth: 5 - nodes generated: 528
goal reached at depth: 7 - nodes generated: 12293
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 5 - nodes generated: 1221
goal reached at depth: 7 - nodes generated: 8763
goal reached at depth: 5 - nodes generated: 954
goal reached at depth: 3 - nodes generated: 3
goal reached at depth: 5 - nodes generated: 796
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./15_puzzle_manhattan.ida_s
tar < ../benchmarks/15-puzzle/15_puzzle.d\=020
puzzle name: 15_puzzle_manhattan
goal reached at depth: 6 - nodes generated: 955
goal reached at depth: 14 - nodes generated: 868915
goal reached at depth: 6 - nodes generated: 3014
goal reached at depth: 6 - nodes generated: 3204
goal reached at depth: 8 - nodes generated: 21023
goal reached at depth: 16 - nodes generated: 152874940
goal reached at depth: 14 - nodes generated: 29580477
goal reached at depth: 6 - nodes generated: 781
goal reached at depth: 6 - nodes generated: 6031
goal reached at depth: 6 - nodes generated: 1222
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

24 Puzzle

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=005
goal reached at depth: 3 - nodes generated: 6
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 3 - nodes generated: 3
goal reached at depth: 1 - nodes generated: 2
goal reached at depth: 3 - nodes generated: 7
goal reached at depth: 5 - nodes generated: 11
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 5 - nodes generated: 11
goal reached at depth: 5 - nodes generated: 9
goal reached at depth: 3 - nodes generated: 3
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=010
goal reached at depth: 8 - nodes generated: 15
goal reached at depth: 4 - nodes generated: 6
goal reached at depth: 6 - nodes generated: 11
goal reached at depth: 2 - nodes generated: 4
goal reached at depth: 6 - nodes generated: 12
goal reached at depth: 4 - nodes generated: 6
goal reached at depth: 6 - nodes generated: 10
goal reached at depth: 6 - nodes generated: 17
goal reached at depth: 4 - nodes generated: 7
goal reached at depth: 0 - nodes generated: 0
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=015
goal reached at depth: 3 - nodes generated: 5
goal reached at depth: 9 - nodes generated: 23
goal reached at depth: 13 - nodes generated: 29
goal reached at depth: 7 - nodes generated: 12
goal reached at depth: 9 - nodes generated: 22
goal reached at depth: 3 - nodes generated: 6
goal reached at depth: 5 - nodes generated: 8
goal reached at depth: 13 - nodes generated: 52
goal reached at depth: 3 - nodes generated: 6
goal reached at depth: 7 - nodes generated: 23
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=020
goal reached at depth: 6 - nodes generated: 11
goal reached at depth: 6 - nodes generated: 10
goal reached at depth: 10 - nodes generated: 22
goal reached at depth: 8 - nodes generated: 16
goal reached at depth: 10 - nodes generated: 17
goal reached at depth: 10 - nodes generated: 16
goal reached at depth: 8 - nodes generated: 17
goal reached at depth: 10 - nodes generated: 598
goal reached at depth: 8 - nodes generated: 16
goal reached at depth: 14 - nodes generated: 115
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms - □ ×
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=030
goal reached at depth: 14 - nodes generated: 24
goal reached at depth: 20 - nodes generated: 1165
goal reached at depth: 18 - nodes generated: 372
goal reached at depth: 10 - nodes generated: 25
goal reached at depth: 14 - nodes generated: 84
goal reached at depth: 8 - nodes generated: 27
goal reached at depth: 10 - nodes generated: 19
goal reached at depth: 8 - nodes generated: 22
goal reached at depth: 14 - nodes generated: 26
goal reached at depth: 8 - nodes generated: 17
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=050
goal reached at depth: 18 - nodes generated: 68
goal reached at depth: 24 - nodes generated: 109
goal reached at depth: 14 - nodes generated: 40
goal reached at depth: 18 - nodes generated: 2066
goal reached at depth: 22 - nodes generated: 81
goal reached at depth: 14 - nodes generated: 65
goal reached at depth: 14 - nodes generated: 443
goal reached at depth: 20 - nodes generated: 20162
goal reached at depth: 12 - nodes generated: 62
goal reached at depth: 24 - nodes generated: 83
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=075
goal reached at depth: 33 - nodes generated: 2360364
goal reached at depth: 25 - nodes generated: 3195
goal reached at depth: 27 - nodes generated: 19333
goal reached at depth: 39 - nodes generated: 1310275
goal reached at depth: 31 - nodes generated: 3798758
goal reached at depth: 33 - nodes generated: 13415
goal reached at depth: 23 - nodes generated: 41261
goal reached at depth: 37 - nodes generated: 10772068
goal reached at depth: 23 - nodes generated: 2184
goal reached at depth: 31 - nodes generated: 37415
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./24_puzzle.ida
_star < ../benchmarks/24-puzzle/24_puzzle.d\=100
goal reached at depth: 24 - nodes generated: 80
goal reached at depth: 38 - nodes generated: 474804
goal reached at depth: 24 - nodes generated: 83
goal reached at depth: 32 - nodes generated: 1604345
goal reached at depth: 24 - nodes generated: 142
goal reached at depth: 34 - nodes generated: 4356
goal reached at depth: 28 - nodes generated: 421
goal reached at depth: 42 - nodes generated: 211237
goal reached at depth: 26 - nodes generated: 4858
goal reached at depth: 40 - nodes generated: 203910
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

Hanoi 4-12

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=005
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 2 - nodes generated: 21
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=010
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 5 - nodes generated: 291
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 3 - nodes generated: 45
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 4 - nodes generated: 124
goal reached at depth: 4 - nodes generated: 111
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=015
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 5 - nodes generated: 734
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 5 - nodes generated: 622
goal reached at depth: 4 - nodes generated: 111
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=020
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 8 - nodes generated: 20367
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 6 - nodes generated: 1227
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 6 - nodes generated: 2480
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 3 - nodes generated: 55
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=025
goal reached at depth: 0 - nodes generated: 0
goal reached at depth: 6 - nodes generated: 735
goal reached at depth: 8 - nodes generated: 29664
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 6 - nodes generated: 2480
goal reached at depth: 8 - nodes generated: 14202
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 7 - nodes generated: 2088
goal reached at depth: 3 - nodes generated: 22
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=030
goal reached at depth: 3 - nodes generated: 45
goal reached at depth: 6 - nodes generated: 2087
goal reached at depth: 7 - nodes generated: 5242
goal reached at depth: 6 - nodes generated: 1227
goal reached at depth: 6 - nodes generated: 1485
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 5 - nodes generated: 315
goal reached at depth: 6 - nodes generated: 1826
goal reached at depth: 4 - nodes generated: 139
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=050
goal reached at depth: 6 - nodes generated: 735
goal reached at depth: 8 - nodes generated: 51152
goal reached at depth: 10 - nodes generated: 310337
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 6 - nodes generated: 1684
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 6 - nodes generated: 1826
goal reached at depth: 3 - nodes generated: 45
goal reached at depth: 7 - nodes generated: 4894
goal reached at depth: 9 - nodes generated: 109237
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=060
goal reached at depth: 6 - nodes generated: 3877
goal reached at depth: 10 - nodes generated: 305048
goal reached at depth: 9 - nodes generated: 126477
goal reached at depth: 8 - nodes generated: 81691
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 10 - nodes generated: 205069
goal reached at depth: 6 - nodes generated: 1857
goal reached at depth: 10 - nodes generated: 370757
goal reached at depth: 10 - nodes generated: 453947
goal reached at depth: 7 - nodes generated: 3901
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=075
goal reached at depth: 6 - nodes generated: 3877
goal reached at depth: 10 - nodes generated: 305048
goal reached at depth: 9 - nodes generated: 126477
goal reached at depth: 8 - nodes generated: 81691
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 10 - nodes generated: 205069
goal reached at depth: 6 - nodes generated: 1857
goal reached at depth: 10 - nodes generated: 370757
goal reached at depth: 10 - nodes generated: 453947
goal reached at depth: 7 - nodes generated: 3901
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=090
goal reached at depth: 6 - nodes generated: 3877
goal reached at depth: 10 - nodes generated: 305048
goal reached at depth: 9 - nodes generated: 126477
goal reached at depth: 8 - nodes generated: 81691
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 10 - nodes generated: 205069
goal reached at depth: 6 - nodes generated: 1857
goal reached at depth: 10 - nodes generated: 370757
goal reached at depth: 10 - nodes generated: 453947
goal reached at depth: 7 - nodes generated: 3901
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_12.ida
_star < ../benchmarks/hanoi_4p12d/hanoi_4p12d.d\=100
Killed
```

Hanoi 4-14

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=005
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 5 - nodes generated: 293
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 3 - nodes generated: 55
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=010
goal reached at depth: 7 - nodes generated: 5631
goal reached at depth: 5 - nodes generated: 162
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 4 - nodes generated: 124
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 2 - nodes generated: 21
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=015
goal reached at depth: 7 - nodes generated: 7655
goal reached at depth: 5 - nodes generated: 843
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 3 - nodes generated: 45
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 5 - nodes generated: 622
goal reached at depth: 1 - nodes generated: 1
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=020
goal reached at depth: 6 - nodes generated: 2302
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 5 - nodes generated: 315
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 5 - nodes generated: 291
goal reached at depth: 5 - nodes generated: 162
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 7 - nodes generated: 5242
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

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File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4pl4d/hanoi_4pl4d.d\=025
goal reached at depth: 6 - nodes generated: 1826
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 5 - nodes generated: 162
goal reached at depth: 5 - nodes generated: 162
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 5 - nodes generated: 125
goal reached at depth: 7 - nodes generated: 2481
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 1 - nodes generated: 1
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4pl4d/hanoi_4pl4d.d\=030
goal reached at depth: 7 - nodes generated: 5242
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 6 - nodes generated: 623
goal reached at depth: 6 - nodes generated: 2422
goal reached at depth: 5 - nodes generated: 125
goal reached at depth: 7 - nodes generated: 14844
goal reached at depth: 7 - nodes generated: 5254
goal reached at depth: 10 - nodes generated: 156705
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 7 - nodes generated: 11420
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4pl4d/hanoi_4pl4d.d\=050
goal reached at depth: 6 - nodes generated: 1258
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 5 - nodes generated: 125
goal reached at depth: 7 - nodes generated: 10498
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 5 - nodes generated: 315
goal reached at depth: 5 - nodes generated: 622
goal reached at depth: 11 - nodes generated: 558668
goal reached at depth: 6 - nodes generated: 1594
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4pl4d/hanoi_4pl4d.d\=060
goal reached at depth: 6 - nodes generated: 2422
goal reached at depth: 5 - nodes generated: 873
goal reached at depth: 10 - nodes generated: 502355
goal reached at depth: 10 - nodes generated: 115188
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 6 - nodes generated: 1485
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 10 - nodes generated: 81229
goal reached at depth: 10 - nodes generated: 246006
goal reached at depth: 8 - nodes generated: 20489
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=075
goal reached at depth: 9 - nodes generated: 72390
goal reached at depth: 5 - nodes generated: 125
goal reached at depth: 9 - nodes generated: 63299
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 5 - nodes generated: 843
goal reached at depth: 8 - nodes generated: 20251
goal reached at depth: 10 - nodes generated: 139907
goal reached at depth: 8 - nodes generated: 20489
goal reached at depth: 5 - nodes generated: 125
goal reached at depth: 8 - nodes generated: 13254
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=090
goal reached at depth: 8 - nodes generated: 72389
goal reached at depth: 10 - nodes generated: 502355
Killed
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_14.ida
_star < ../benchmarks/hanoi_4p14d/hanoi_4p14d.d\=100
goal reached at depth: 5 - nodes generated: 843
goal reached at depth: 11 - nodes generated: 1929883
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 4 - nodes generated: 124
goal reached at depth: 8 - nodes generated: 20355
goal reached at depth: 8 - nodes generated: 20489
goal reached at depth: 9 - nodes generated: 42343
goal reached at depth: 12 - nodes generated: 4083965
goal reached at depth: 11 - nodes generated: 822328
goal reached at depth: 8 - nodes generated: 17845
```

Hanoi 4-17

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=005
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 3 - nodes generated: 45
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=010
goal reached at depth: 4 - nodes generated: 111
goal reached at depth: 0 - nodes generated: 0
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 1 - nodes generated: 1
goal reached at depth: 3 - nodes generated: 55
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=015
goal reached at depth: 8 - nodes generated: 12834
goal reached at depth: 5 - nodes generated: 162
goal reached at depth: 6 - nodes generated: 1427
goal reached at depth: 5 - nodes generated: 315
goal reached at depth: 5 - nodes generated: 315
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 3 - nodes generated: 55
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 7 - nodes generated: 11420
goal reached at depth: 3 - nodes generated: 55
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=020
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 7 - nodes generated: 14577
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 4 - nodes generated: 51
goal reached at depth: 3 - nodes generated: 45
goal reached at depth: 8 - nodes generated: 10925
goal reached at depth: 3 - nodes generated: 22
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 4 - nodes generated: 161
goal reached at depth: 4 - nodes generated: 161
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

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File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=025
goal reached at depth: 6 - nodes generated: 1594
goal reached at depth: 7 - nodes generated: 10856
goal reached at depth: 6 - nodes generated: 1826
goal reached at depth: 7 - nodes generated: 5476
goal reached at depth: 11 - nodes generated: 545969
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 7 - nodes generated: 4782
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 3 - nodes generated: 50
goal reached at depth: 4 - nodes generated: 81
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=030
goal reached at depth: 7 - nodes generated: 9777
goal reached at depth: 6 - nodes generated: 2559
goal reached at depth: 6 - nodes generated: 2422
goal reached at depth: 6 - nodes generated: 1427
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 7 - nodes generated: 15311
goal reached at depth: 6 - nodes generated: 2302
goal reached at depth: 7 - nodes generated: 6267
goal reached at depth: 9 - nodes generated: 81692
goal reached at depth: 7 - nodes generated: 20985
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=050
goal reached at depth: 13 - nodes generated: 11712720
goal reached at depth: 9 - nodes generated: 44257
goal reached at depth: 10 - nodes generated: 192064
goal reached at depth: 9 - nodes generated: 16958
goal reached at depth: 4 - nodes generated: 81
goal reached at depth: 7 - nodes generated: 15311
goal reached at depth: 4 - nodes generated: 124
goal reached at depth: 8 - nodes generated: 10346
goal reached at depth: 7 - nodes generated: 7805
goal reached at depth: 5 - nodes generated: 162
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=060
Killed
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=075
goal reached at depth: 12 - nodes generated: 11712719
goal reached at depth: 9 - nodes generated: 41514
goal reached at depth: 11 - nodes generated: 1016917
goal reached at depth: 8 - nodes generated: 81691
goal reached at depth: 2 - nodes generated: 21
goal reached at depth: 11 - nodes generated: 1891231
goal reached at depth: 5 - nodes generated: 291
goal reached at depth: 6 - nodes generated: 2480
goal reached at depth: 9 - nodes generated: 66715
goal reached at depth: 9 - nodes generated: 44547
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

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waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=090
goal reached at depth: 4 - nodes generated: 139
goal reached at depth: 9 - nodes generated: 20490
goal reached at depth: 10 - nodes generated: 189017
Killed
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=100
goal reached at depth: 6 - nodes generated: 1485
goal reached at depth: 5 - nodes generated: 162
goal reached at depth: 10 - nodes generated: 327662
goal reached at depth: 8 - nodes generated: 71204
Killed
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./hanoi4_17.ida
_star < ../benchmarks/hanoi_4p17d/hanoi_4p17d.d\=2000
^C^C
```

Topspin 12-4

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=005  
goal reached at depth: 5 - nodes generated: 158  
goal reached at depth: 5 - nodes generated: 39  
goal reached at depth: 5 - nodes generated: 99  
goal reached at depth: 5 - nodes generated: 100  
goal reached at depth: 5 - nodes generated: 53  
goal reached at depth: 5 - nodes generated: 54  
goal reached at depth: 5 - nodes generated: 31  
goal reached at depth: 5 - nodes generated: 46  
goal reached at depth: 5 - nodes generated: 41  
goal reached at depth: 5 - nodes generated: 97  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=010  
goal reached at depth: 9 - nodes generated: 65576  
goal reached at depth: 4 - nodes generated: 42  
goal reached at depth: 8 - nodes generated: 18088  
goal reached at depth: 8 - nodes generated: 37814  
goal reached at depth: 8 - nodes generated: 5111  
goal reached at depth: 8 - nodes generated: 12789  
goal reached at depth: 4 - nodes generated: 17  
goal reached at depth: 8 - nodes generated: 1727  
goal reached at depth: 8 - nodes generated: 6290  
goal reached at depth: 8 - nodes generated: 3567  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=015  
goal reached at depth: 8 - nodes generated: 7964  
goal reached at depth: 8 - nodes generated: 39202  
goal reached at depth: 8 - nodes generated: 88259  
goal reached at depth: 10 - nodes generated: 26230  
goal reached at depth: 10 - nodes generated: 80462  
goal reached at depth: 8 - nodes generated: 5158  
goal reached at depth: 9 - nodes generated: 339075  
goal reached at depth: 10 - nodes generated: 824971  
goal reached at depth: 9 - nodes generated: 319730  
goal reached at depth: 8 - nodes generated: 28146  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=020  
goal reached at depth: 10 - nodes generated: 90501  
goal reached at depth: 10 - nodes generated: 1236817  
goal reached at depth: 10 - nodes generated: 36659  
goal reached at depth: 8 - nodes generated: 24563  
goal reached at depth: 9 - nodes generated: 451565  
goal reached at depth: 10 - nodes generated: 65848  
goal reached at depth: 9 - nodes generated: 17469  
goal reached at depth: 8 - nodes generated: 53971  
goal reached at depth: 8 - nodes generated: 5510  
goal reached at depth: 10 - nodes generated: 81828  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

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waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms - □ ×
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=030
goal reached at depth: 8 - nodes generated: 5531
goal reached at depth: 9 - nodes generated: 35475
goal reached at depth: 9 - nodes generated: 11176
goal reached at depth: 9 - nodes generated: 6939
goal reached at depth: 9 - nodes generated: 116632
goal reached at depth: 9 - nodes generated: 50014
goal reached at depth: 10 - nodes generated: 46532
goal reached at depth: 10 - nodes generated: 721235
goal reached at depth: 9 - nodes generated: 31689
goal reached at depth: 9 - nodes generated: 57828
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=050
goal reached at depth: 12 - nodes generated: 4581820
goal reached at depth: 9 - nodes generated: 170967
goal reached at depth: 9 - nodes generated: 176321
goal reached at depth: 10 - nodes generated: 620252
goal reached at depth: 10 - nodes generated: 190255
goal reached at depth: 9 - nodes generated: 45600
goal reached at depth: 10 - nodes generated: 2285418
goal reached at depth: 9 - nodes generated: 39705
goal reached at depth: 10 - nodes generated: 822713
goal reached at depth: 8 - nodes generated: 91046
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=075
goal reached at depth: 9 - nodes generated: 80913
goal reached at depth: 9 - nodes generated: 6905
goal reached at depth: 9 - nodes generated: 103957
goal reached at depth: 8 - nodes generated: 34034
goal reached at depth: 9 - nodes generated: 121992
goal reached at depth: 10 - nodes generated: 42492
goal reached at depth: 9 - nodes generated: 44313
goal reached at depth: 8 - nodes generated: 39970
goal reached at depth: 8 - nodes generated: 12811
goal reached at depth: 9 - nodes generated: 32152
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=090
goal reached at depth: 10 - nodes generated: 709660
goal reached at depth: 8 - nodes generated: 56533
goal reached at depth: 10 - nodes generated: 344877
goal reached at depth: 9 - nodes generated: 3744
goal reached at depth: 10 - nodes generated: 145276
goal reached at depth: 8 - nodes generated: 3407
goal reached at depth: 11 - nodes generated: 594678
goal reached at depth: 7 - nodes generated: 2427
goal reached at depth: 9 - nodes generated: 139372
goal reached at depth: 10 - nodes generated: 1265240
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$
```

```
waleria@waleria-Inspiron-5558: ~/Desktop/proyecto-1-ci5437/algorithms - □ ×
File Edit View Search Terminal Help
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=100
goal reached at depth: 9 - nodes generated: 82099
goal reached at depth: 10 - nodes generated: 1612927
goal reached at depth: 9 - nodes generated: 95533
goal reached at depth: 10 - nodes generated: 352369
goal reached at depth: 10 - nodes generated: 214740
goal reached at depth: 8 - nodes generated: 54217
goal reached at depth: 7 - nodes generated: 1343
goal reached at depth: 9 - nodes generated: 221554
goal reached at depth: 10 - nodes generated: 733269
goal reached at depth: 9 - nodes generated: 98730
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=2000
goal reached at depth: 9 - nodes generated: 149020
goal reached at depth: 7 - nodes generated: 7794
goal reached at depth: 10 - nodes generated: 962047
goal reached at depth: 9 - nodes generated: 167366
goal reached at depth: 9 - nodes generated: 60728
goal reached at depth: 11 - nodes generated: 621716
goal reached at depth: 7 - nodes generated: 76
goal reached at depth: 8 - nodes generated: 418
goal reached at depth: 10 - nodes generated: 99441
goal reached at depth: 9 - nodes generated: 7009
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1
2_4.ida_star < ../benchmarks/topspin_12_4/topspin_12_4.d\=2000000
goal reached at depth: 9 - nodes generated: 238880
goal reached at depth: 10 - nodes generated: 400037
goal reached at depth: 9 - nodes generated: 7010
goal reached at depth: 11 - nodes generated: 996963
goal reached at depth: 9 - nodes generated: 69523
goal reached at depth: 9 - nodes generated: 24836
goal reached at depth: 7 - nodes generated: 1666
goal reached at depth: 8 - nodes generated: 24740
goal reached at depth: 9 - nodes generated: 81266
goal reached at depth: 10 - nodes generated: 97655
```

Topspin 14_4

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
4_4.ida_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=005  
goal reached at depth: 5 - nodes generated: 73  
goal reached at depth: 5 - nodes generated: 59  
goal reached at depth: 5 - nodes generated: 24  
goal reached at depth: 5 - nodes generated: 200  
goal reached at depth: 9 - nodes generated: 696711  
goal reached at depth: 5 - nodes generated: 66  
goal reached at depth: 5 - nodes generated: 81  
goal reached at depth: 5 - nodes generated: 124  
goal reached at depth: 5 - nodes generated: 437  
goal reached at depth: 5 - nodes generated: 59  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
4_4.ida_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=010  
goal reached at depth: 10 - nodes generated: 1751193  
goal reached at depth: 10 - nodes generated: 3495702  
goal reached at depth: 8 - nodes generated: 9827  
goal reached at depth: 10 - nodes generated: 599993  
goal reached at depth: 10 - nodes generated: 8528964  
goal reached at depth: 10 - nodes generated: 3618187  
goal reached at depth: 11 - nodes generated: 3839168  
goal reached at depth: 6 - nodes generated: 514  
goal reached at depth: 8 - nodes generated: 2921  
goal reached at depth: 10 - nodes generated: 4427258  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
4_4.ida_star < ../benchmarks/topspin_14_4/topspin_14_4.d\=015  
goal reached at depth: 10 - nodes generated: 1222316  
goal reached at depth: 12 - nodes generated: 15577662  
Killed
```

Topspin 17-4

```
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms - □ ×  
File Edit View Search Terminal Help  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
7_4.ida_star < ../benchmarks/topspin_17_4/topspin_17_4.d\=005  
goal reached at depth: 5 - nodes generated: 329  
goal reached at depth: 5 - nodes generated: 593  
goal reached at depth: 5 - nodes generated: 954  
goal reached at depth: 5 - nodes generated: 473  
goal reached at depth: 5 - nodes generated: 25  
goal reached at depth: 5 - nodes generated: 379  
goal reached at depth: 3 - nodes generated: 19  
goal reached at depth: 5 - nodes generated: 77  
goal reached at depth: 5 - nodes generated: 44  
goal reached at depth: 5 - nodes generated: 43  
waleria@waleria-Inspiron-5558:~/Desktop/proyecto-1-ci5437/algorithms$ ./topspin1  
7_4.ida_star < ../benchmarks/topspin_17_4/topspin_17_4.d\=010  
goal reached at depth: 10 - nodes generated: 171386  
goal reached at depth: 8 - nodes generated: 8882  
goal reached at depth: 9 - nodes generated: 126912  
goal reached at depth: 10 - nodes generated: 736968  
goal reached at depth: 10 - nodes generated: 26553  
goal reached at depth: 8 - nodes generated: 2628  
goal reached at depth: 10 - nodes generated: 1751936  
goal reached at depth: 10 - nodes generated: 159822  
goal reached at depth: 10 - nodes generated: 1411868  
goal reached at depth: 10 - nodes generated: 874136
```