AI 1: Exercise Sheet 1 – Discussion of Solutions

TECHNISCHE UNIVERSITÄT DARMSTADT

WIRTSCHAFTS INFORMATIK

Welcome!

We will start in a few minutes, please stay tuned!

SESSION GUIDELINES:

- Please ensure that you **stay muted** while others talk.
- Feel free to **ask questions in the chat at any time**.

Artificial Intelligence | Basics of Algorithms & Application

Solutions for Exercise Sheet 1: “Intelligent Agents”

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Hi!

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  - **Bachelor**: Information Systems at TU Darmstadt
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You‘re interested in writing a thesis about the impact of AI on organizations?

Don‘t hesitate to contact me!

Exercise 1.1a: Agent Types (1/2)

After watching our exciting lecture on intelligent agents, you decide to take a short break and go for a walk with your best mate. After discussing numerous fascinating topics (such as today's weather, GPT-3, and your latest binge-watching on Netflix), your friend wants to know more about what you have learned today about AI—especially about the different kinds of intelligent agents that you just mentioned.

Instantly, your friend raises the following questions that you try to address as a newly self-proclaimed AI expert:

a. "Intelligent agent", you say? Can you please **give some examples** for such **"intelligent agents"** besides your vacuum robot? What would be fitting:
   - ***performance measures***,
   - ***parts of environment***,
   - ***actuators***, and
   - ***sensors***

   for these examples?

Exercise 1.1a: Agent Types (2/2)

Solution

Examples:

Agent	Performance Measures	Parts of Environment	Actuators	Sensors
Self-driving Car	Minimize accidents, minimize time to reach goal, ...	Other cars, pedestriants, road signs, driving rules, …	Wheels, brakes, …	Lidar sensors, cameras, distance sensors, …
Image Classifier	Maximize correctly classified images	(Labeled) Images	Label output	(image upload)
…	…	…	…	…

Exercise 1.1b: Agent Types (1/7) – Overview of Characteristics

Task

i. ***Fully*** **vs.** ***partially*** **observable:**

- **Fully:** The agent‘s sensors give it access to the complete state of the environment at each point in time.
- **Partial:** The agent‘s sensors can only observe parts of the state of the environment.

ii. ***Single*** **agent vs.** ***multi*****agent:**

- **Single agent:** An agent operating by itself in an environment.
- **Multiagent:** Multiple agents operate in an environment and affect each other.

iii. ***Deterministic*** **vs.** ***stochastic:***

- **Deterministic:** The next state of the environment is completely determined by the current state and the action executed by the agent(s).
- **Stochastic:** The next state of the environment does not only depend on agents’ actions (e.g., due to chance).

iv. ***Episodic*** **vs.** ***sequential:***

- **Episodic:** Subsequent episodes do not depend on what actions occurred in previous episodes.
- **Sequential:** The agent engages in a series of connected episodes.

v. ***Static*** **vs.** ***dynamic:***

- **Static:** The environment does not change while the agent is “thinking”.
- **Dynamic:** The environment continuously asks the agent what it wants to do.

vi. ***Discrete*** **vs.** ***continuous***

- **Discrete:** The number of distinct percepts and actions is limited.
- **Continuous**: The number of distinct percepts and actions is not limited.

vii. ***Known*** **vs.** ***unknown***

- **Known:** The environment is known to the agent
- **Unknown:** The environment is unknown to the agent and it must learn about it

Exercise 1.1b: Agent Types (1/7)

Task

b. *You just said that an agent's environment can have different characteristics, including:*

i. ***fully*** vs. ***partially*** observable

ii. ***single*** agent vs. ***multi***agent

iii. ***deterministic*** vs. ***stochastic***

iv. ***episodic*** vs. ***sequential***

v. ***static*** vs. ***dynamic***

vi. ***discrete*** vs. ***continuous***

vii. ***known*** vs. ***unknown***

However, I am unsure whether I understood this correctly.

Can you please explain **which** of the **two different forms** of **each characteristic applies** to the following **examples** respectively? **Why**?
(the examples are listed on the right)

1. **Chess**
2. **Poker**
3. **Taxi driving**
4. **Internet book-shopping agent**
   The agent tries to find the cheapest offer for a certain book. If it finds a book, it decides by itself whether it wants to buy the book or not. To do so, it tries to gather as much information as possible from the internet by crawling internet bookstores. It can be assumed that neither the internet nor the sellers' inventory changes significantly during the action of the agent.
5. **Robot soccer player**
   The robot has sensors (cameras, etc.) which allow it to see the location of the soccer field from its perspective. With this information it has to determine the ball, has to get out of the way of other robot players and must try to shoot a goal.

Exercise 1.1b: Agent Types (2/7)

	Chess
i. **fully** vs. **partially** observable	**Fully observable** The entire board can be observed at any time
ii. **single** agent vs. **multi**agent	**Multiagent** The two players affect each other‘s actions
iii. **deterministic** vs. **stochastic**	**Deterministic** The next game state is completely determined by a player’s action
iv. **episodic** vs. **sequential**	**Sequential** A player’s action depends on the course of play so far
v. **static** vs. **dynamic**	**Static** The board does not change until a player makes a move
vi. **discrete** vs. **continuous**	**Discrete** There is a finite number of possible game sequences
vii. ***known*** vs. ***unknown***	**Known** The rules and board state after each action is known

Exercise 1.1b: Agent Types (3/7)

Solution

	Poker
i. **fully** vs. **partially** observable	**Partially observable** Each player only sees his/her own and any played cards
ii. **single** agent vs. **multi**agent	**Multiagent** The players affect each other's actions
iii. **deterministic** vs. **stochastic**	**Stochastic** Each player holds a random set of cards
iv. **episodic** vs. **sequential**	**Sequential** A player's action depends on the course of play so far
v. **static** vs. **dynamic**	**Static** The cards do not change until a player makes a move
vi. **discrete** vs. **continuous**	**Discrete** There is a finite number of possible game sequences
vii. ***known*** vs. ***unknown***	**Known** The rules are known

Exercise 1.1b: Agent Types (4/7)

	Taxi Driving
i. **fully** vs. **partially** observable	**Partially observable** No driver can observe the entire world around him/her
ii. **single** agent vs. **multi**agent	**Multiagent** Other drivers (and bikers, pedestrians, …) affect a driver's actions
iii. **deterministic** vs. **stochastic**	**Stochastic** The real world consists of many random elements
iv. **episodic** vs. **sequential**	**Sequential** A driver's action depends on his/her previous moves
v. **static** vs. **dynamic**	**Dynamic** The world changes continuously while driving
vi. **discrete** vs. **continuous**	**Continuous** There is an unfinite number of possible life sequences
vii. ***known*** vs. ***unknown***	**Unknown** The dynamics of the world remain unknown in their entirety

Exercise 1.1b: Agent Types (5/7)

- **Goal:** Tries to find the cheapest offer for a certain book
- Approach:
  - If it finds a book, it decides by itself whether it wants to buy the book
  - Tries to gather as much information as possible from the internet by crawling internet bookstores
- **Assumption:** Neither the internet nor the sellers' inventory changes significantly during the action of the agent

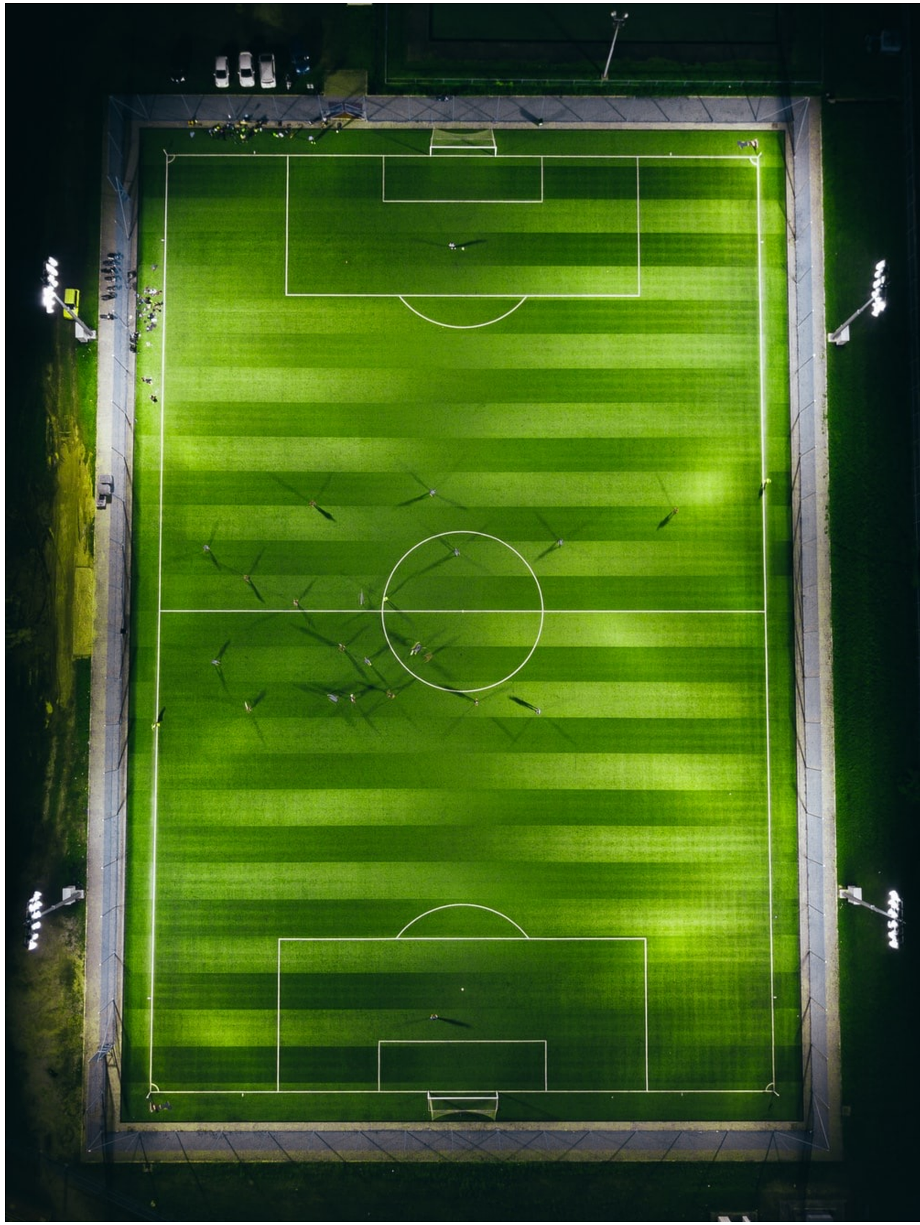
	Internet Book-Shopping Agent
i. **fully** vs. **partially** observable	**Partially observable** Also the best agents cannot crawl the entire internet
ii. **single** agent vs. **multi**agent	**Single agent** Other agents' actions do not affect the agent's decision (due to our assumption)
iii. **deterministic** vs. **stochastic**	**Deterministic** The agent can only decide between "buy" and "not buy"
iv. **episodic** vs. **sequential**	**Episodic** Searching or buying books do not affect further actions (due to our assumption)
v. **static** vs. **dynamic**	**Static** The internet does not change significantly while the agent acts (due to our assumption)
vi. **discrete** vs. **continuous**	**Discrete** Its actions cover a finite number of steps (search, find, buy, …)
vii. ***known*** vs. ***unknown***	**Known** It is clear to the agent what happens when deciding (not) to buy

Exercise 1.1b: Agent Types (6/7)

Solution

- **Sensing:** The robot has sensors (cameras, etc.) which allow it to see the location of the soccer field from its perspective
- **Approach:**
  - With this information it has to determine the ball,
  - has to get out of the way of other robot players and
  - must try to shoot a goal

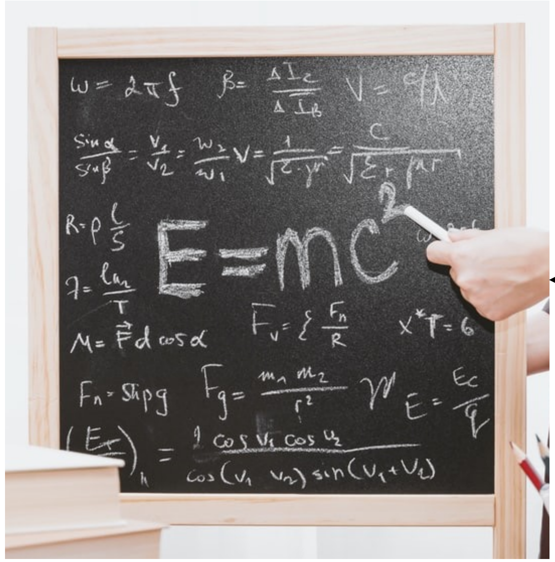
	Robot Soccer Player
i. **fully** vs. **partially** observable	**Partially observable** The robot's sensors can only observe a small part of the world
ii. **single** agent vs. **multi**agent	**Multiagent** Soccer is played with and against other players
iii. **deterministic** vs. **stochastic**	**Stochastic** It's impossible to foresee the exact direction that the ball will take
iv. **episodic** vs. **sequential**	**Sequential** Potential future events must be predicted and considered
v. **static** vs. **dynamic**	**Dynamic** The game continous while a player plans the next moves
vi. **discrete** vs. **continuous**	**Continuous** A player can have infinite possible positions; real time is continuous
vii. ***known*** vs. ***unknown***	**Unknown** The dynamics of the world remain unknown in their entirety



Exercise 1.1b: Agent Types (7/7)

	Chess	Poker	Taxi Driving	Internet Book-Shopping Agent	Robot Soccer Player
i. **fully** vs. **partially** observable	**Fully observable** The entire board can be observed at any time	**Partially observable** Each player only sees his/her own and any played cards	**Partially observable** No driver can observe the entire world around him/her	**Partially observable** Also the best agents cannot crawl the entire internet	**Partially observable** The robot's sensors can only observe a small part of the world
ii. **single** agent vs. **multi**agent	**Multiagent** The two players affect each other's actions	**Multiagent** The players affect each other's actions	**Multiagent** Other drivers (and bikers, pedestrians, …) affect a driver's actions	**Single agent** Other agents' actions do not affect the agent's decision (due to our assumption)	**Multiagent** Soccer is played with and against other players
iii. **deterministic** vs. **stochastic**	**Deterministic** The next game state is completely determined by a player's action	**Stochastic** Each player holds a random set of cards	**Stochastic** The real world consists of many random elements	**Deterministic** The agent can only decide between "buy" and "not buy"	**Stochastic** It's impossible to foresee the exact direction that the ball will take
iv. **episodic** vs. **sequential**	**Sequential** A player's action depends on the course of play so far	**Sequential** A player's action depends on the course of play so far	**Sequential** A driver's action depends on his/her previous moves	**Episodic** Searching or buying books do not affect further actions (due to our assumption)	**Sequential** Potential future events must be predicted and considered
v. **static** vs. **dynamic**	**Static** The board does not change until a player makes a move	**Static** The cards do not change until a player makes a move	**Dynamic** The world changes continuously while driving	**Static** The internet does not change significantly while the agent acts (due to our assumption)	**Dynamic** The game continous while a player plans the next moves
vi. **discrete** vs. **continuous**	**Discrete** There is a finite number of possible game sequences	**Discrete** There is a finite number of possible game sequences	**Continuous** There is an unfinite number of possible life sequences	**Discrete** Its actions cover a finite number of steps (search, find, buy, …)	**Continuous** A player can have infinite possible positions; real time is continuous
vii. ***known*** vs. ***unknown***	**Known** The rules and board state after each action is known	**Known** The rules are known	**Unknown** The dynamics of the world remain unknown in their entirety	**Known** It is clear to the agent what happens when deciding (not) to buy	**Unknown** The dynamics of the world remain unknown in their entirety

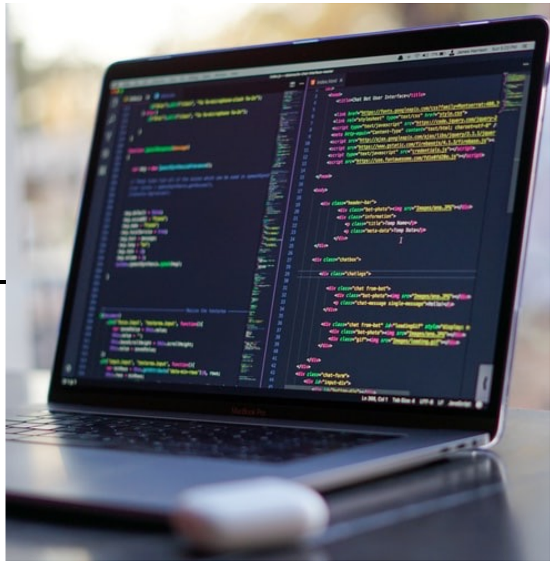
Exercise 1.2a: “Agent Function” vs. “Agent Program”(1/2)



“**Agent Function**” vs. “**Agent Program**”

same but different?

1 ← implements — N?



Please answer the following questions to further explore how they relate to one another:

a. Can there be **more than one agent program** that implements **a given agent function**?

Please **either** provide an **example** or show **why giving one is not possible**.

Exercise 1.2a: “Agent Function” vs. “Agent Program”(2/2)

Solution

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YES

There can be **more than one agent program**

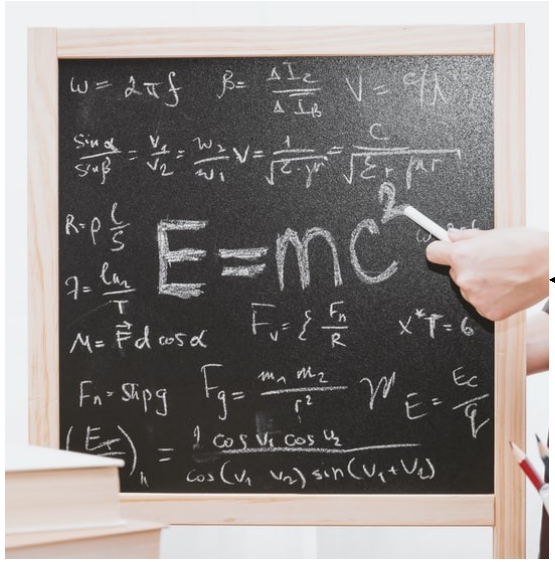
that implements **a given agent function**

Example:

e.g., simply use a working program and add null or print statements that do not affect the agent’s behavior

Exercise 1.2b: “Agent Function” vs. “Agent Program”(1/2)

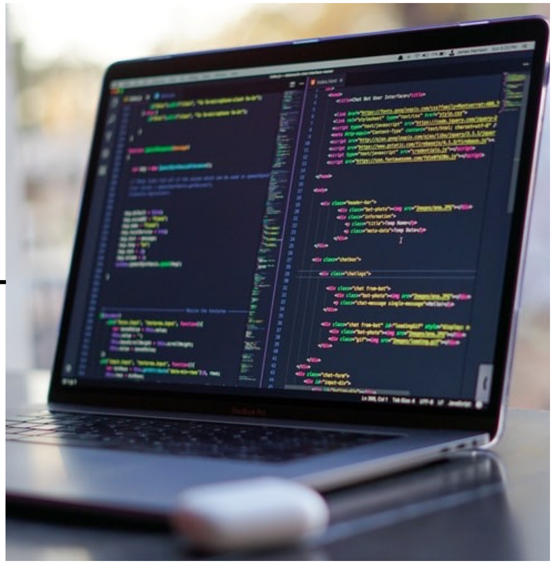
Task



“**Agent Function**” vs. “**Agent Program**”

same but different?

implements



Please answer the following questions to further explore how they relate to one another:

b. Are there **agent functions** that **<u>cannot</u>** be **implemented** by any **agent program**?

Exercise 1.2b: “Agent Function” vs. “Agent Program”(2/2)

Solution

YES

There are **agent functions**

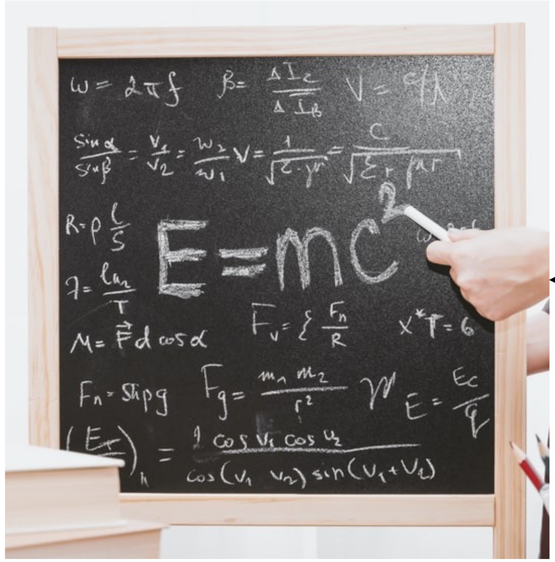
that **cannot be implemented** by any program

Example:

e.g., an agent function that aims to count until infinity

- ➢ each agent program will run out of memory at some point and fail

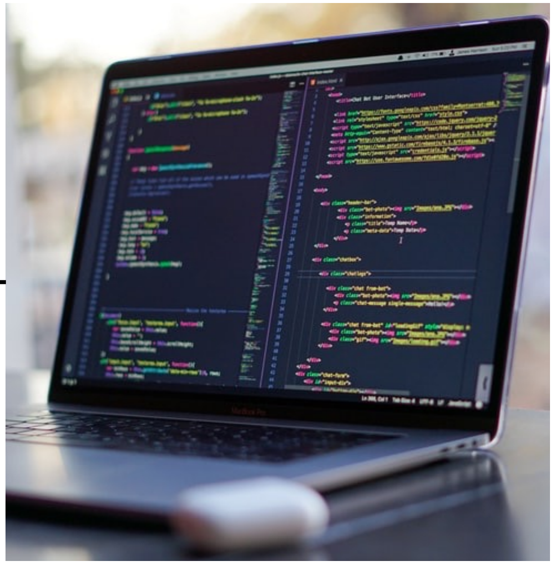
Exercise 1.2c: “Agent Function” vs. “Agent Program”(1/2)



“**Agent Function**” vs. “**Agent Program**”

same but different?

1? ← implements — 1



Please answer the following questions to further explore how they relate to one another:

c. Given a fixed machine architecture,
does each **agent program implement <u>exactly one</u> agent function**?

Exercise 1.2c: “Agent Function” vs. “Agent Program”(2/2)

Solution

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Y E S

each **agent program** implements

<u>exactly one</u> agent function

Explanation:

The agent’s behavior is fixed by the architecture and program. It’s simply the definition of an agent function: each agent implements exactly one agent function.

Exercise 1.3a: Rationality (1/2)

*One underlying **objective** of creating an **intelligent agent** is to design its **behavior to be <u>rational</u>**.*

- *But what does it actually **mean** to **act** "**rationally**"?*

Let's explore it together in more detail:

a. The so-called "**omniscience**" and "**rationality**" are two similar concepts. How can we **define each** of the two concepts and **how** do they **differ**?

Exercise 1.3a: Rationality (2/2)

Omniscience

An agent performs always the optimal action from a global point of view

- ➢ The agent knows everything; knows every aspect of the world

Rationality

An agent performs the best action in relation to its available information

- ➢ The agent does not know everything; knows only a part of the world

Exercise 1.3b: Rationality (1/2)

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Assume that your **vacuum robot** starts **cleaning** your apartment.

After six hours of vacuuming, you finally realize that your robot **did not stop** vacuuming although your **floor** is **perfectly clean** by now:

the **dirt sensor stopped working**,
leading to the robot **continuously sensing dirt everywhere**.

Did the robot act **irrational**?

Img source: today.com

Exercise 1.3b: Rationality (2/2)

Solution

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N O

The robot **acted rational**

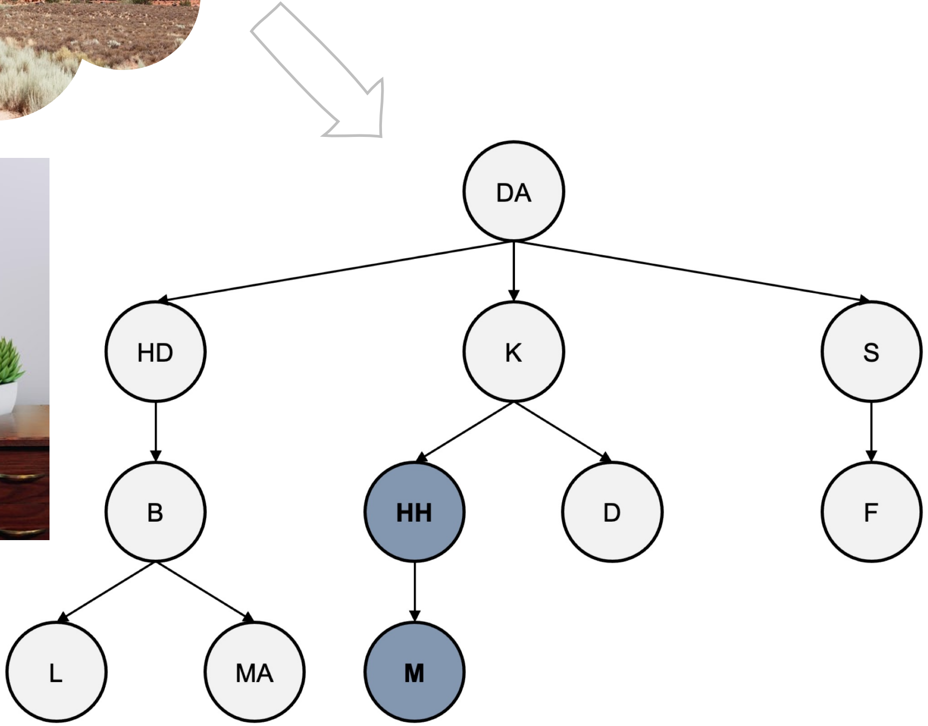
Explanation:

The floor appeared dirty for the whole time,
vacuuming thus remained the obvious reasonable action to perform
in order to get the "seemingly dirty" apartment clean.

Exercise 1.4: Solving Problems by Searching (BFS vs. DFS) (1/2)

Task

Background: *Looking back at how bored you were at home during last summer, you decide to do a road trip through Germany this year if this is possible again. Based on various criteria, you created the following tree of potential paths you can combine for this trip (the letters in the nodes represent abbreviations for German cities as found on license plates):*



Plan: You decide that your road trip should start in Darmstadt (DA) and either end in Hamburg (HH) or Munich (M). As you want to minimize costs, you want to reduce the number of visited nodes. As an AI expert, you decide to look at this problem from the perspective of search algorithms. Considering breath-first search (BFS) and depth-first search (DFS):*

a. Indicate the **order of nodes** for **both search algorithms** until they **reach**:

1. **Hamburg (HH)**
2. **Munich (M**)

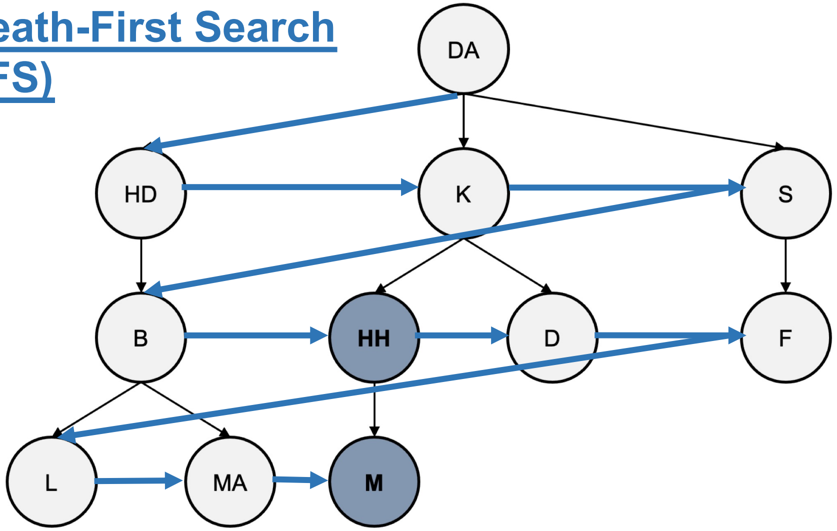
b. For **each** of the **two goals**, which algorithm covers **less nodes** until it **reaches Hamburg (HH)** or **Munich (M)** respectively?

** Please assume that the algorithms always choose the left-most node if they can choose between multiple nodes*

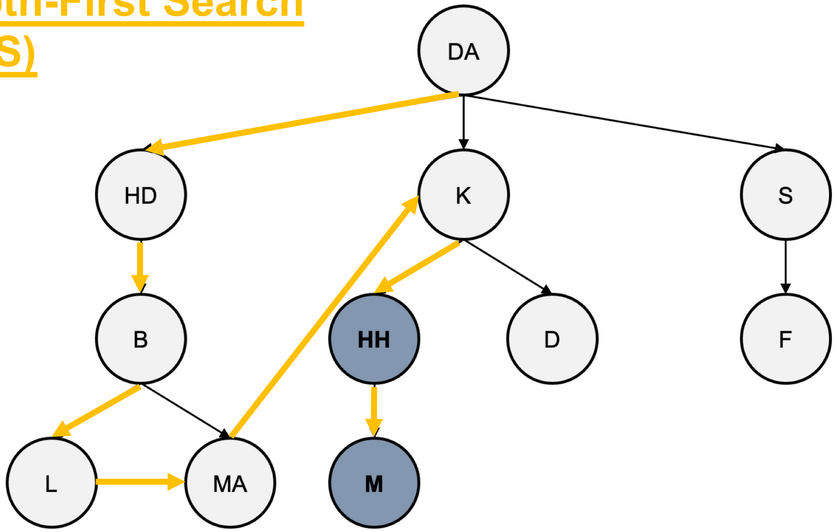
Exercise 1.4: Solving Problems by Searching (BFS vs. DFS) (2/2)

Solution

Breath-First Search (BFS)



Depth-First Search (DFS)



a. Indicate the **order of nodes** for both search algorithms until they reach:

1. **Hamburg (HH)**
   - **Breath-First Search (BFS):** DA→HD→K→S→B→**HH**
   - **Depth-First Search (DFS):** DA→HD→B→L→MA→K→**HH**
2. **Munich (M)**
   - **Breath-First Search (BFS):** DA→HD→K→S→B→HH→D→F→L→MA→**M**
   - **Depth-First Search (DFS):** DA→HD→B→L→MA→K→HH→**M**

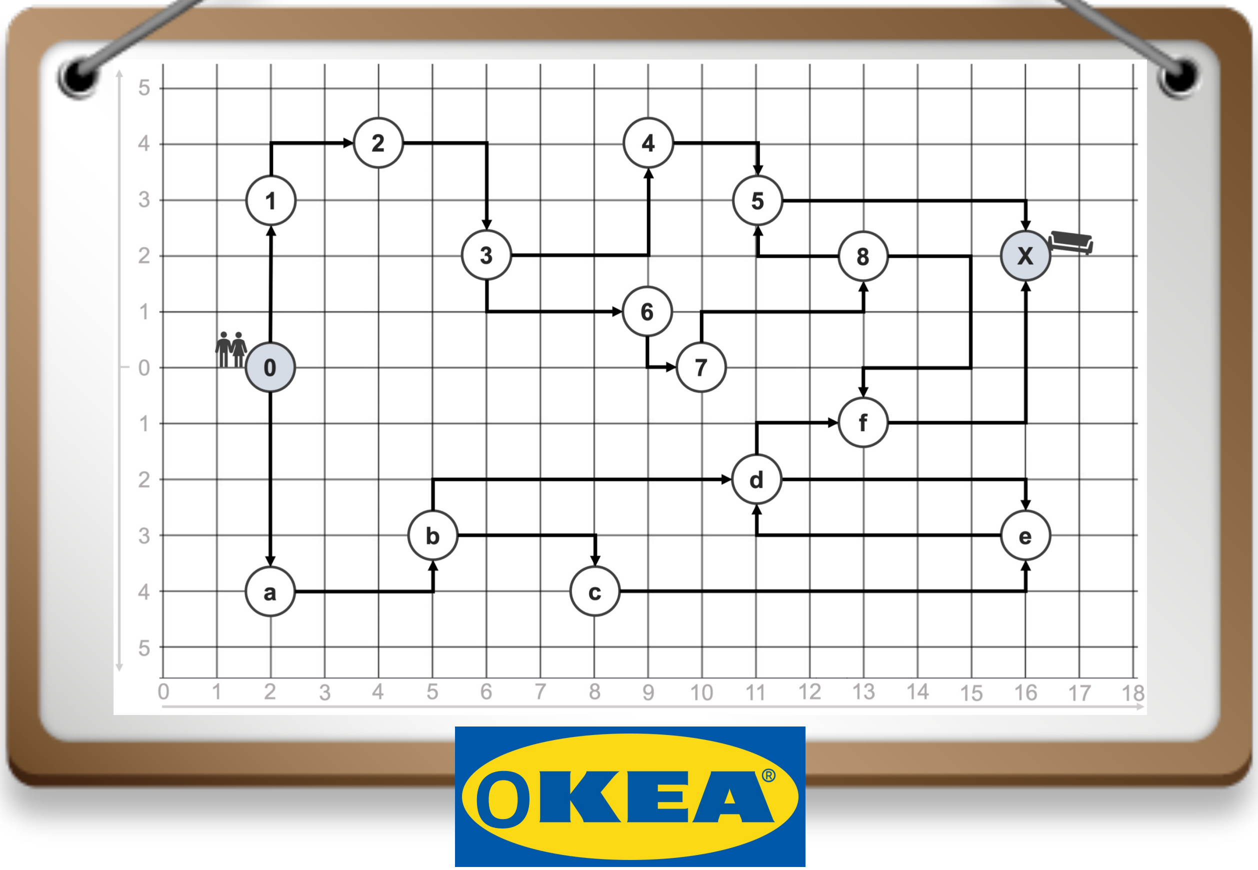
b. Which algorithm covers **less nodes** until it **reaches:**

1. **Hamburg (HH)**
   - **Breath-First Search (BFS):** covers **6** nodes ⟵ less nodes!
   - **Depth-First Search (DFS):** covers **7** nodes
2. **Munich (M)**
   - **Breath-First Search (BFS):** covers **11** nodes
   - **Depth-First Search (DFS):** covers **8** nodes ⟵ less nodes!

Exercise 1.5a: Solving Problems by Searching (GBF vs. A*) (1/2)

Background: Having developed a devastating back pain from laying on your old sofa, your significant other decided that the time has come for you to buy a new - comfortable - sofa. When you arrive at your favorite furniture store “Okea”, you check out the floor plan (see image below) to locate the sofa section.

Floor Plan: On the floor plan, you see that each section is indicated by a number or letter and that certain sections are connected with one another. Moreover, you notice that you are currently in section “0” (which is specialized on much-too-dim lamps) and that your desired sofas are located in section “X”. To avoid passing too many compelling offerings, you want to take the shortest path possible. Unfortunately, “Okea” does not indicate exact route lengths on their floor plans. Therefore, you decide that the most reasonable choice for a helpful heuristic might be the Euclidian distance between a section and the sofa section (“X”).

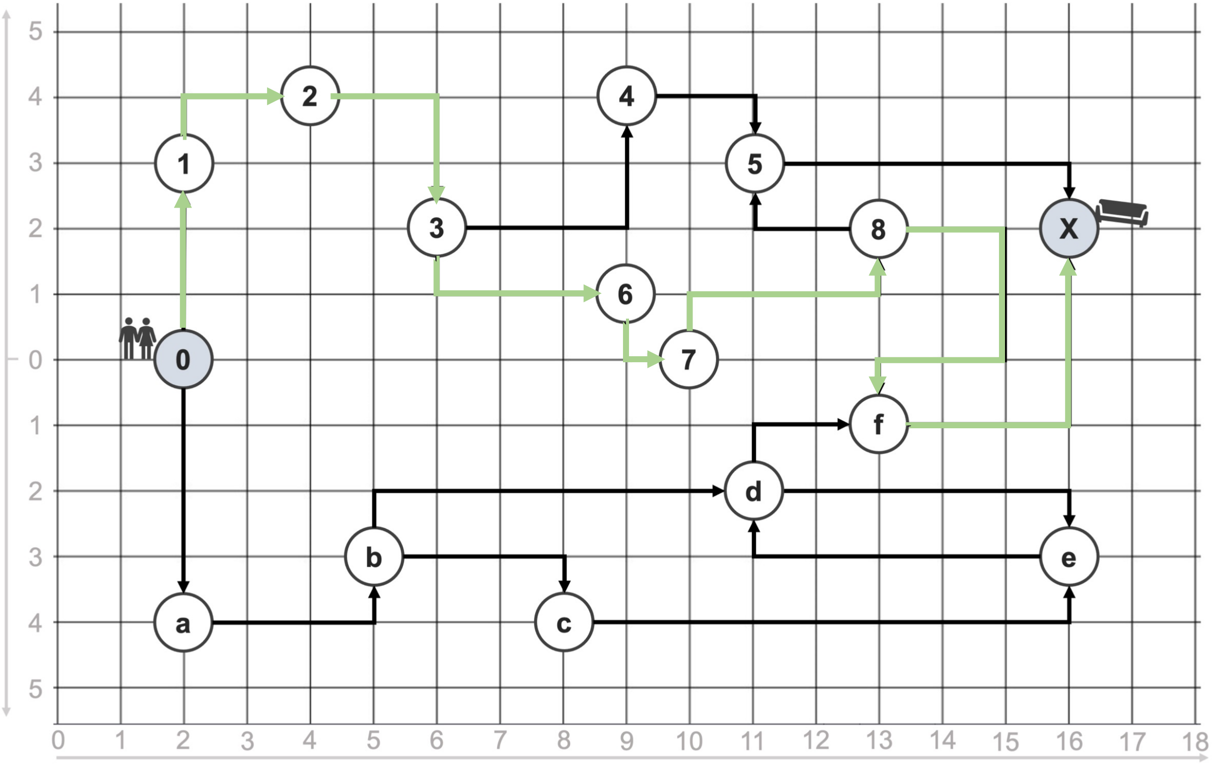


a. Based on your **considerations above**, you decide to use “**greedy best first**” search to find the **shortest path** from **0** to **X**.

➢ **Which path will you use?**

Exercise 1.5a: Solving Problems by Searching (GBF vs. A*) (2/2)

Solution



Euclidean Distances:

- d(1, X) = $\sqrt{(2-16)^2+(3-2)^2}$ ≈ 14.04
- d(2, X) = $\sqrt{(4-16)^2+(4-2)^2}$ ≈ 12.16
- d(3, X) = $\sqrt{(6-16)^2+(2-2)^2}$ ≈ 10
- d(4, X) = $\sqrt{(9-16)^2+(4-2)^2}$ ≈ 7.28
- d(5, X) = $\sqrt{(11-16)^2+(3-2)^2}$ ≈ 5.1
- d(6, X) = $\sqrt{(9-16)^2+(1-2)^2}$ ≈ 7.07
- d(7, X) = $\sqrt{(10-16)^2+(0-2)^2}$ ≈ 6.32
- d(8, X) = $\sqrt{(13-16)^2+(2-2)^2}$ ≈ 3

- d(a, X) = $\sqrt{(2-16)^2+(-4-2)^2}$ ≈ 15.23
- d(b, X) = $\sqrt{(5-16)^2+(-3-2)^2}$ ≈ 12.08
- d(c, X) = $\sqrt{(8-16)^2+(-4-2)^2}$ ≈ 10
- d(d, X) = $\sqrt{(11-16)^2+(-2-2)^2}$ ≈ 6.4
- d(e, X) = $\sqrt{(16-16)^2+(-3-2)^2}$ ≈ 5
- d(f, X) = $\sqrt{(13-16)^2+(-1-2)^2}$ ≈ 4.24

Greedy Best First: 0 → 1 → 2 → 3 → 6 → 7 → 8 → f → X

Exemplary decisions:

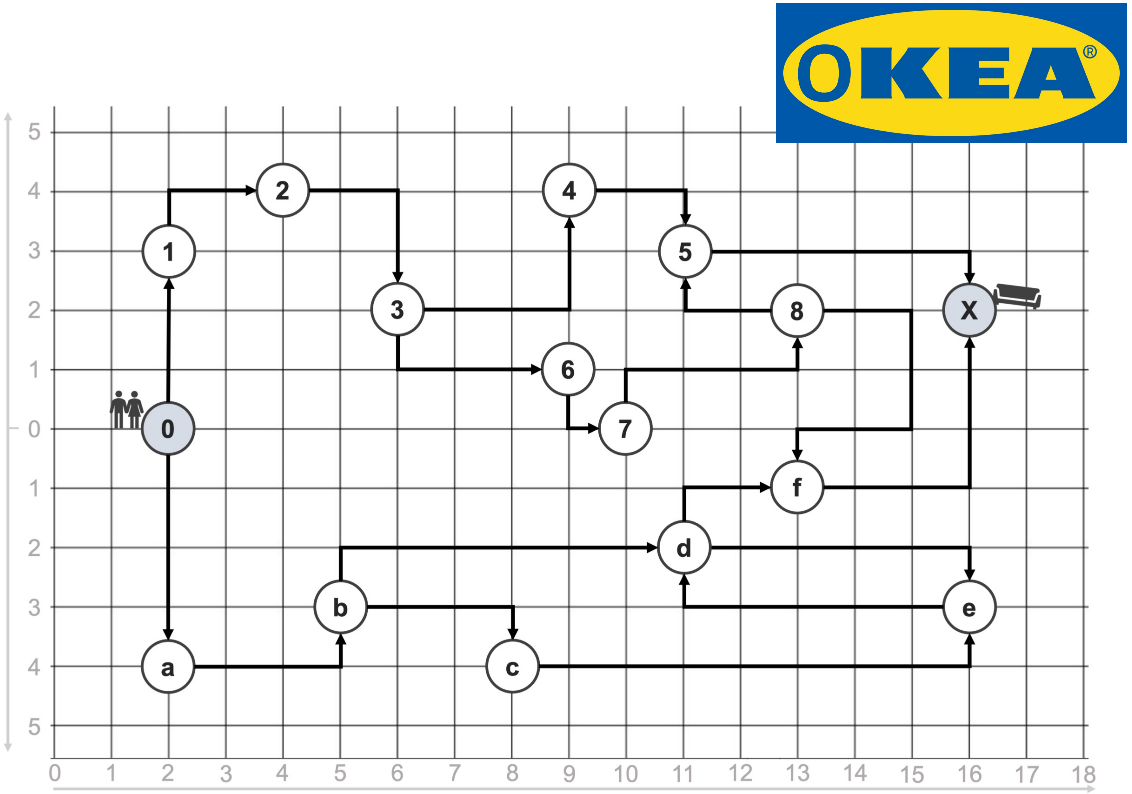
- **“1” vs. “a”:** d(1, X)= 14.04 < d(a, X)= 15.23 ☞ choose “1”
- **“5” vs. “f”:** d(5, X)= 5.1 > d(f, X)= 4.24 ☞ choose “f”

Exercise 1.5b: Solving Problems by Searching (GBF vs. A*) (1/2)

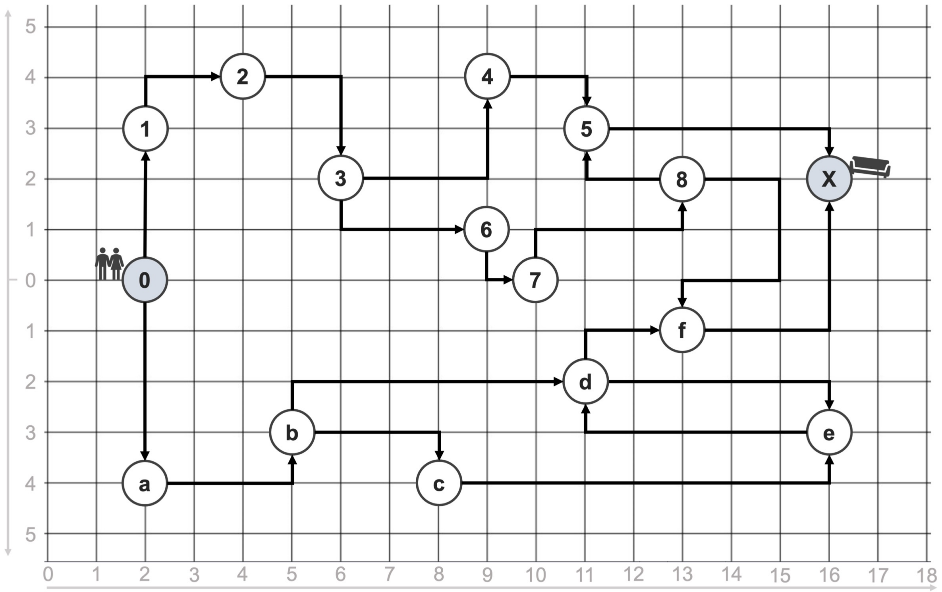
b. Your significant other challenges you that (s)he will **reach** the **sofa** section **faster** than **you**.

To achieve this, (s)he develops a path using **A* search** instead.

- **Which path will (s)he use?**
- **Is this path shorter than your path** (from the previous task)**?**



Exercise 1.5b: Solving Problems by Searching (GBF vs. A*) (2/2)



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- d(d, X) = $\sqrt{(11-16)^2+(-2-2)^2}$ ≈ 6.4
- d(e, X) = $\sqrt{(16-16)^2+(-3-2)^2}$ ≈ 5
- d(f, X) = $\sqrt{(13-16)^2+(-1-2)^2}$ ≈ 4.24

A* finds two possible solutions (result of each = 24):

- **Solution #1:** 0 → a → b → d → f → X
- **Solution #2:** 0 → 1 → 2 → 3 → 4 → 5 → X

Exemplary decisions:

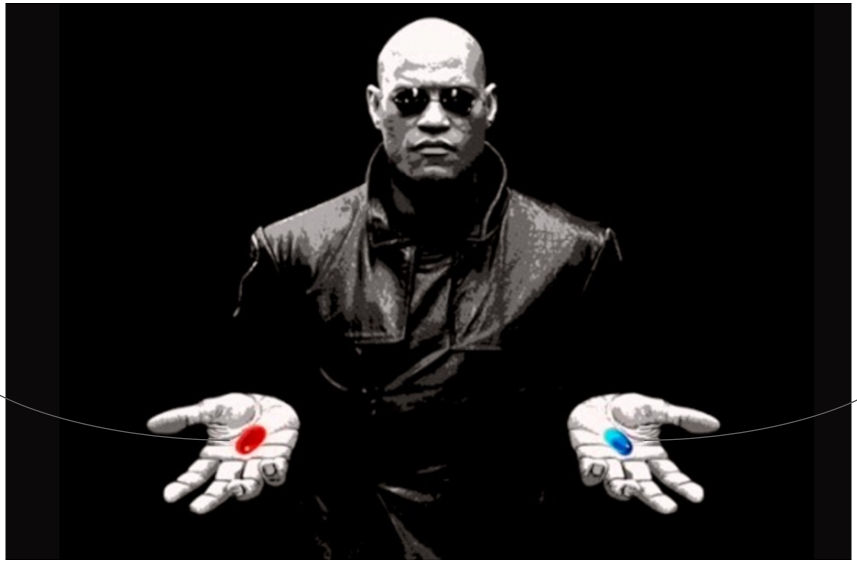
1. **"1" vs. "a":** d(1, X)= 0 + 14.04 = **14.04** < d(a, X)= 0 + 15.23 = 15.23 ☞ **0 → 1**
2. **"2" vs. "a":** d(2, X)= 3 + 12.16 = **15.16** < d(a, X)= 0 + 15.23 = 15.23 ☞ **0 → 1 → 2**
3. **"3" vs. "a":** d(3, X)= 3 + 3 + 10 = 16 > d(a, X)= 0 + 15.23 = **15.23** ☞ **0 → a**
4. **"3" vs. "b":** d(3, X)= 3 + 3 + 9.95 = **15.95** < d(b, X)= 4 + 12.08 = 16.08 ☞ **0 → 1 → 2 → 3**
5. ….

Exercise 1.5c: Solving Problems by Searching (GBF vs. A*) (1/2)

c. If you have to **choose** between using **greedy best first** or **A* search:**

In **which situations** would you use **either one**?

Greedy Best First



A*

Exercise 1.5c: Solving Problems by Searching (GBF vs. A*) (2/2)

Greedy Best First

✓ Less computing intensive
✗ Does not necessarily choose the best solution

A*

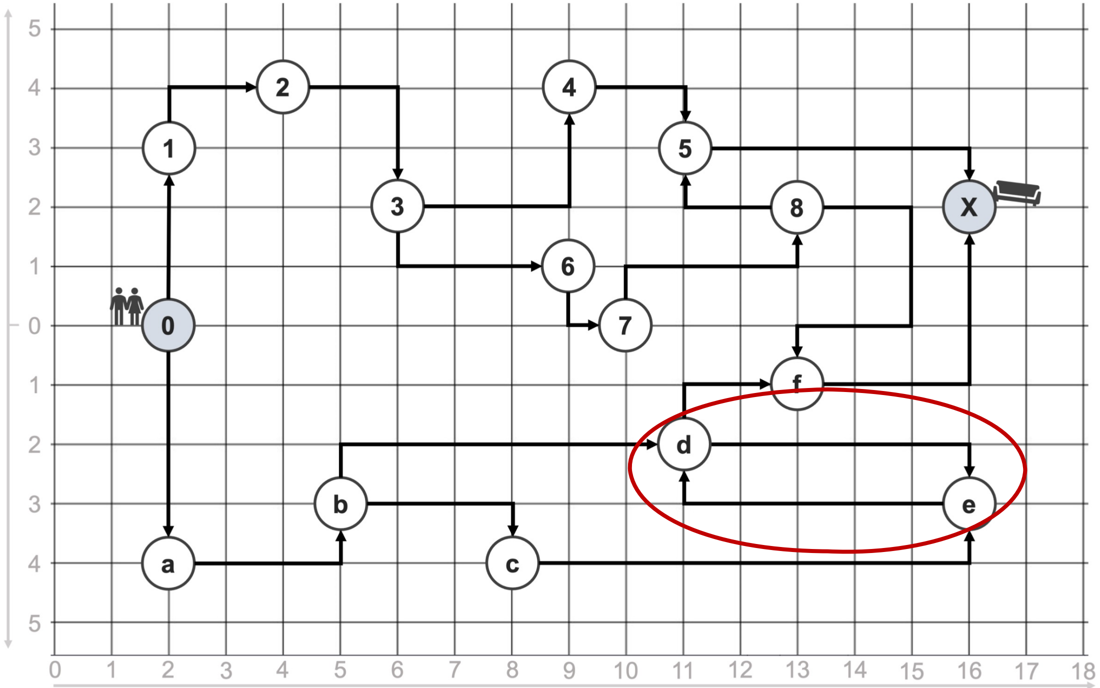
✓ More computing intensive
✗ Determines the optimal solution

Exercise 1.5d: Solving Problems by Searching (GBF vs. A*) (1/2)

d. Right before you start your journey towards the sofa section, you notice the **loop between** section “**d**” and “**e**”.

➢ Is this a problem for you (or your significant other)?

Problem for you



No problem

Exercise 1.5d: Solving Problems by Searching (GBF vs. A*) (2/2)

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Solution

**In this case,
it should not be a problem for anyone!**

(**But note:** there are scenarios in which loops can be a problem!)

Thank You!