Fundamentals of Artificial Intelligence
Exercise 2a: Uninformed Search

Sebastian Mair

Technical University of Munich

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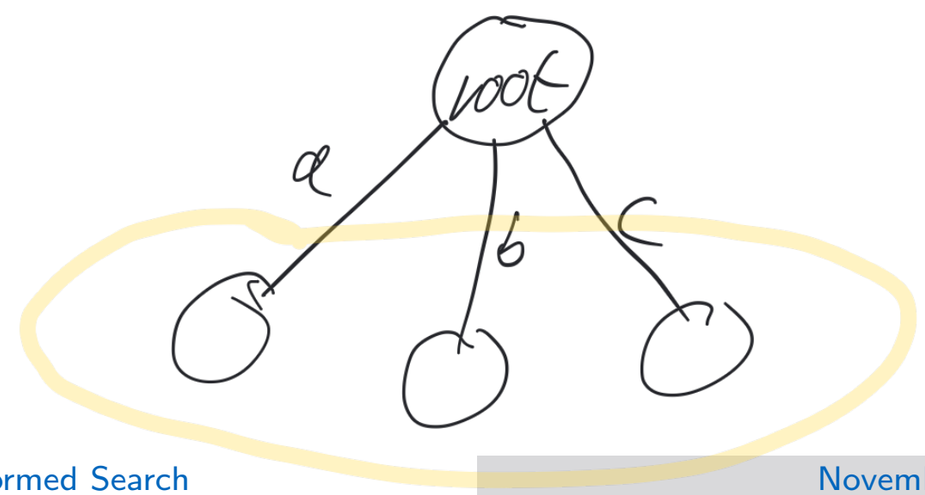
Recap: Solving Problems by Searching

Search problem: defined by

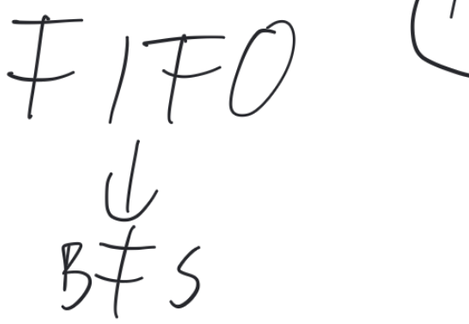
- state space
- initial state
- actions
- transition model
- goal test
- action cost

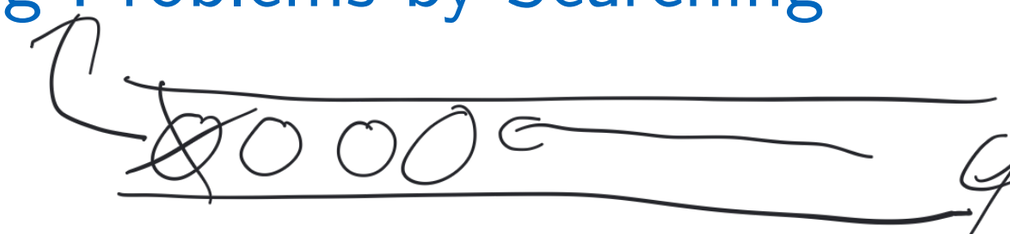
Search tree: contains

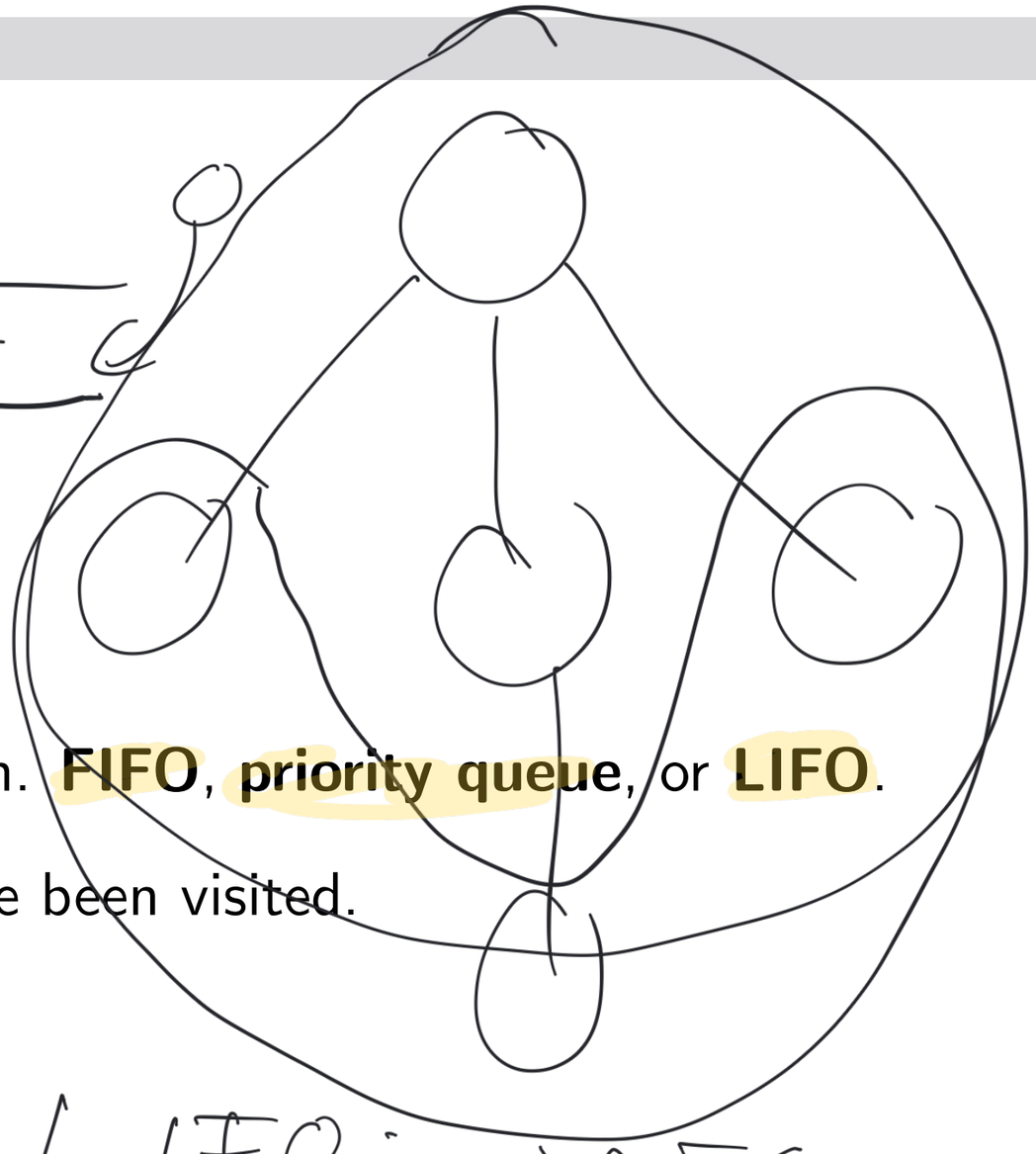
- root (initial state)
- branches (actions)
- nodes (reached states)
- leaves (unexpanded nodes)



Recap: Solving Problems by Searching

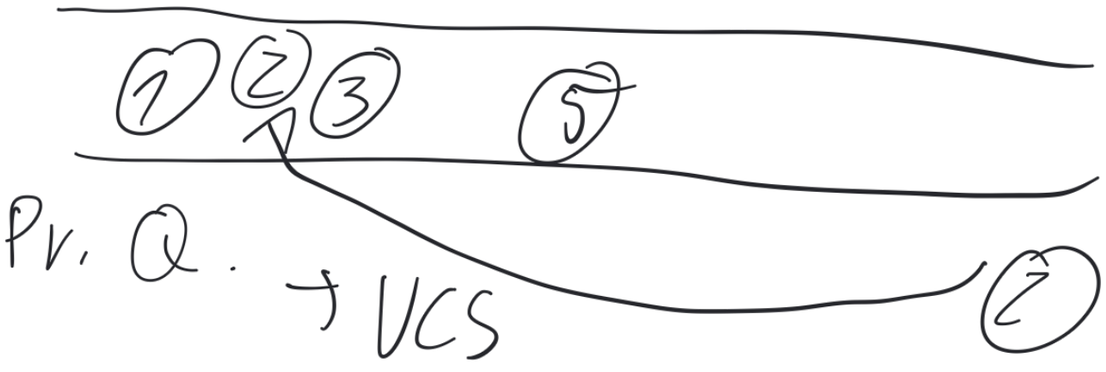


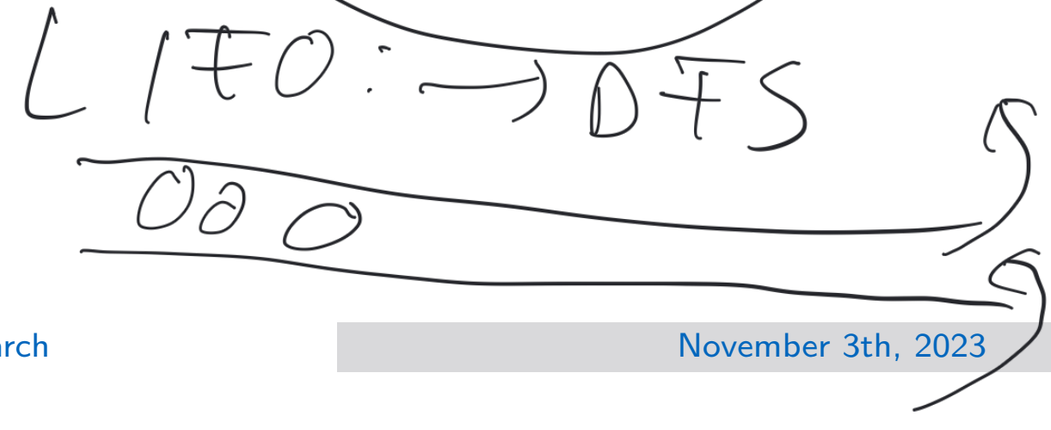




The search algorithms use:

- **frontier**: all leaf nodes available for expansion. **FIFO**, **priority queue**, or **LIFO**.
- **reached** set/lookup table: all states that have been visited.



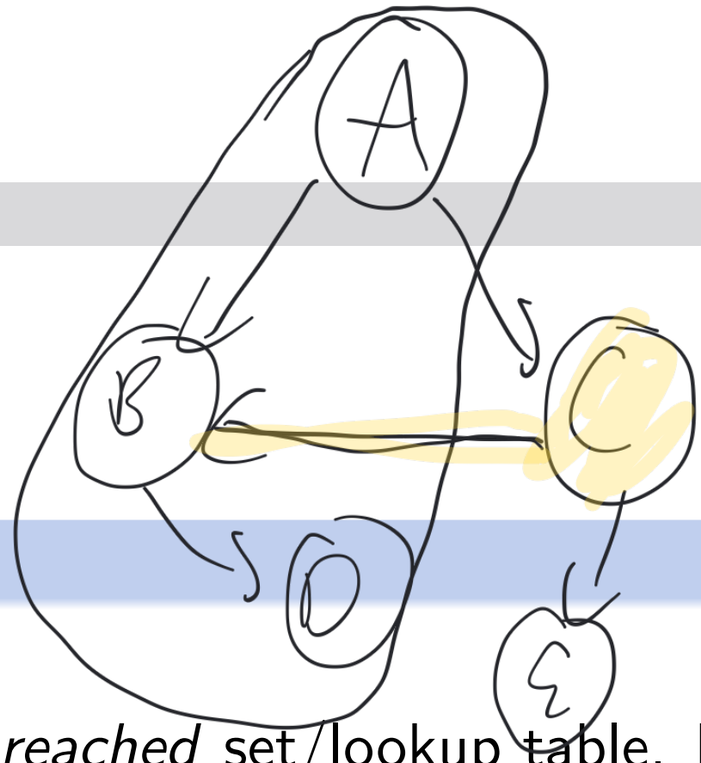


Recap: Performance Measures

4 Criteria for measuring problem-solving performance:

- **Completeness**: Is it guaranteed that the algorithm finds a solution if one exists?
- **Optimality**: Does the strategy find the optimal solution (minimum costs)?
- **Time complexity**: How long does it take to find a solution?
- **Space complexity**: How much memory is needed to perform the search?

Recap: Classifying Search Algorithms



Tree-like Search vs. Graph-Search

- **Tree-like search**: Revisiting states is possible
- **Graph search**: Remember visited states in the *reached* set/lookup table. No revisiting of states $\rightarrow$ usually better time complexity

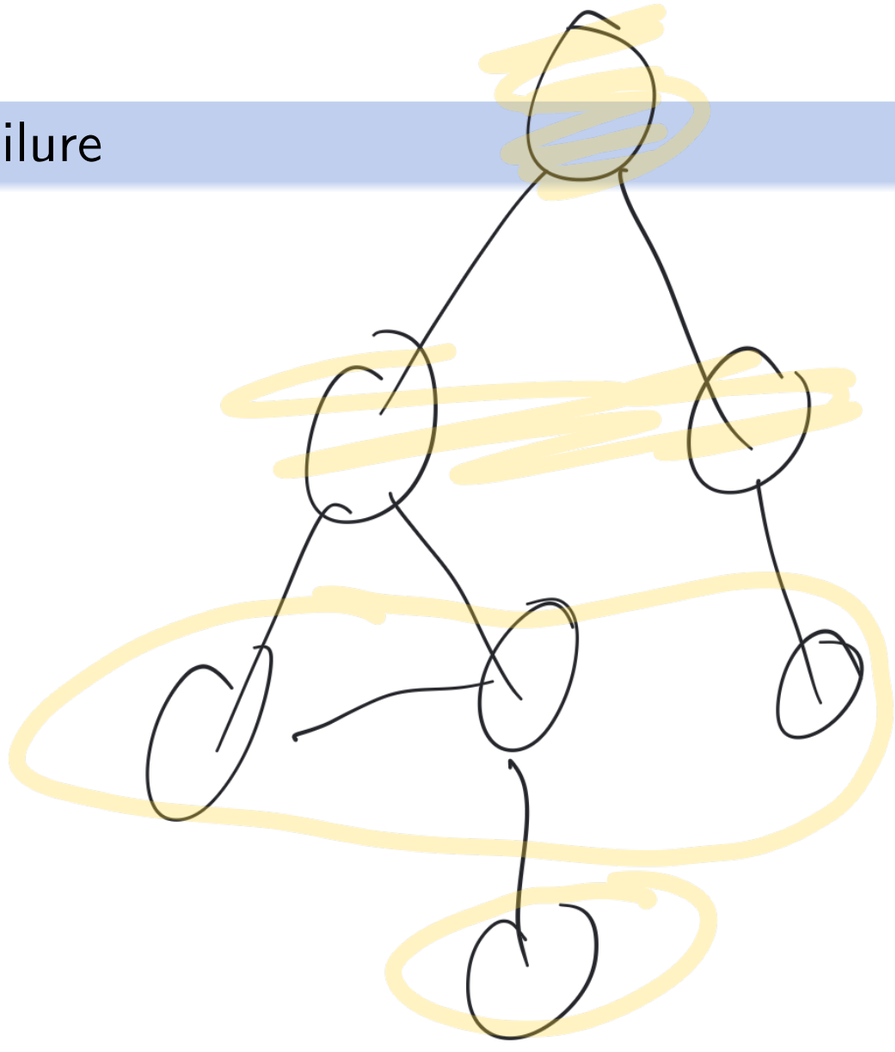
Uninformed vs. Informed Search

- **Uninformed Search**: Searching "blindly", i.e., no additional information apart from the provided problem definition (e.g., BFS, UCS, DFS, ...)
- **Informed Search**: Estimate how promising a state is to reach the goal using heuristic functions (e.g., GBFS, A*, ...)

Recap: Breadth-First Search

function Breadth-First-Search (problem) **returns** a solution or failure

node ← `Node(State=`*problem*`.Initial-State, Path-Cost=0)`
if *problem*`.Is-Goal(`*node*`.State)` **then return** `Solution(`*node*`)`
frontier ← a FIFO queue with *node* as the only element
reached ← {*node*`.State`}
loop do
  if `Is-Empty(`*frontier*`)` **then return** failure
  node ← `Pop(`*frontier*`)` // chooses a shallowest node in *frontier*
  for each *child* **in** `Expand(`*problem*, *node*`)` **do**
    s ← *child*`.State`
    if *problem*`.Is-Goal(`*s*`)` **then return** `Solution(`*child*`)`
    if *s* is not in *reached* **then**
      add *s* to *reached*
      frontier ← `Add(`*child*,*frontier*`)`



Recap: Uniform-Cost Search: $f(n) = g(n) =$ `n.PATH-COST`

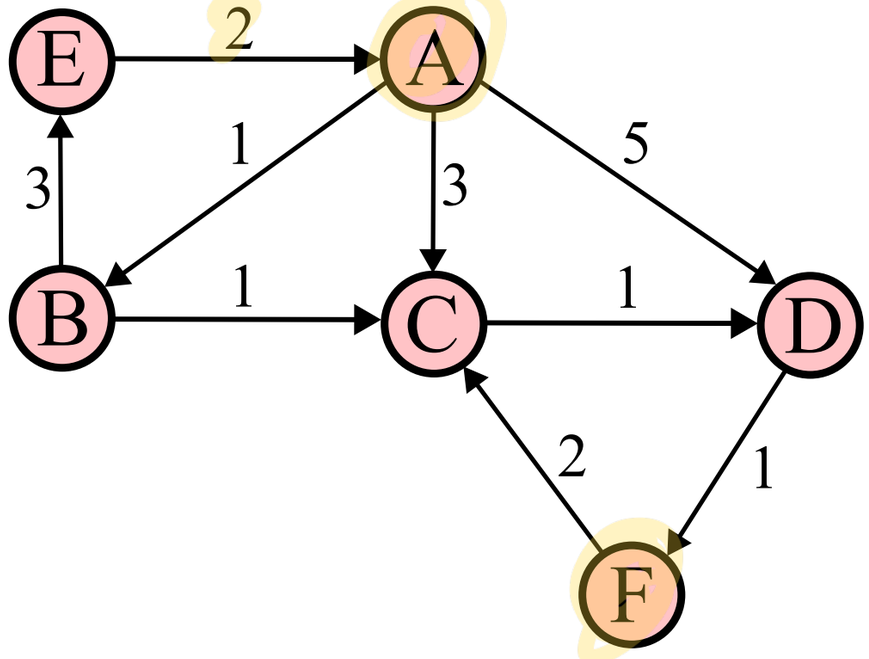
function Best-First-Search (problem, f) **returns** a solution or failure

node ← `Node(State=`*problem*`.Initial-State,Path-Cost=0)`
frontier ← a priority queue ordered by f, with *node* as the only element
reached ← a lookup table, with one entry (*node*`.State` → *node*)
loop do
  if `Is-Empty(`*frontier*`)` **then return** failure
  node ← `Pop(`*frontier*`)` // chooses the node n with minimum $f(n)$ in *frontier*
  if *problem*`.Is-Goal(`*node*`.State)` **then return** `Solution(`*node*`)`
  for each *child* **in** `Expand(`*problem*`,`*node*`)` **do**
    s ← *child*`.State`
    if *s* is not in *reached* **or** *child.Path-Cost* $<$ *reached*[s]`.Path-Cost` **then**
      reached[s] ← *child*
      frontier ← `Add(`*child*`,`*frontier*`)`

Problem 2.1: Search Algorithms Basics

- Start: A, goal: F
- Action costs are shown on the arcs
- If there is no clear preference, we visit the state next that is first alphabetically.

Tasks: perform Breadth-First, Depth-First and Uniform-Cost search.



Problem 2.1: Search Algorithms Basics

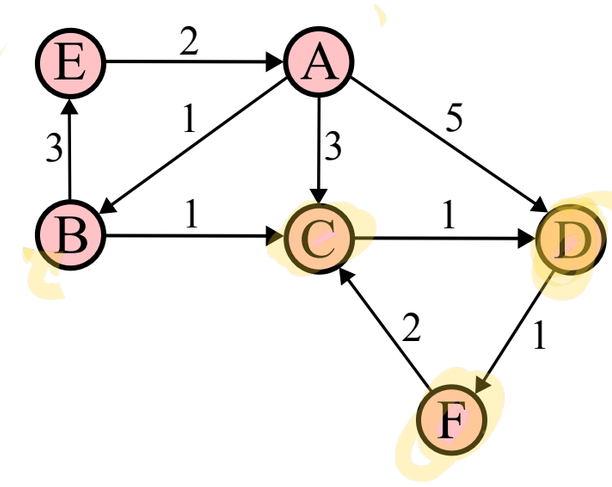
Breadth-First: FIFO

Node	Frontier	Reached
–	A(–)	A(–), B(A), C(A), D(A), E(B)
A(–)	B(A), C(A), D(A)	
B(A)	C(A), D(A), E(B)	
C(A)	D(A), E(B)	
D(A)	E(B)	

A – D – F

→ goal found

A – D – F



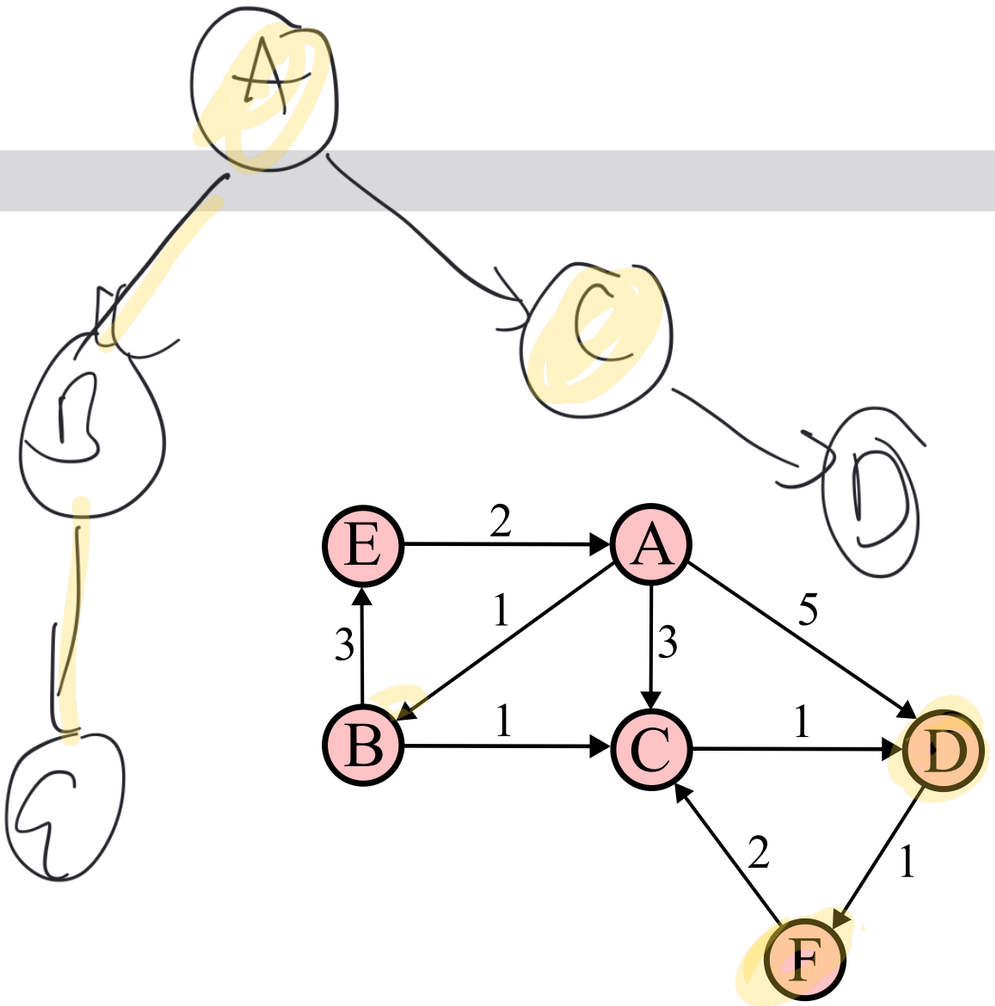
What is the result?
Today's tweedback code: **zjqb**
(twbk.de/zjqb)

A – B – C – D – F

Problem 2.1: Search Algorithms Basics

Depth-First: LIFO

Node	Frontier
-	A ~~(C)~~
A(-)	B(A), C(A), ~~D(A)~~
D(A)	B(A), C(A), ~~F(D)~~
F(D)	→ goal



What is the result?
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(twbk.de/zjqb)

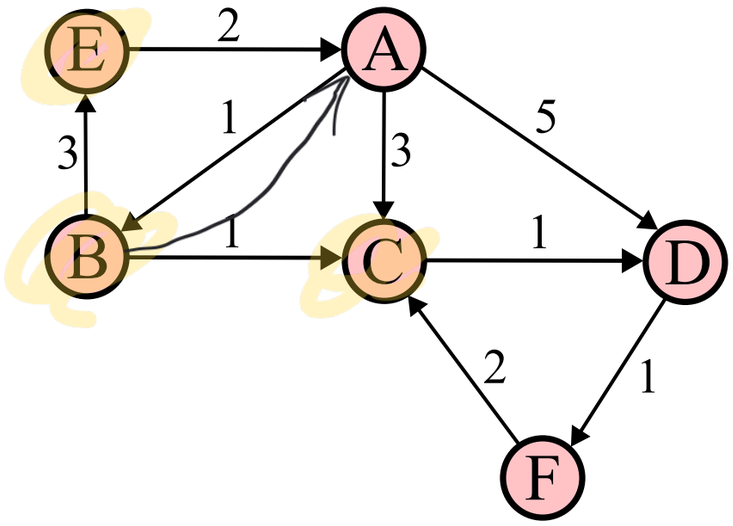
A-B-C-D-F

A-D-F

Problem 2.1: Search Algorithms Basics

Depth-First:

Node	Frontier
–	A (–)
A(–)	D(A), C(A), ~~B(A)~~
B(A)	D(A), C(A), E(B), ~~C(B)~~
C(B)	D(A), C(A), E(B), ~~D(C)~~
D(C)	F(D)
F(D)	



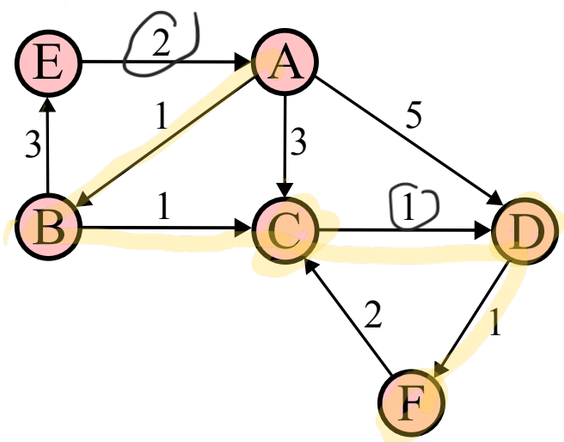
What is the result, if we reverse the order of visiting child nodes and check for cycles of length 2?
Today's tweedback code: **zjqb**
(twbk.de/zjqb)

A – B – C – D – F

Problem 2.1: Search Algorithms Basics

Uniform-Cost:

Node	Children	Frontier	Reached
–	–	A(0,–)	A(0,–)
A(0,–)	B(1,A), C(3,A), D(5,A)	B(1,A), C(3,A), D(5,A)	B(1,A), C(3,A), D(5,A)
B(1,A)	C(2,B), E(4,B)	C(2,B), D(5,A), E(4,B)	C(2,B), E(4,B)
C(2,B)	D(3,C)	D(3,C), E(4,B)	D(3,C), E(4,B)
D(3,C)	F(4,D)	E(4,B), F(4,D)	F(4,D)



What is the result?
Today's tweedback code: **zjqb**
(twbk.de/zjqb)

Problem 2.2: Application of Search Algorithms: Transport

I have bought 120 bricks at the hardware store, which I need to transport. I have the following means of transport, which I consider in the given order:

1. **bus (b)** – I can carry up to 30 bricks, costing 3 €
2. **car (c)** – it can carry up to 100 bricks, costing 5 €
3. **delivery (d)** – it delivers all the bricks, costing 29 €

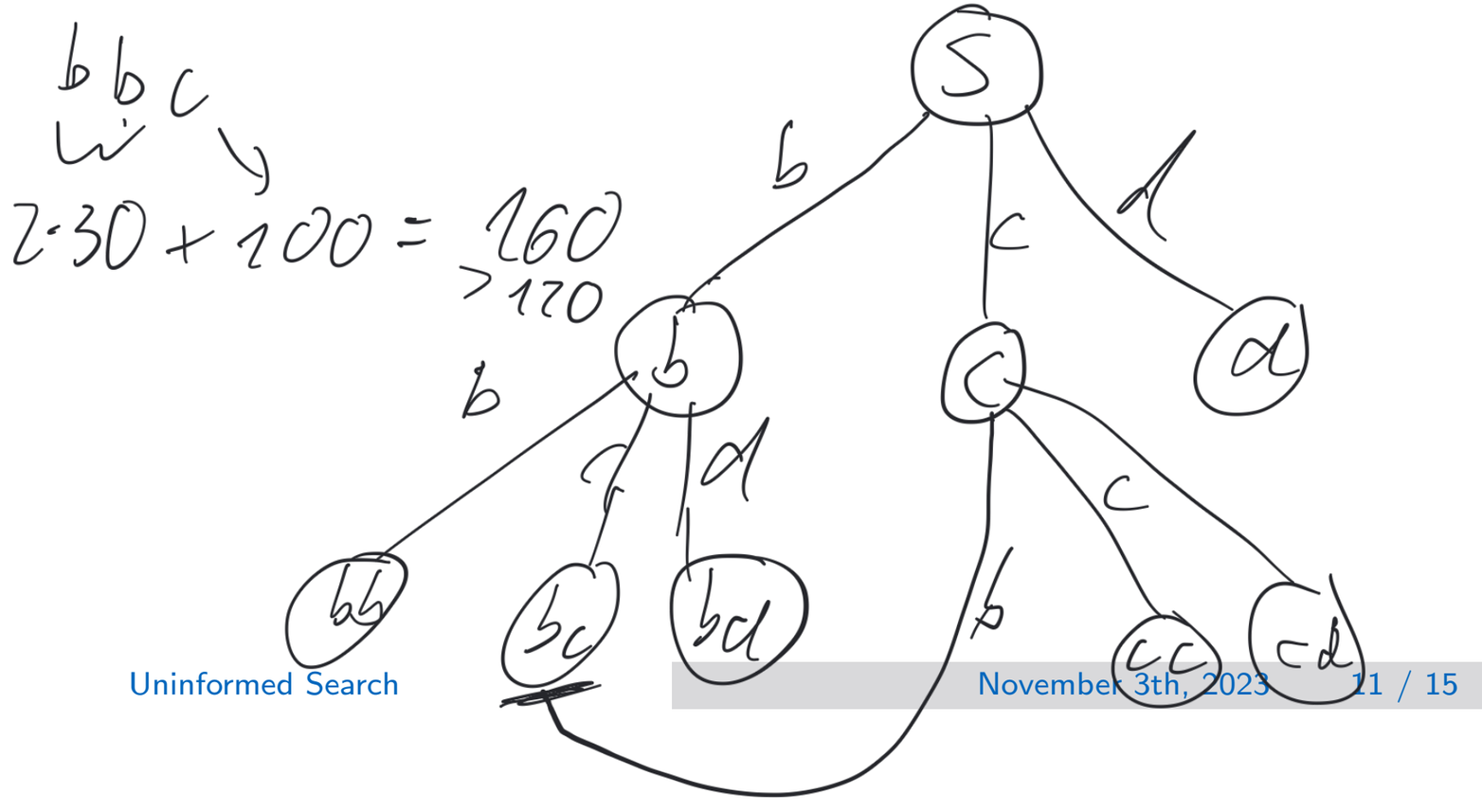
Problem 2.2: Application of Search Algorithms: Transport

I have bought 120 bricks at the hardware store, which I need to transport. I have the following means of transport, which I consider in the given order:

1. **bus** (b) – I can carry up to 30 bricks, costing 3 €
2. **car** (c) – it can carry up to 100 bricks, costing 5 €
3. **delivery** (d) – it delivers all the bricks, costing 29 €

Let us define the search problem:

- state space
- initial state
- actions
- transition model
- goal test
- path cost



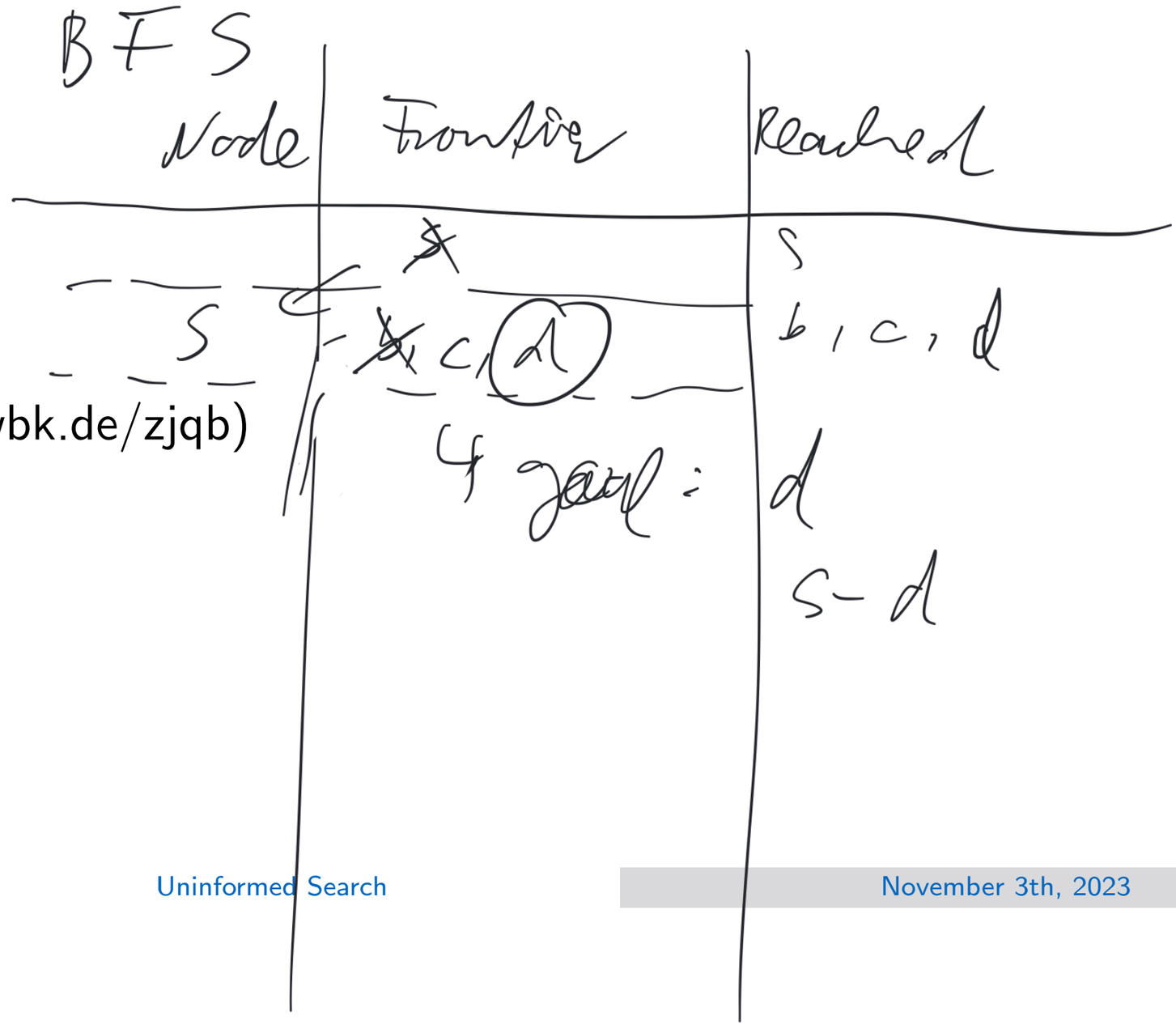
Problem 2.2.1:

Assuming I want to make as few trips as possible, which search method should I use and what is the resulting solution?

120 bricks, following actions:

1. **bus (b)** – 30 bricks, 3 €
2. **car (c)** – 100 bricks, 5 €
3. **delivery (d)** – all bricks, 29 €

Today's tweedback code: **zjqb** (twbk.de/zjqb)



Problem 2.2.2:

Assuming I want to ~~minimize~~ the cost, which search method should I use and what is the resulting solution?

120 bricks, following actions:

1. **bus (b)** – 30 bricks, 3 €
2. **car (c)** – 100 bricks, 5 €
3. **delivery (d)** – all bricks, 29 €

Today's tweedback code: **zjqb** (twbk.de/zjqb)

Node	Frontier	Reached
–	~~s(0)~~	s(0), b(3), c(5)
s(0)	~~b(3)~~, c(5), d(29)	d(29), bb(6), bc(8), bd(32), cc(10), cd(34), bbb(9), bbc(11), bbd(35)
b(3)	bb(6), bc(8), bd(32), cc(10), cd(34), bbb(9), bbc(11), bbd(35)	
c(5)	bb(6), bc(8), bd(32), cc(10), cd(34), bbb(9), bbc(11), bbd(35)	
bb(6)	bc(8), bd(32), cc(10), cd(34), bbb(9), bbc(11), bbd(35)	
bc(8)	bd(32), cc(10), cd(34), bbb(9), bbc(11), bbd(35)	

30 + 100 = 130 → bc

Problem 2.2.3:

Perform depth-first search.

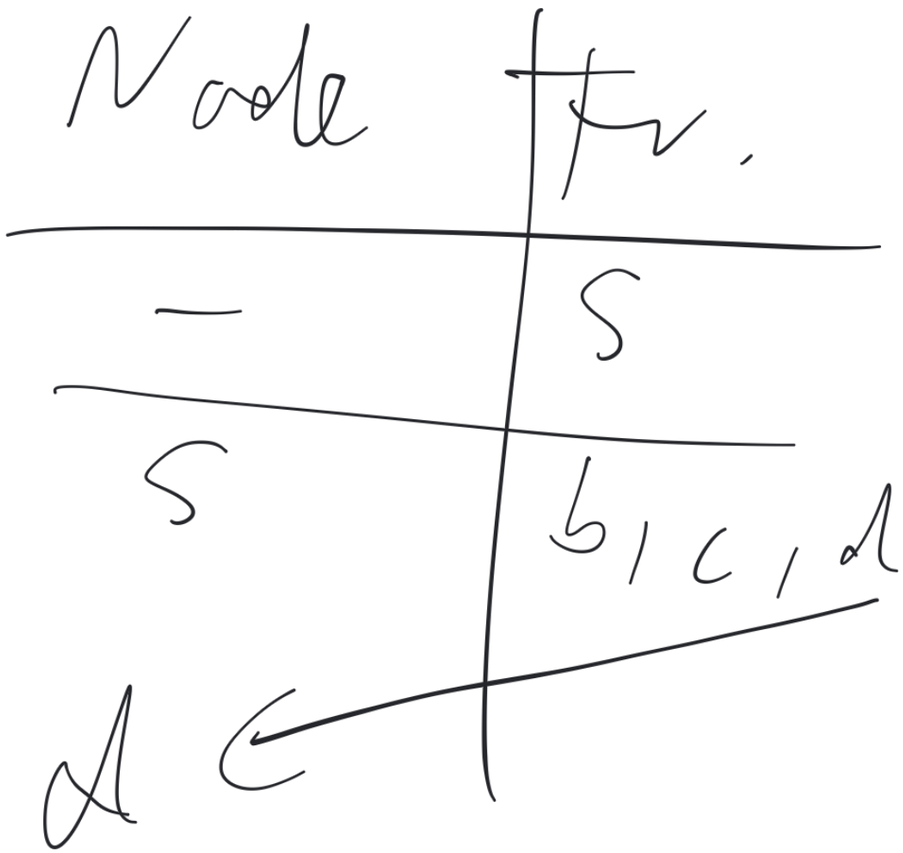
120 bricks, following actions:

1. **bus (b)** – 30 bricks, 3 €
2. **car (c)** – 100 bricks, 5 €
3. **delivery (d)** – all bricks, 29 €

Today's tweedback code: **zjqb** (twbk.de/zjqb)

LIFO

b, c, d



Problem 2.2.4:

Perform depth-first search again, but now assume I explore actions in the order: delivery, car, bus.

120 bricks, following actions:

1. **bus** (b) – 30 bricks, 3 €
2. **car** (c) – 100 bricks, 5 €
3. **delivery** (d) – all bricks, 29 €

b - b - b - b

Today's tweedback code: **zjqb** (twbk.de/zjqb)