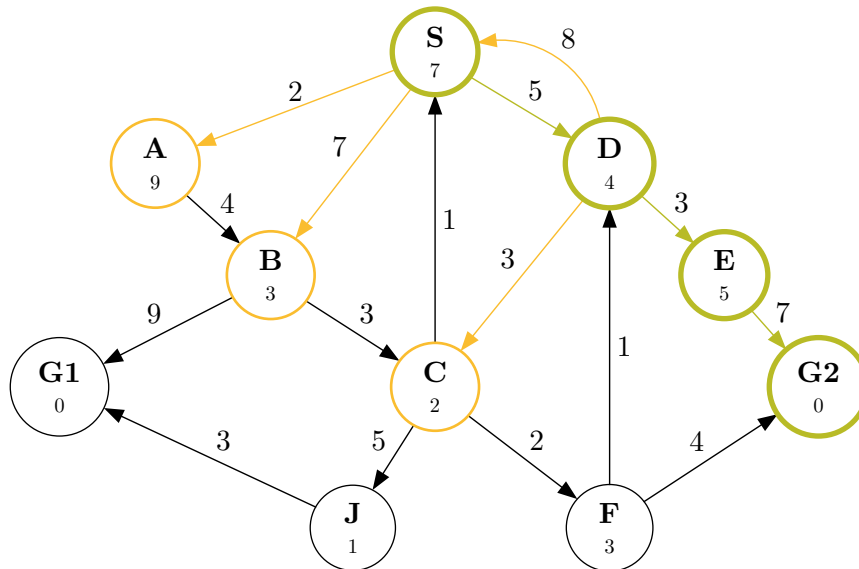


1 E.A.3.1

1.1 Ricerca in profondità

DFS (depth first search)



| # | | azioni | esplorati | frontiera |
|---|----|-----------|---------------|--|
| 0 | ∅ | {} | {} | [(S, g: 0, h: 7, f: 7, d: 0),] |
| 1 | S | {A, B, D} | {S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (D, g: 5, h: 4, f: 9, d: 1),] |
| 2 | D | {C, E, S} | {D, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (C, g: 8, h: 2, f: 10, d: 2), (E, g: 8, h: 5, f: 13, d: 2),] |
| 3 | E | {G2} | {D, E, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (C, g: 8, h: 2, f: 10, d: 2), (G2, g: 15, h: 0, f: 15, d: 3),] |
| 4 | G2 | {} | {D, E, G2, S} | is goal |

Percorso $S \rightarrow D \rightarrow E \rightarrow G2$

Costo $5 + 3 + 7 = 15$

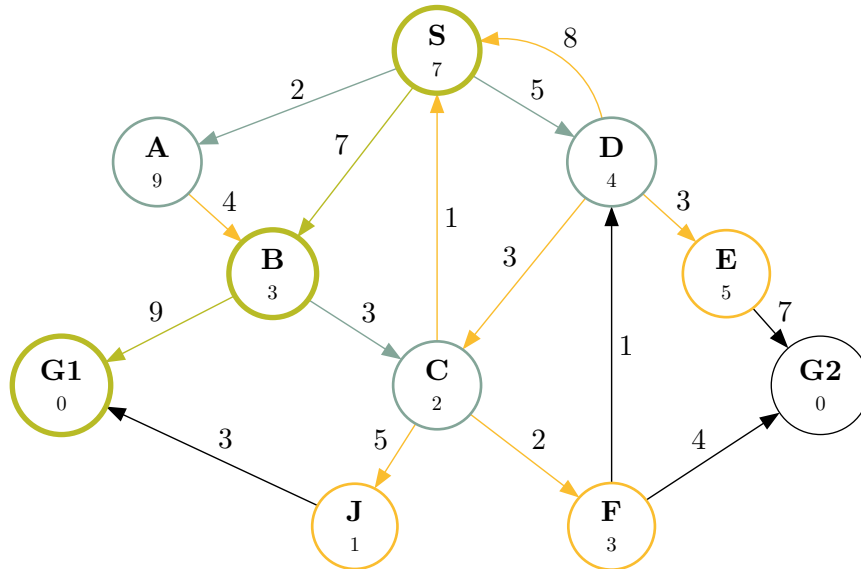
Iterazioni 1

Ottimalità il cammino non è ottimale (il costo ottimale è 14)

Generalmente la DFS non garantisce l'ottimalità

1.2 Ricerca in ampiezza

BFS (breach first search)



| # | | azioni | esplorati | frontiera |
|---|-------------|-----------|--------------|--|
| 0 | \emptyset | {} | {} | [(S, g: 0, h: 7, f: 7, d: 0),] |
| 1 | S | {A, B, D} | {S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (D, g: 5, h: 4, f: 9, d: 1),] |
| 2 | A | {B} | {A, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (D, g: 5, h: 4, f: 9, d: 1),] |
| 3 | B | {C, G1} | {A, B, S} | [(D, g: 5, h: 4, f: 9, d: 1), (C, g: 10, h: 2, f: 12, d: 2), (G1, g: 16, h: 0, f: 16, d: 2),] |
| 4 | D | {C, E, S} | {A, B, D, S} | [(C, g: 10, h: 2, f: 12, d: 2), (G1, g: 16, h: 0, f: 16, d: 2), (E, g: 8, h: 5, f: 13, d: 2),] |

| # | | azioni | esplorati | frontiera |
|---|----|-----------|------------------|--|
| 5 | C | {F, J, S} | {A, B, C, D, S} | [(G1, g: 16, h: 0, f: 16, d: 2), (E, g: 8, h: 5, f: 13, d: 2), (F, g: 12, h: 3, f: 15, d: 3), (J, g: 15, h: 1, f: 16, d: 3),] |
| 6 | G1 | {} | {A, B, D, G1, S} | is goal |

Percorso $S \rightarrow B \rightarrow G1$

Costo $7 + 9 = 16$

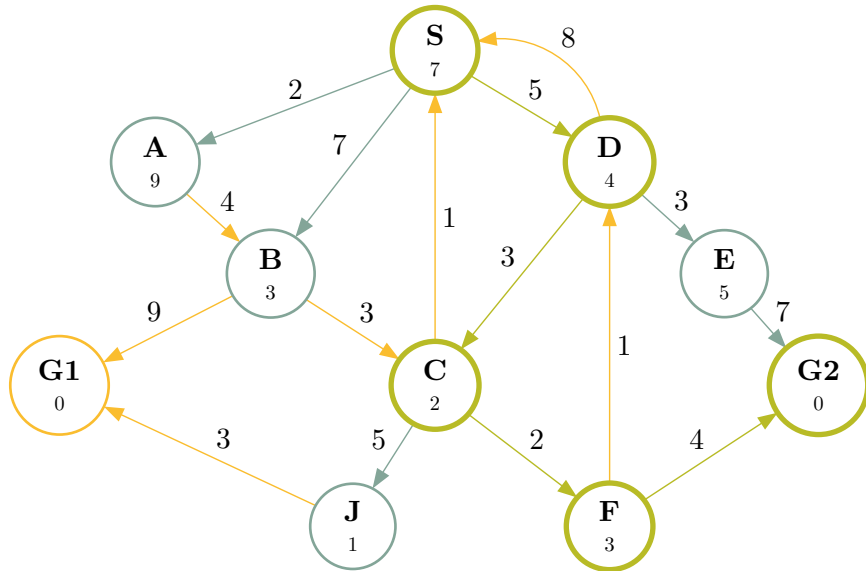
Iterazioni 1

Ottimalità il cammino non è ottimale

Generalmente la BFS garantisce l'ottimalità solo se il costo per tutte le azioni è lo stesso (perché la BFS trova il minor numero di azioni per raggiungere l'obiettivo)

1.3 Ricerca a costi uniformi

Min cost search



| # | | azioni | esplorati | frontiera |
|---|---|-----------|--------------|---|
| 0 | ∅ | {} | {} | { (S, g: 0, h: 7, f: 7, d: 0), } |
| 1 | S | {A, B, D} | {S} | { (A, g: 2, h: 9, f: 11, d: 1), (D, g: 5, h: 4, f: 9, d: 1), (B, g: 7, h: 3, f: 10, d: 1), } |
| 2 | A | {B} | {A, S} | { (D, g: 5, h: 4, f: 9, d: 1), (B, g: 6, h: 3, f: 9, d: 2), } |
| 3 | D | {C, E, S} | {A, D, S} | { (B, g: 6, h: 3, f: 9, d: 2), (C, g: 8, h: 2, f: 10, d: 2), (E, g: 8, h: 5, f: 13, d: 2), } |
| 4 | B | {C, G1} | {A, B, D, S} | { (C, g: 8, h: 2, f: 10, d: 2), (E, g: 8, h: 5, f: 13, d: 2), (G1, g: 15, h: 0, f: 15, d: 3), } |

| # | | azioni | esplorati | frontiera |
|---|----|-----------|------------------------------|--|
| 5 | C | {F, J, S} | {A, B, C, D, S} | { (E, g: 8, h: 5, f: 13, d: 2), (F, g: 10, h: 3, f: 13, d: 3), (J, g: 13, h: 1, f: 14, d: 3), (G1, g: 15, h: 0, f: 15, d: 3), } |
| 6 | E | {G2} | {A, B, C, D, E, S} | { (F, g: 10, h: 3, f: 13, d: 3), (J, g: 13, h: 1, f: 14, d: 3), (G1, g: 15, h: 0, f: 15, d: 3), (G2, g: 15, h: 0, f: 15, d: 3), } |
| 7 | F | {D, G2} | {A, B, C, D, E, F, S} | { (J, g: 13, h: 1, f: 14, d: 3), (G2, g: 14, h: 0, f: 14, d: 4), (G1, g: 15, h: 0, f: 15, d: 3), } |
| 8 | J | {G1} | {A, B, C, D, E, F, J, S} | { (G2, g: 14, h: 0, f: 14, d: 4), (G1, g: 15, h: 0, f: 15, d: 3), } |
| 9 | G2 | {} | {A, B, C, D, E, F, G2, J, S} | is goal |

Percorso $S \rightarrow D \rightarrow C \rightarrow F \rightarrow G2$

Costo $5 + 3 + 2 + 4 = 14$

Iterazioni 1

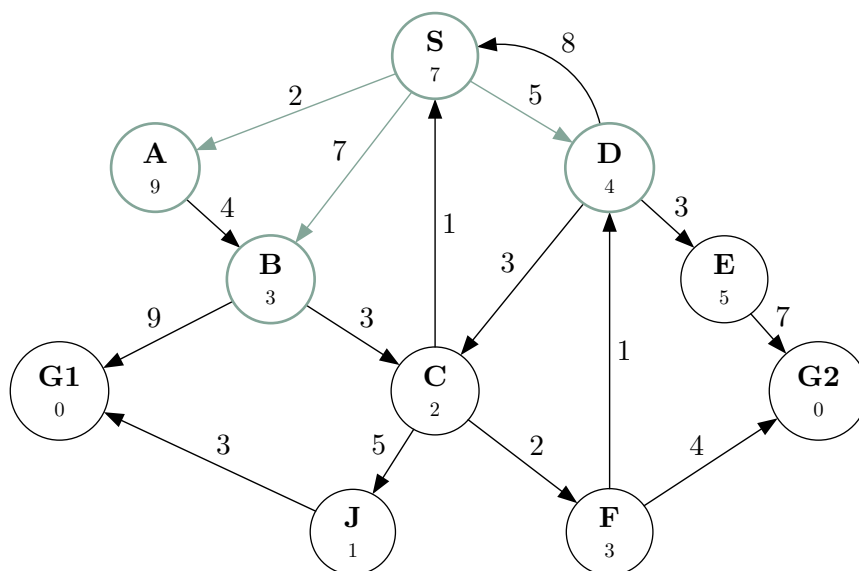
Ottimalità il costo è quello ottimale

L'algoritmo Min cost trova sempre il cammino ottimale (tranne in grafi infiniti)

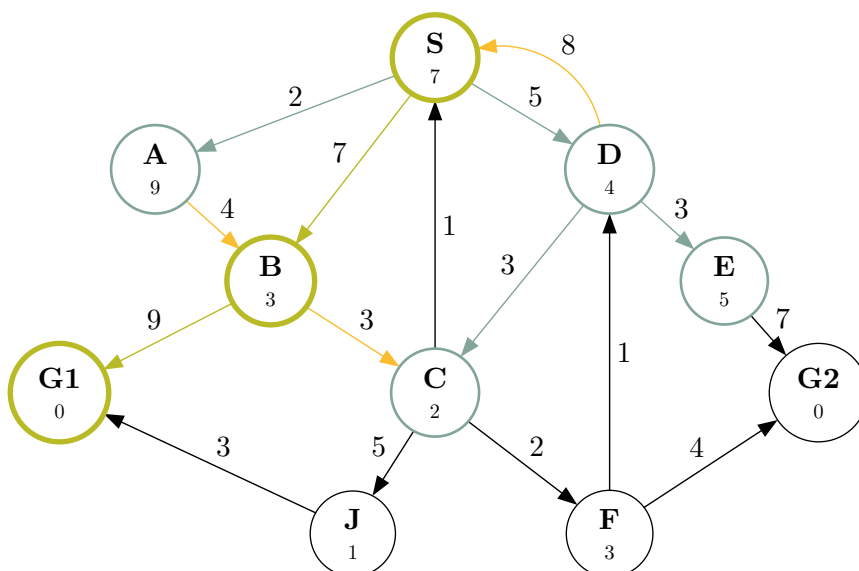
1.4 Ricerca ad approfondimento iterativo

Iterative deepening search

1.4.1 Iterazione 1



1.4.2 Iterazione 2



| # | | azioni | esplorati | frontiera |
|----|----|-----------|---------------------|--|
| 0 | ∅ | {} | {} | [(S, g: 0, h: 7, f: 7, d: 0),] |
| 1 | S | {A, B, D} | {S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (D, g: 5, h: 4, f: 9, d: 1),] |
| 2 | D | {} | {D, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1),] |
| 3 | B | {} | {B, D, S} | [(A, g: 2, h: 9, f: 11, d: 1),] |
| 4 | A | {} | {A, B, D, S} | [] |
| 5 | ∅ | {} | {} | [(S, g: 0, h: 7, f: 7, d: 0),] |
| 6 | S | {A, B, D} | {S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (D, g: 5, h: 4, f: 9, d: 1),] |
| 7 | D | {C, E, S} | {D, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (C, g: 8, h: 2, f: 10, d: 2), (E, g: 8, h: 5, f: 13, d: 2),] |
| 8 | E | {} | {D, E, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (C, g: 8, h: 2, f: 10, d: 2),] |
| 9 | C | {} | {C, D, E, S} | [(A, g: 2, h: 9, f: 11, d: 1), (B, g: 7, h: 3, f: 10, d: 1),] |
| 10 | B | {C, G1} | {B, C, D, E, S} | [(A, g: 2, h: 9, f: 11, d: 1), (G1, g: 16, h: 0, f: 16, d: 2),] |
| 11 | G1 | {} | {B, C, D, E, G1, S} | is goal |

Percorso $S \rightarrow B \rightarrow G1$

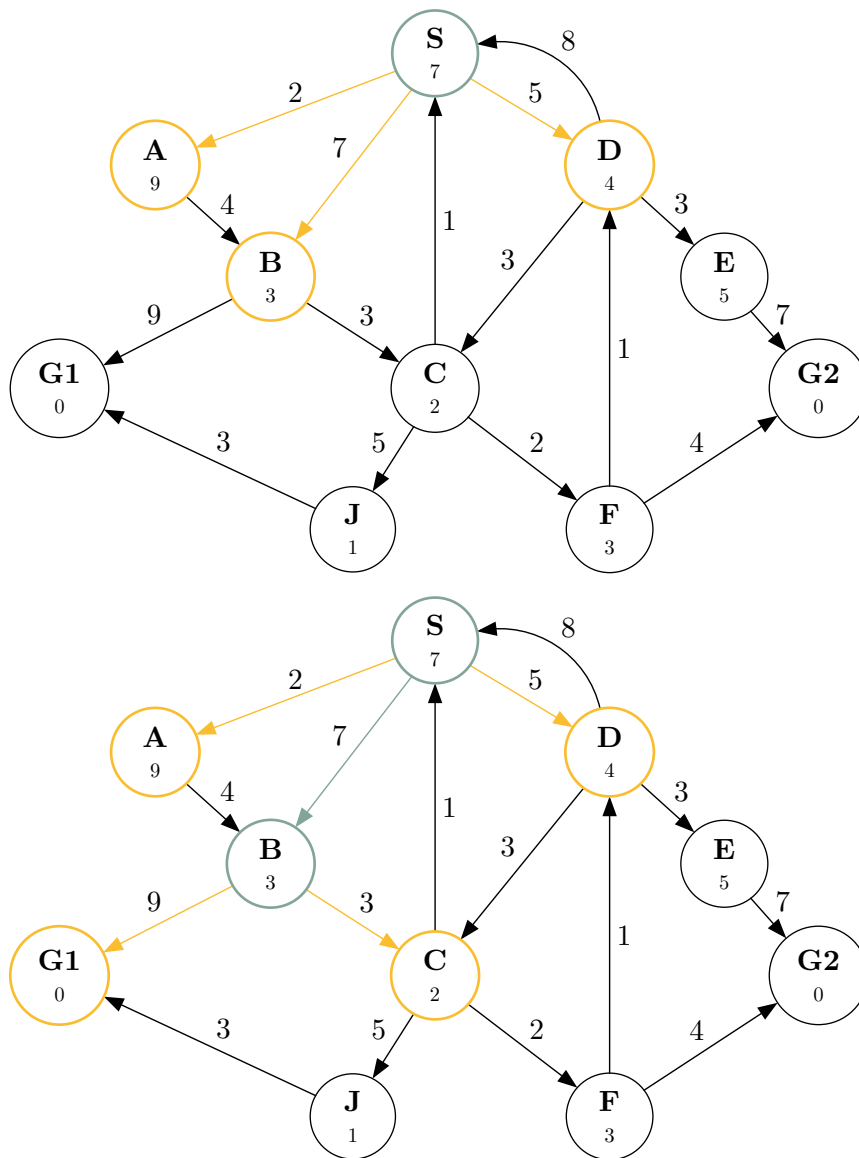
Costo $7 + 9 = 16$

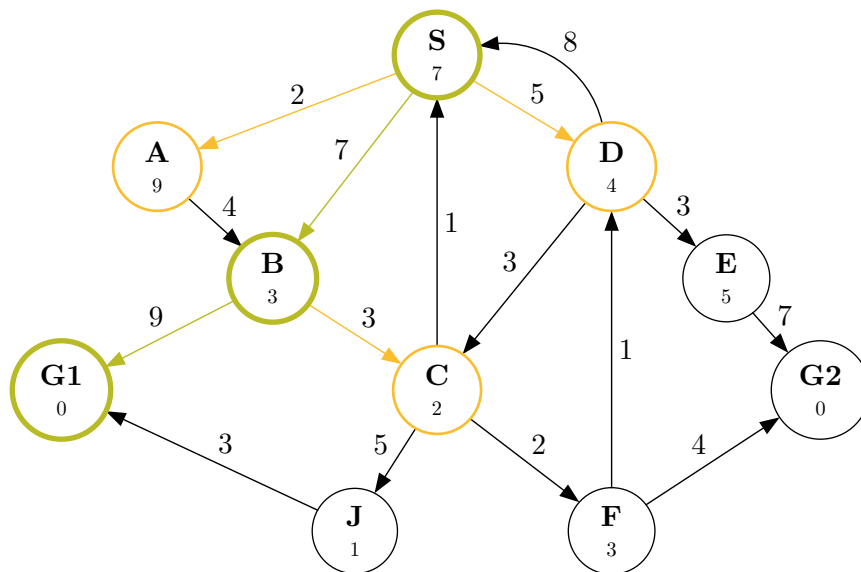
Iterazioni 2

Ottimalità il percorso non è ottimale

1.5 Ricerca best-first greedy

Best-first greedy search





| # | | azioni | esplorati | frontiera |
|---|-------------|-----------|------------|--|
| 0 | \emptyset | {} | {} | { (S, g: 0, h: 7, f: 7, d: 0), } |
| 1 | S | {A, B, D} | {S} | { (B, g: 7, h: 3, f: 10, d: 1), (D, g: 5, h: 4, f: 9, d: 1), (A, g: 2, h: 9, f: 11, d: 1), } |
| 2 | B | {C, G1} | {B, S} | { (G1, g: 16, h: 0, f: 16, d: 2), (C, g: 10, h: 2, f: 12, d: 2), (D, g: 5, h: 4, f: 9, d: 1), (A, g: 2, h: 9, f: 11, d: 1), } |
| 3 | G1 | {} | {B, G1, S} | is goal |

Percorso $S \rightarrow B \rightarrow G1$

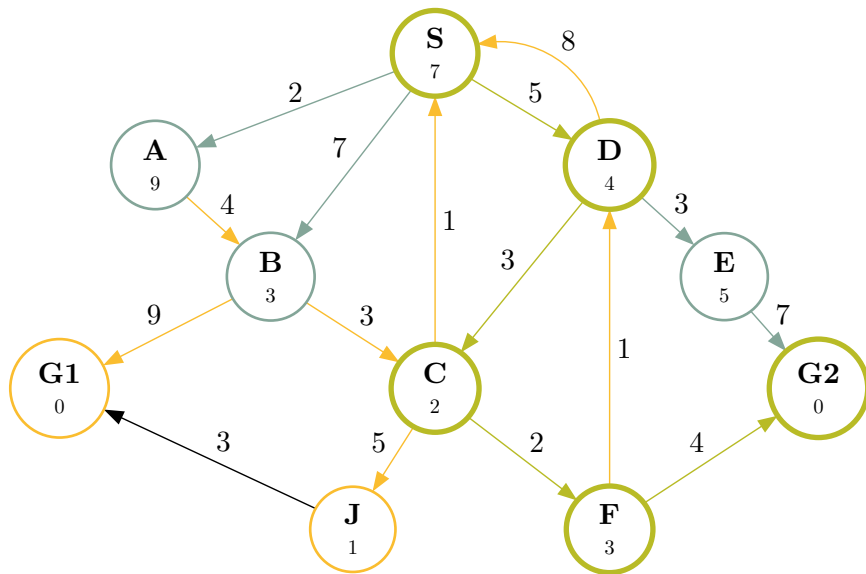
Costo $7 + 9 = 16$

Iterazioni 1

Ottimalità la soluzione non è ottimale

1.6 A*

A*



| # | | azioni | esplorati | frontiera |
|---|---|-----------|--------------|--|
| 0 | ∅ | {} | {} | { (S, g: 0, h: 7, f: 7, d: 0), } |
| 1 | S | {A, B, D} | {S} | { (D, g: 5, h: 4, f: 9, d: 1), (B, g: 7, h: 3, f: 10, d: 1), (A, g: 2, h: 9, f: 11, d: 1), } |
| 2 | D | {C, E, S} | {D, S} | { (B, g: 7, h: 3, f: 10, d: 1), (C, g: 8, h: 2, f: 10, d: 2), (A, g: 2, h: 9, f: 11, d: 1), (E: g: 8, h: 5, f: 13, d: 2), } |
| 3 | B | {C, G1} | {B, D, S} | { (C, g: 8, h: 2, f: 10, d: 2), (A, g: 2, h: 9, f: 11, d: 1), (E: g: 8, h: 5, f: 13, d: 2), (G1: g: 16, h: 0, f: 16, d: 2), } |
| 4 | C | {F, J, S} | {B, C, D, S} | { (A, g: 2, h: 9, f: 11, d: 1), } |

| # | | azioni | esplorati | frontiera |
|---|----|---------|------------------------------|--|
| | | | | (E: g: 8, h: 5, f: 13, d: 2), (F: g: 10, h: 3, f: 13, d: 3), (J: g: 13, h: 1, f: 14, d: 3), (G1: g: 16, h: 0, f: 16, d: 2), } |
| 5 | A | {B} | {A, B, C, D, S} | { (E: g: 8, h: 5, f: 13, d: 2), (F: g: 10, h: 3, f: 13, d: 3), (J: g: 13, h: 1, f: 14, d: 3), (G1: g: 16, h: 0, f: 16, d: 2), } |
| 6 | E | {G2} | {A, B, C, D, E, S} | { (F: g: 10, h: 3, f: 13, d: 3), (J: g: 13, h: 1, f: 14, d: 3), (G2: g: 15, h: 0, f: 15, d: 3), (G1: g: 16, h: 0, f: 16, d: 2), } |
| 7 | F | {D, G2} | {A, B, C, D, E, F, S} | { (G2, g: 14, h: 0, f: 14, d: 4), (J: g: 13, h: 1, f: 14, d: 3), (G1, g: 16, h: 0, f: 16, d: 2), } |
| 8 | G2 | {} | {A, B, C, D, E, F, G2, S} | is goal |

Percorso $S \rightarrow D \rightarrow C \rightarrow F \rightarrow G2$

Costo $5 + 3 + 2 + 4 = 14$

Iterazioni 1

Ottimalità la soluzione è ottimale

L'algoritmo A^* è ottimale quando la funzione $h(s)$ è consistente (quindi anche ammissibile)

1.7 Euristica

Come si nota dalla tabella sotto l'euristica è **ammissibile**, perché per ogni stato s vale $h(s)$ è minore o uguale al costo minimo per raggiungere un obiettivo.

| s | $h(s)$ | $\text{dist}(s)$ |
|-----|--------|------------------|
| A | 4 | 13 |
| B | 3 | 9 |
| C | 2 | 6 |
| D | 4 | 9 |
| E | 5 | 7 |
| F | 3 | 4 |
| G1 | 0 | 0 |
| G2 | 0 | 0 |
| J | 1 | 3 |
| S | 7 | 14 |

L'euristica **non è consistente** perché $9 = h(A) > 4 + h(B) = 4 + 3 = 7$, è solo un caso che A* trova il percorso ottimale in questo esempio.