Reasoning with Ontologies for Non-Player Character Decision-Making in Games

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PhD Student: Sylvain LAPEYRADE
Supervisors: Christophe REY, Bruno BACHELET, Loïc YON

LIMOS – Clermont Auvergne University, France

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PhD context

Context: Game designers want **possible** “emergent behaviours” for their NPCs

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Why possible?

Emergent behaviours are not **always** desirable:

- Game designers may want to **fully control** player experience
- Emergent behaviours are more likely to be **incoherent**
- Players might want to be able to **predict** NPCs behaviour

Emergent behaviours

Why designers would want emergent behaviours anyway?

- To avoid having to anticipate every possible case
- To enable a more personalised experience for the player
- To be less predictible for the player

Game AI behavioural techniques state of the art[1]

- Ad hoc algorithms (Hard-coded, poor re-usability)
- Finite-State Machines (Hard-coded, poor scaling)
- Behavioural Trees (Hard-coded, poor scaling)
- Utility-based AI (Tuning utilities can be laborious)
- Action Planning (Difficult to use, can be expensive)
- Learning-based AI (Resource intensive, black box)

[1] From reference books in Game AI: Yannakakis and Togelius [2018], Millington [2019] and review article: Simonov et al. [2019]

Is the trend changing?

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Recent projects using logic-based methods

- **Versu** – Evans and Short [2014]
- **MKULTRA** – Horswill [2015]
- **EmbASP** – Calimeri et al. [2018]
- **UnityIIS** – Brännström and Nieves [2021]
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Note: They are not yet adopted by the general industry

PhD proposition

Rule-based systems principles to create emergent behaviours

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Declare facts and rules about the game

- Bob is a man.
- A man is a human.
- Any human can move up, down, left and right.
- Any human can shoot an arrow up, down, left and right.

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Listing 3: The same predicates in Prolog

```
1 man(bob).
2 human(X):- man(X).
3 move(X, Direction):- human(X),
4     member(Direction, [up, down, right, left]).
5 shoot(X, Direction):- human(X),
6     member(Direction, [up, down, right, left]).
```

Ontologies and knowledge inference

Observation: it seems very intuitive to create rules about a game declaratively, as is done in board games

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Whithout stating it explicitly, it can be infered that:

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Conclusion: By simply stating what is true in the world, behaviours not explicitly designed can emerge dynamically

$\Rightarrow$ This means having **planning** and **explicability** is possible!

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Resources available for NPCs AI can be very limited

Fix: The whole behaviour generation process must be optimised, e.g. with rule pruning, multi-threading, etc.

How to make inferences? Use inference engine like Prolog

We chose SWI-Prolog beacause:

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Well-Founded Semantics (WFS) – Van Gelder et al. [1991]

- What is unknown is no longer assumed to be *false* (NAF)
- In the WFS a proposition can be *true*, *false* or *undefined*
- *Undefined* values are used for uncertainty and contradiction

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No entirely satisfying solution... so we coded our own interface:
`github.com/sylvainlapeyrade/mqi_csharp`

Global architecture

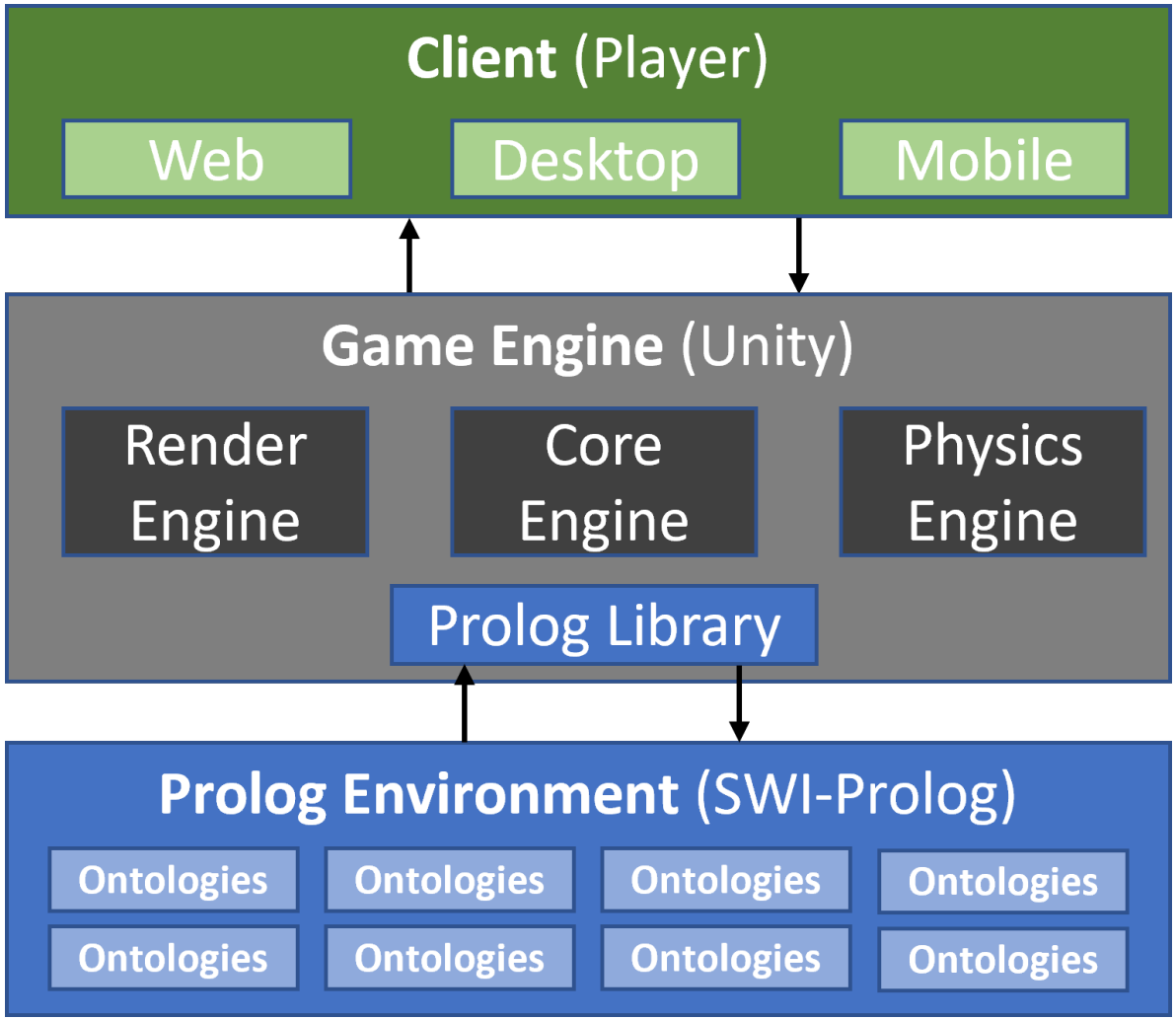
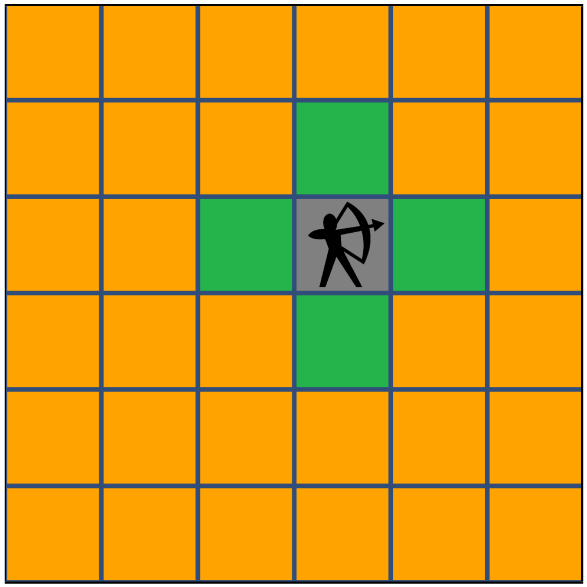
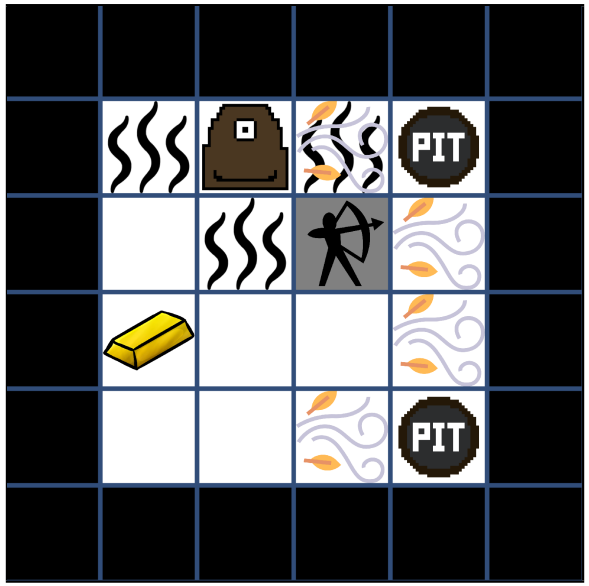


Figure 1: Architecture of the integration of a logic programming environment in a game engine

Prototype: Wumpus World



(a) View of the Agent



(b) View of the world

Principle of Wumpus World

An agent explores a cave, finds the gold and leaves without dying.

Example extended from Russell and Norvig [2021], and Warren [1999].

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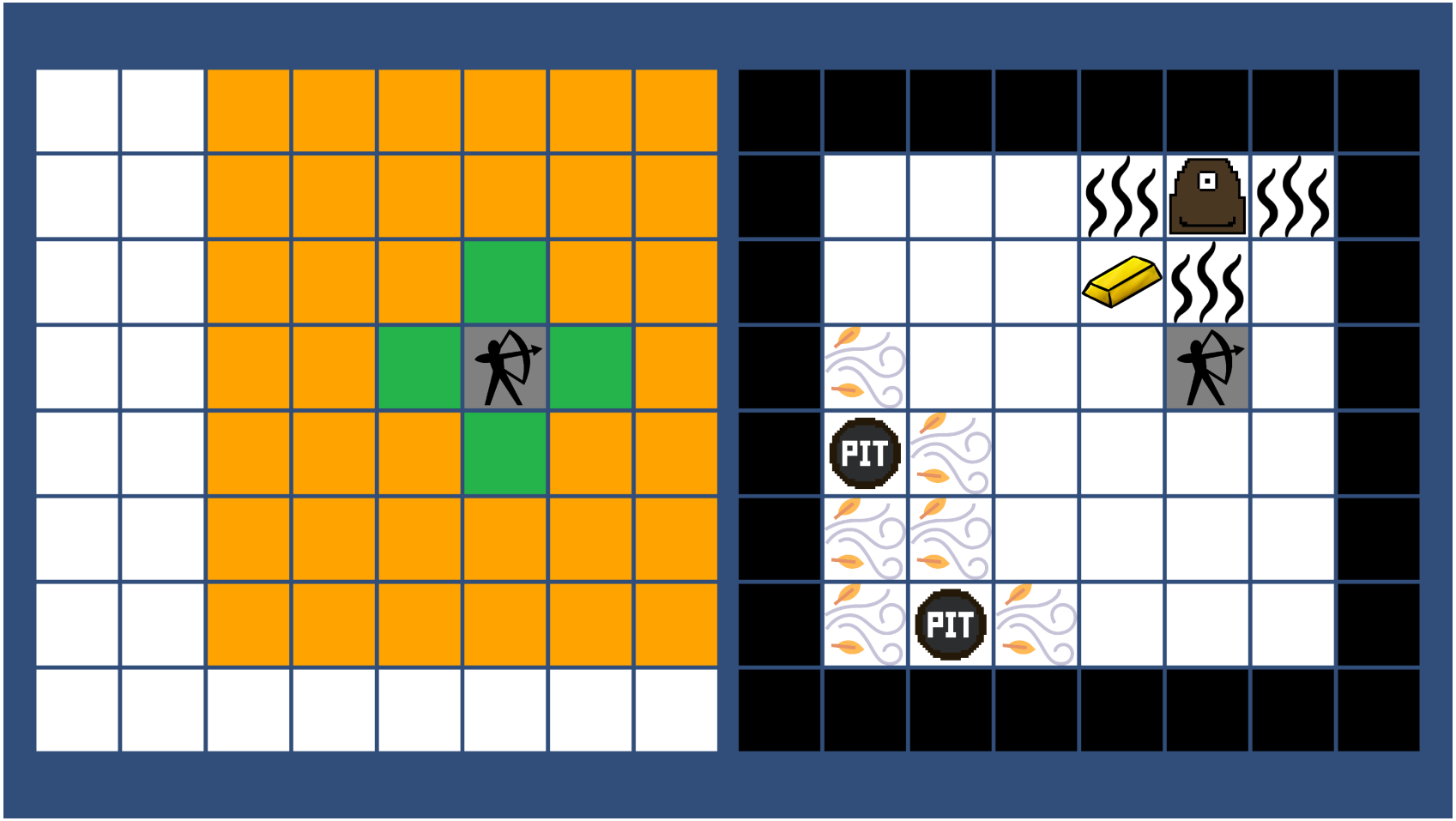

Figure 3: Turn 1.

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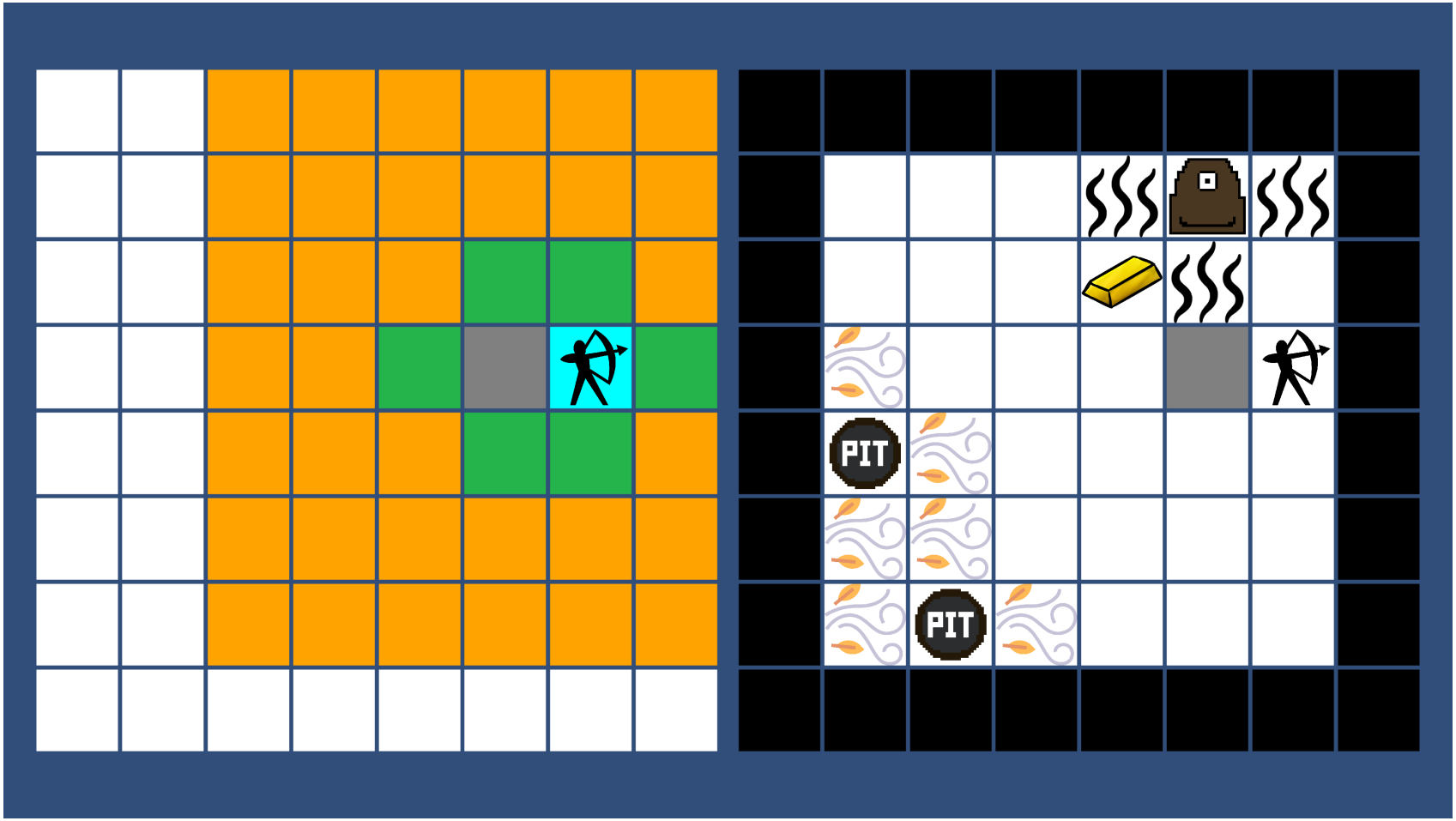

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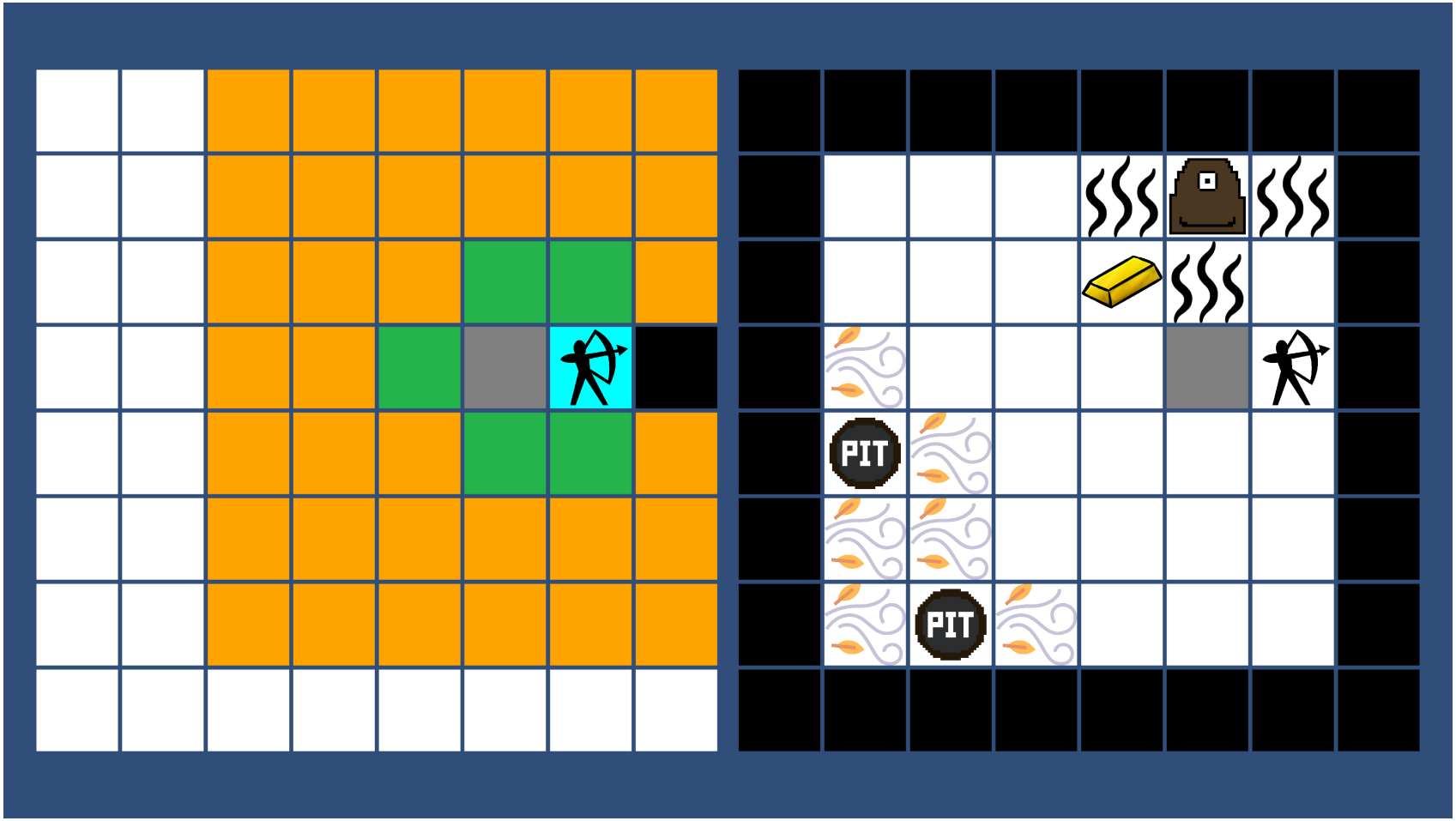

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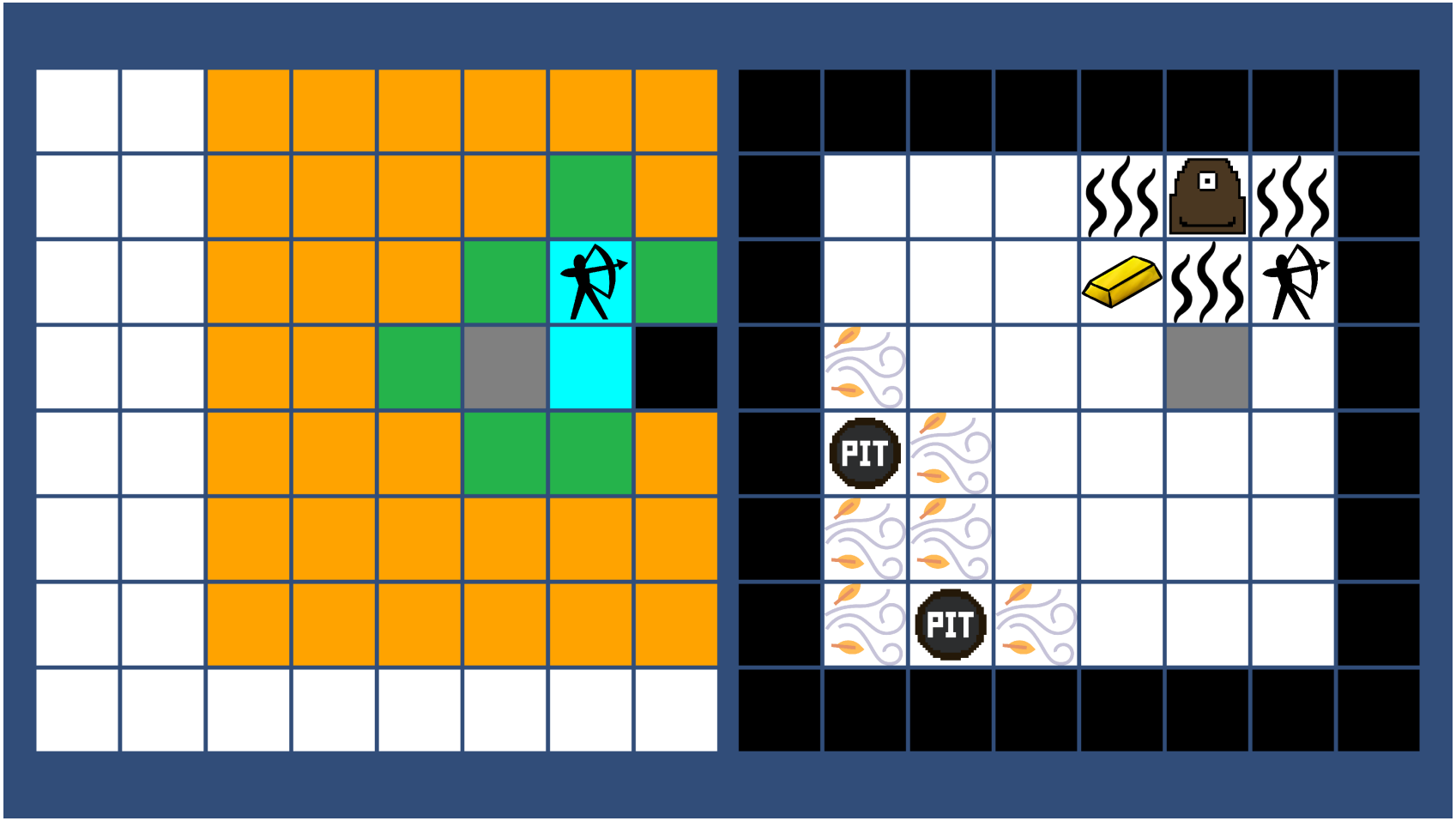

Figure 3: Turn 4.

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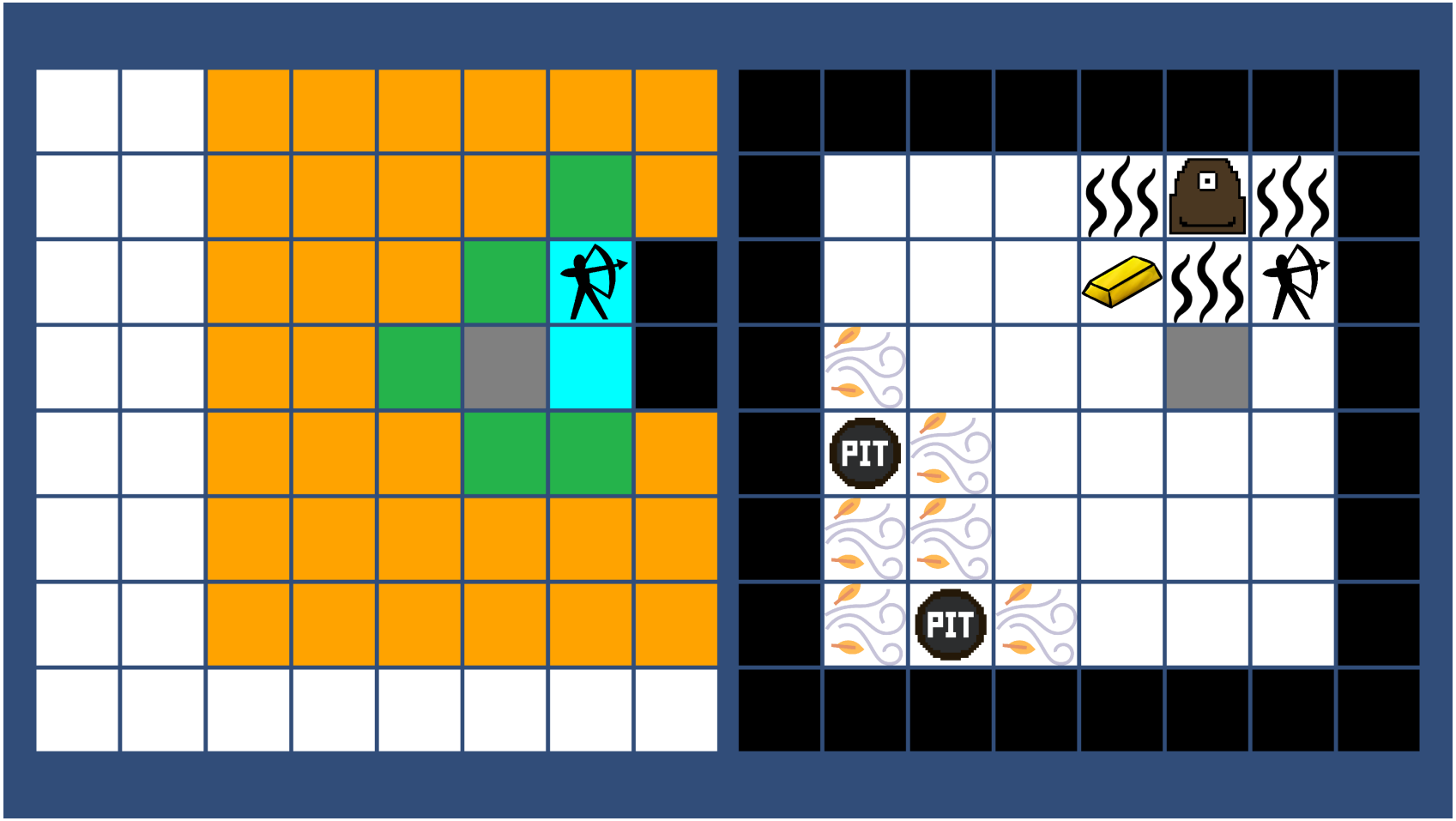

Figure 3: Turn 5.

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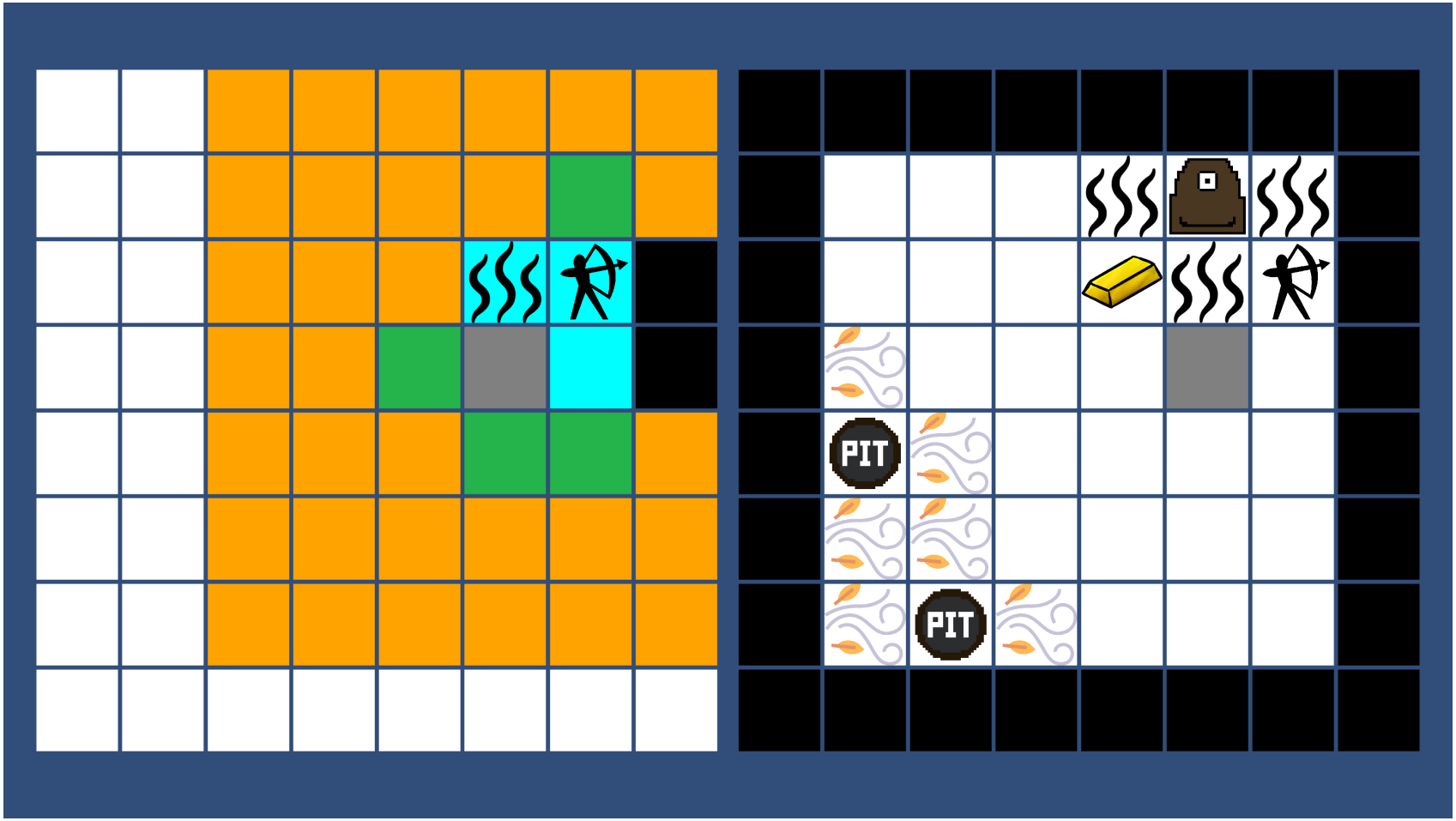

Figure 3: Turn 6.

Prototype: Wumpus World example

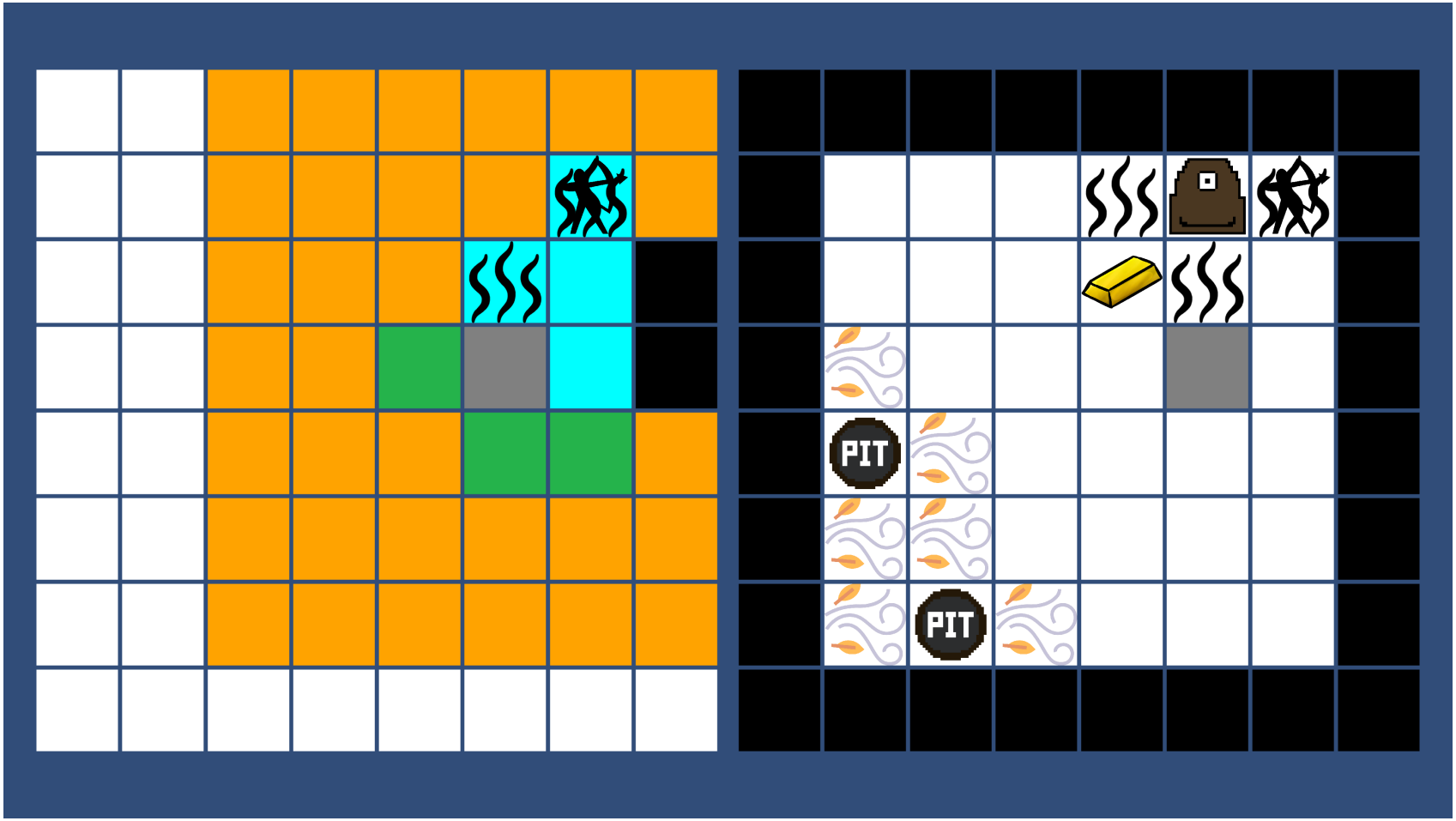

Figure 3: Turn 7.

Prototype: Wumpus World example

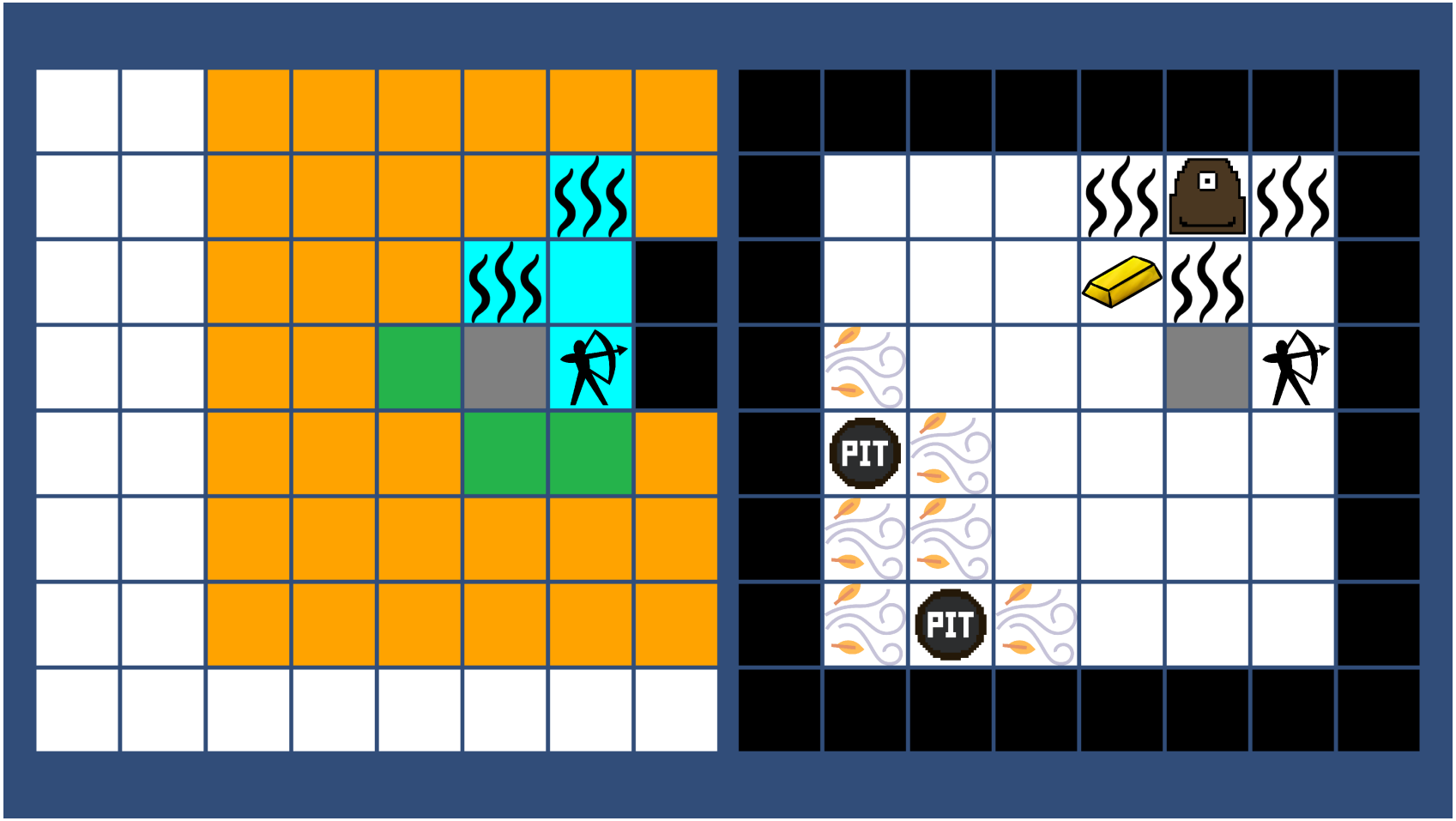

Figure 3: Turn 8.

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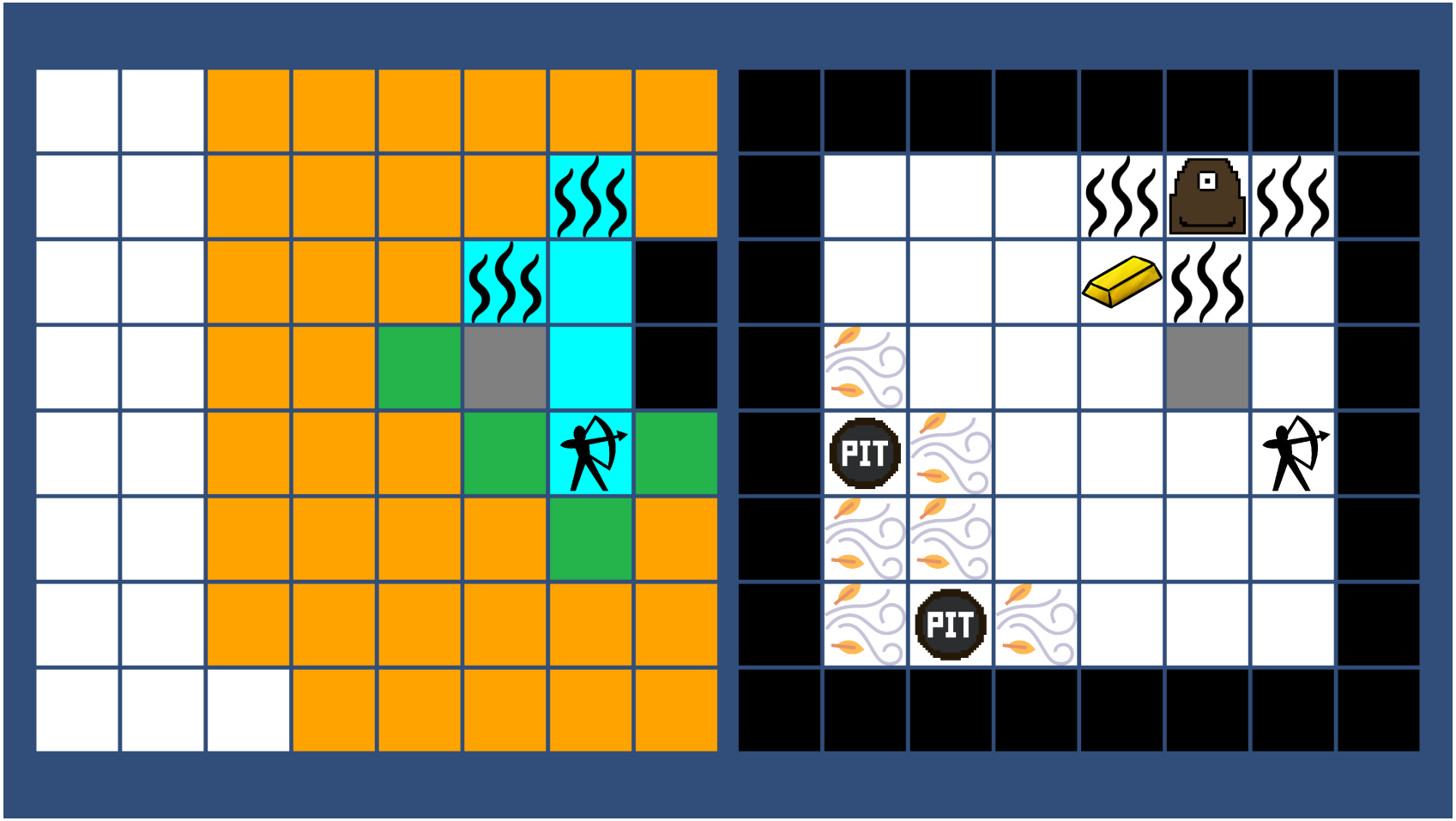

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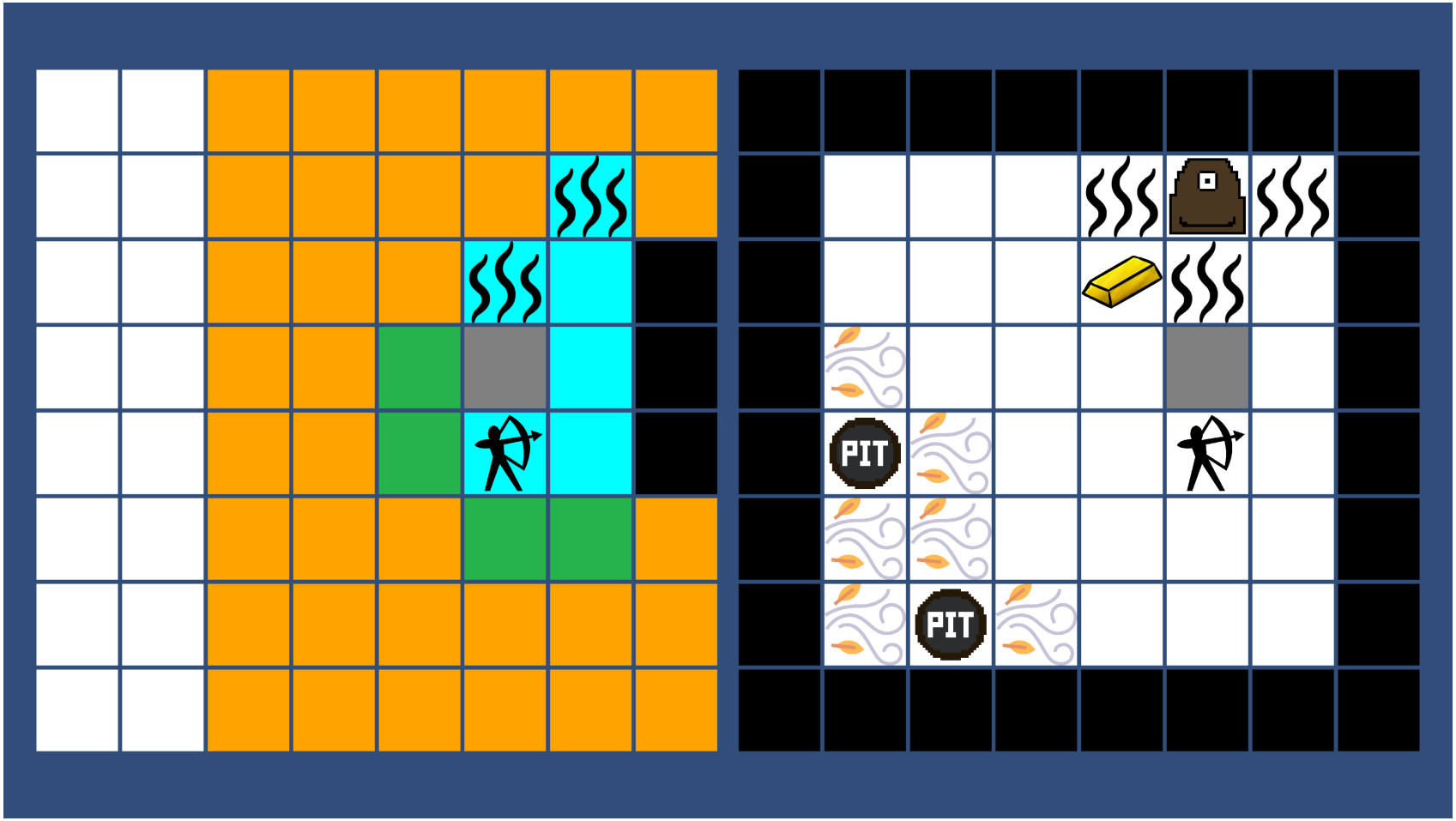

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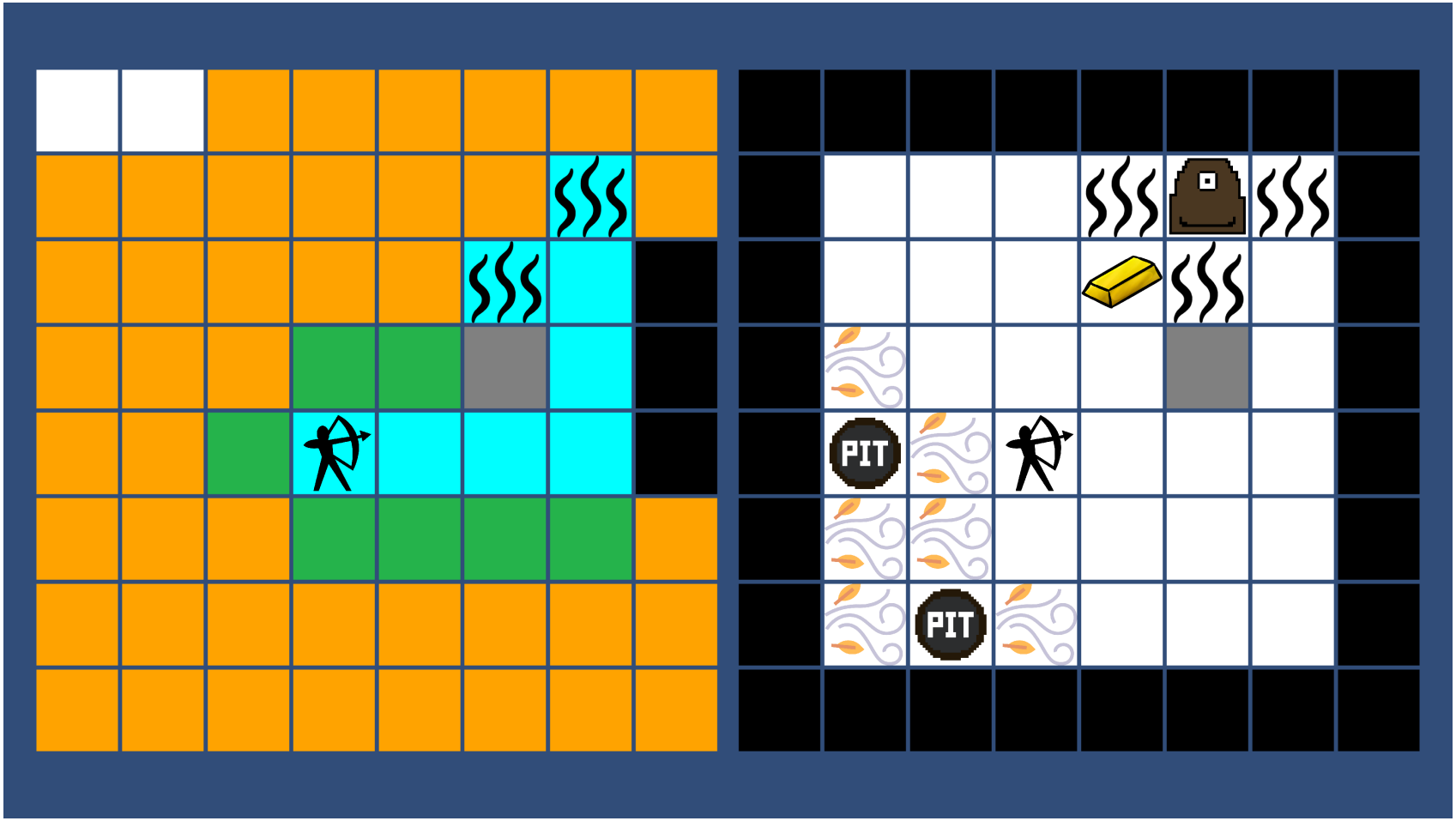

Figure 3: Turn 11.

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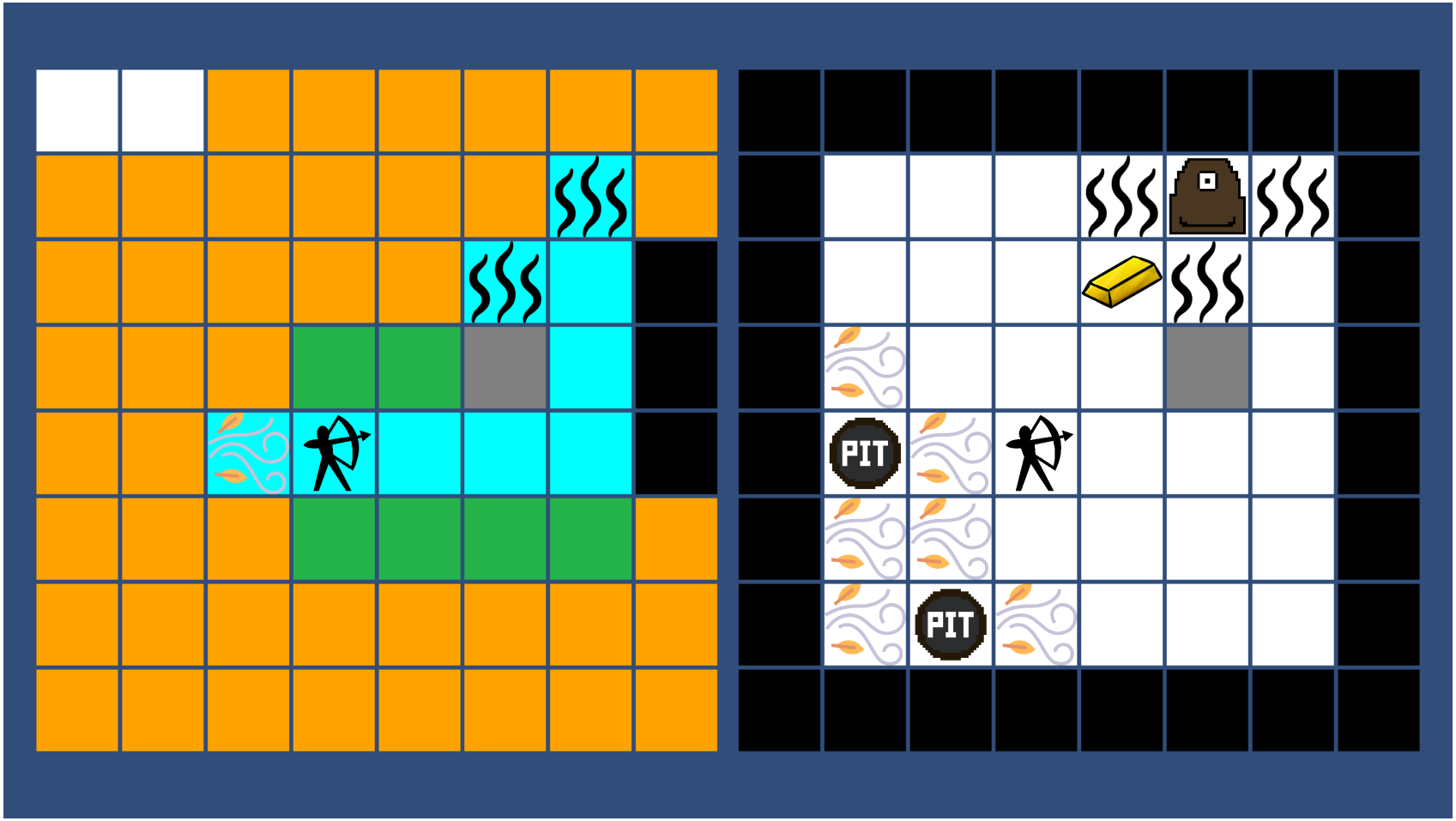

Figure 3: Turn 12.

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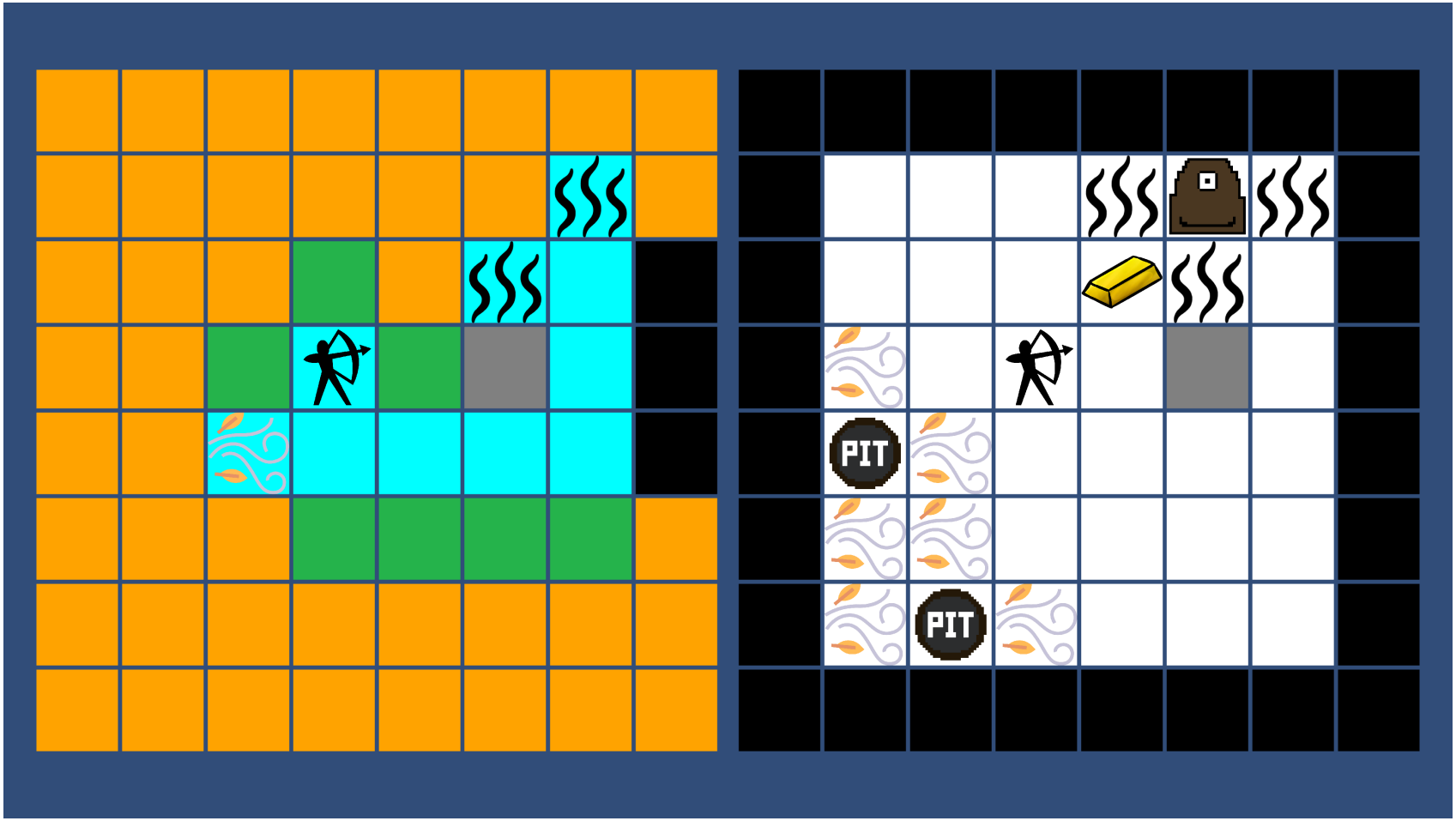

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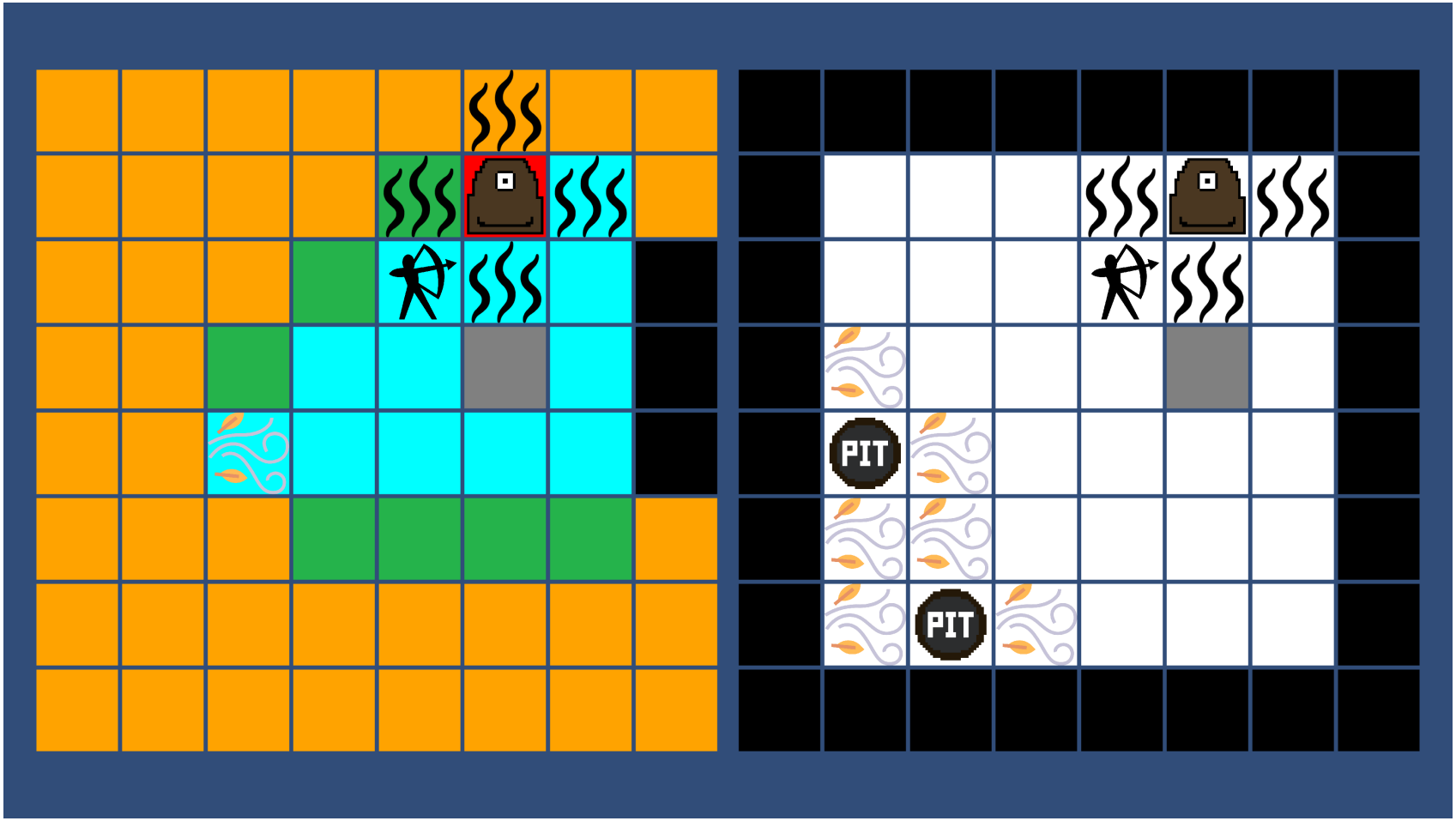

Figure 3: Turn 14.

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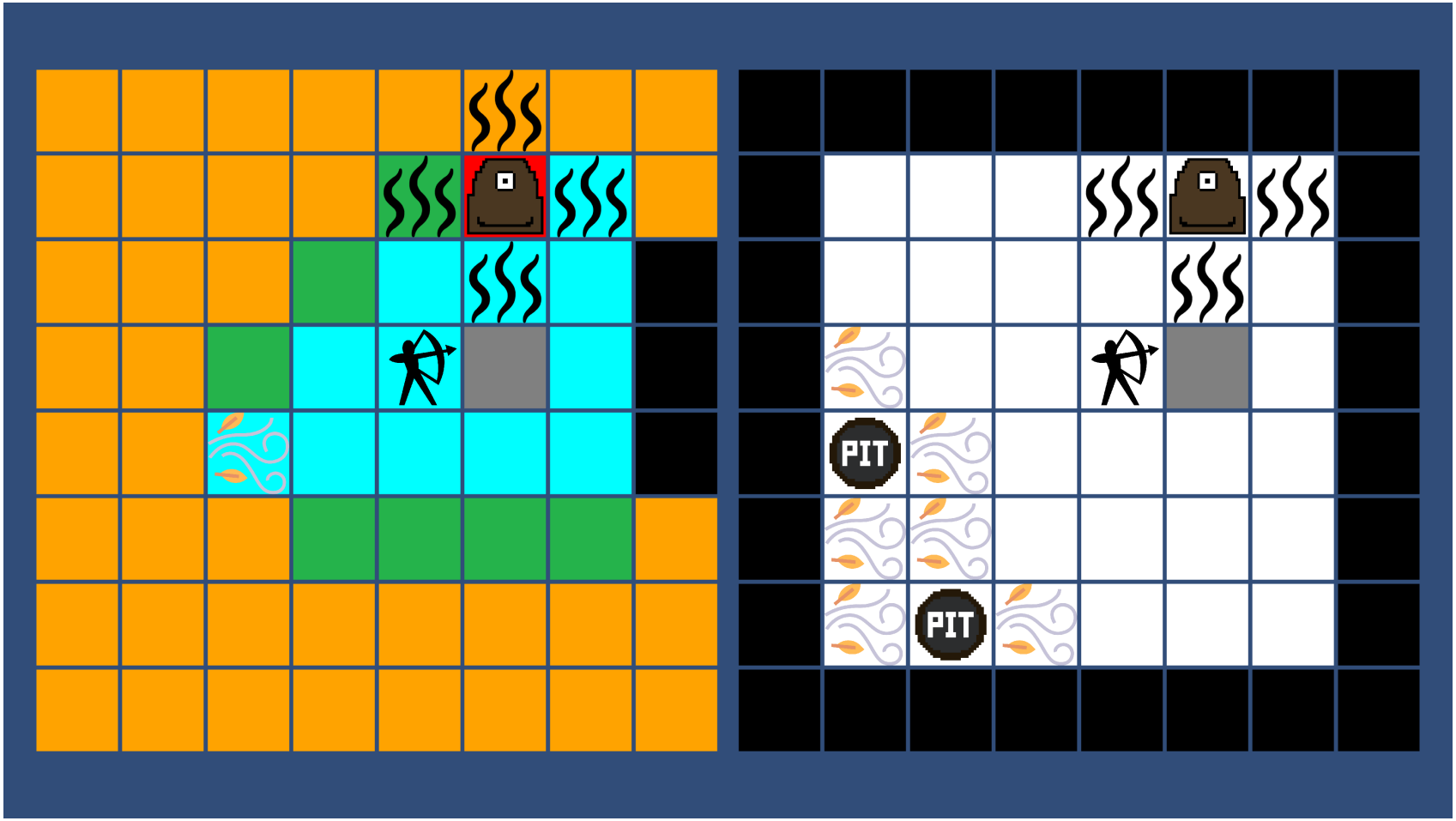

Figure 3: Turn 15.

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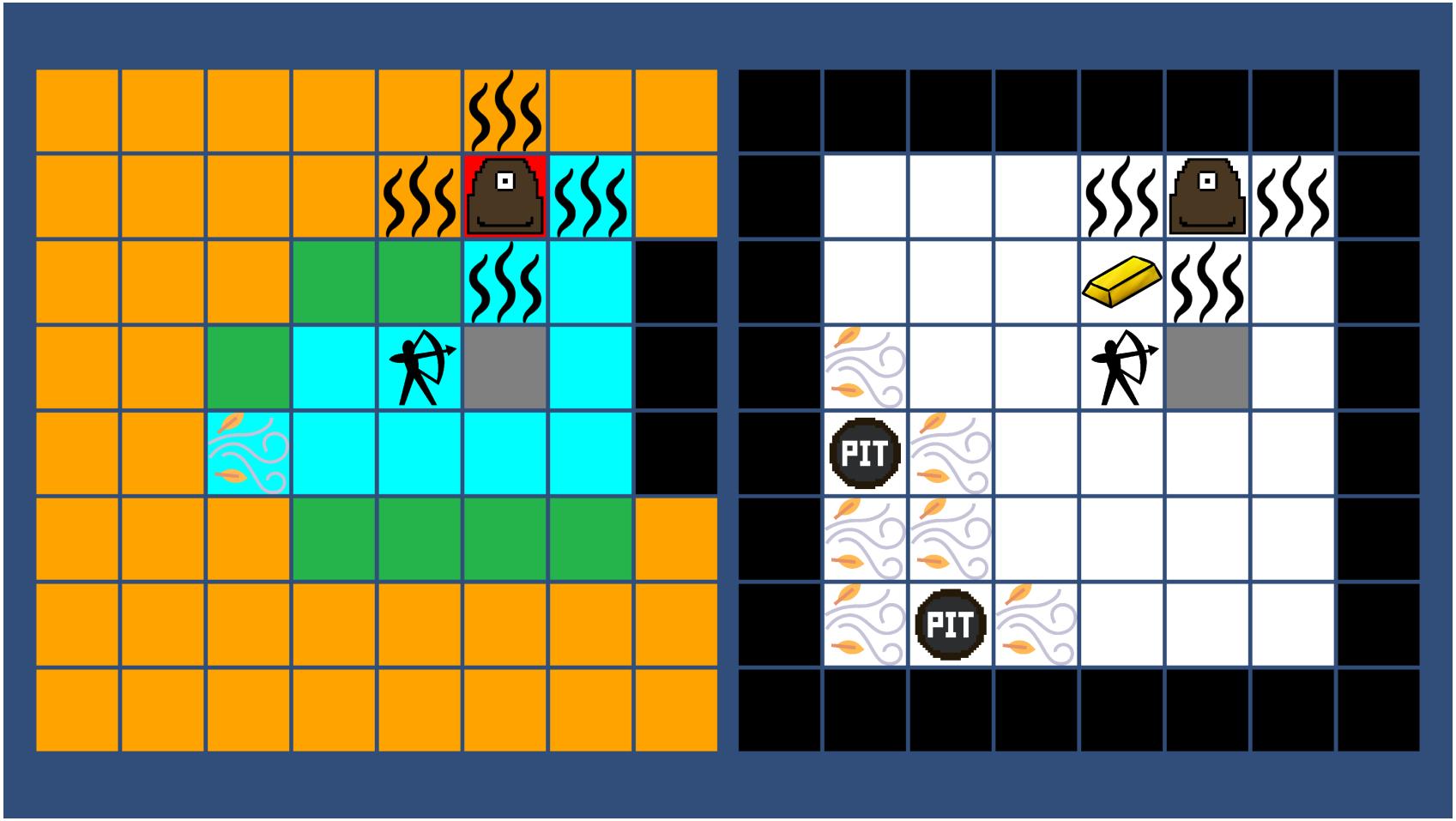
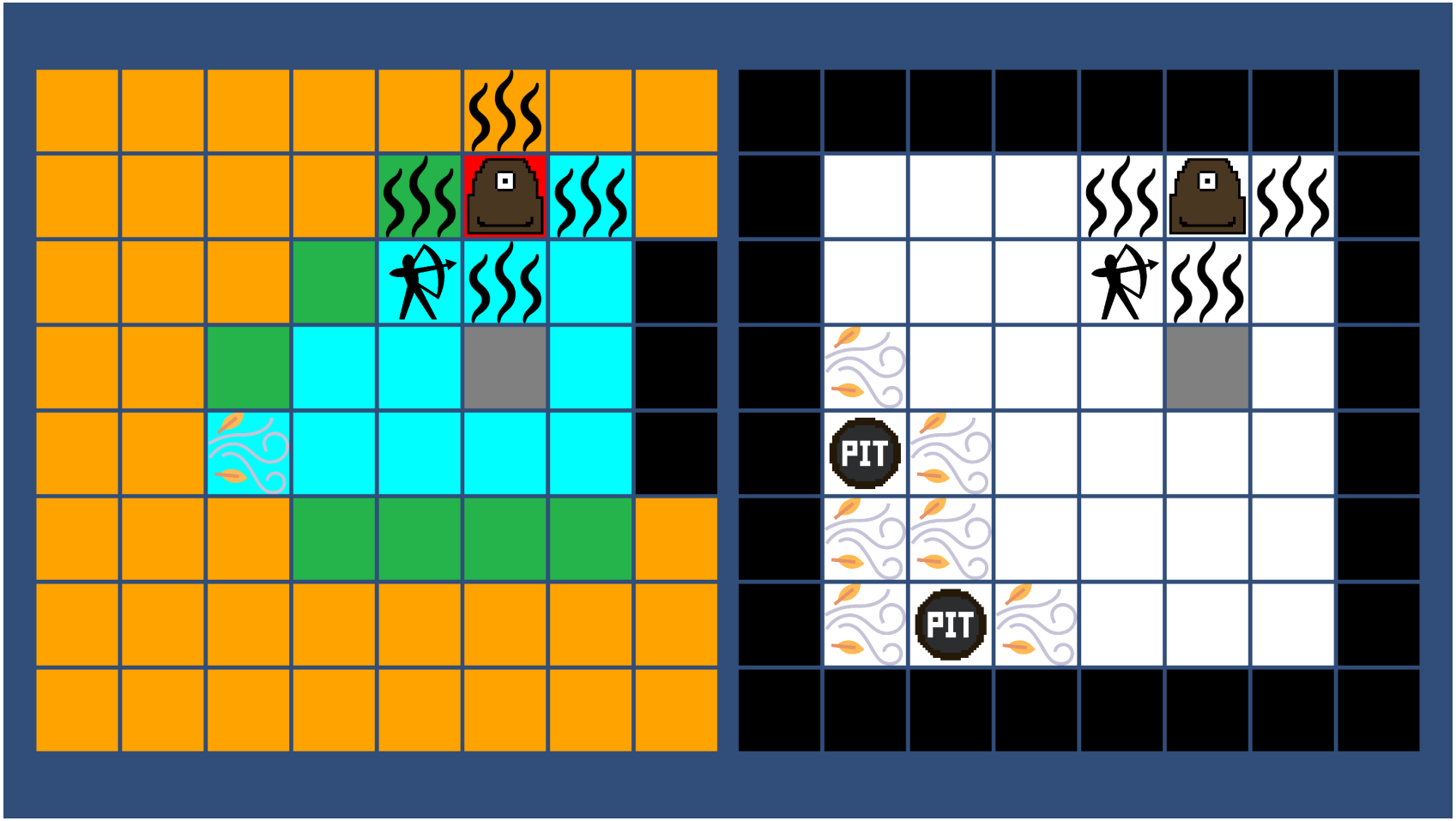


Figure 3: Turn 16.

Prototype: Wumpus World example



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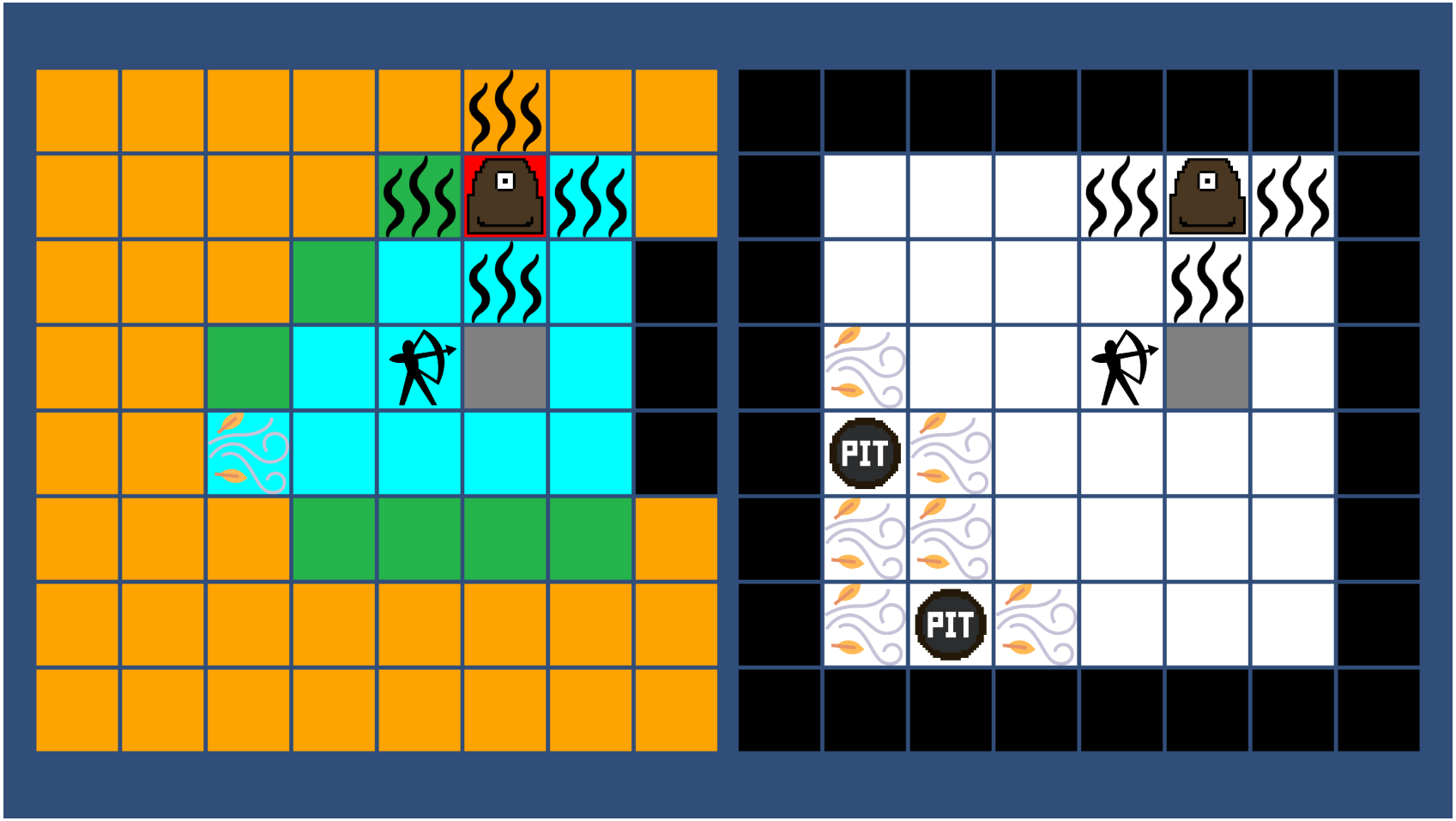
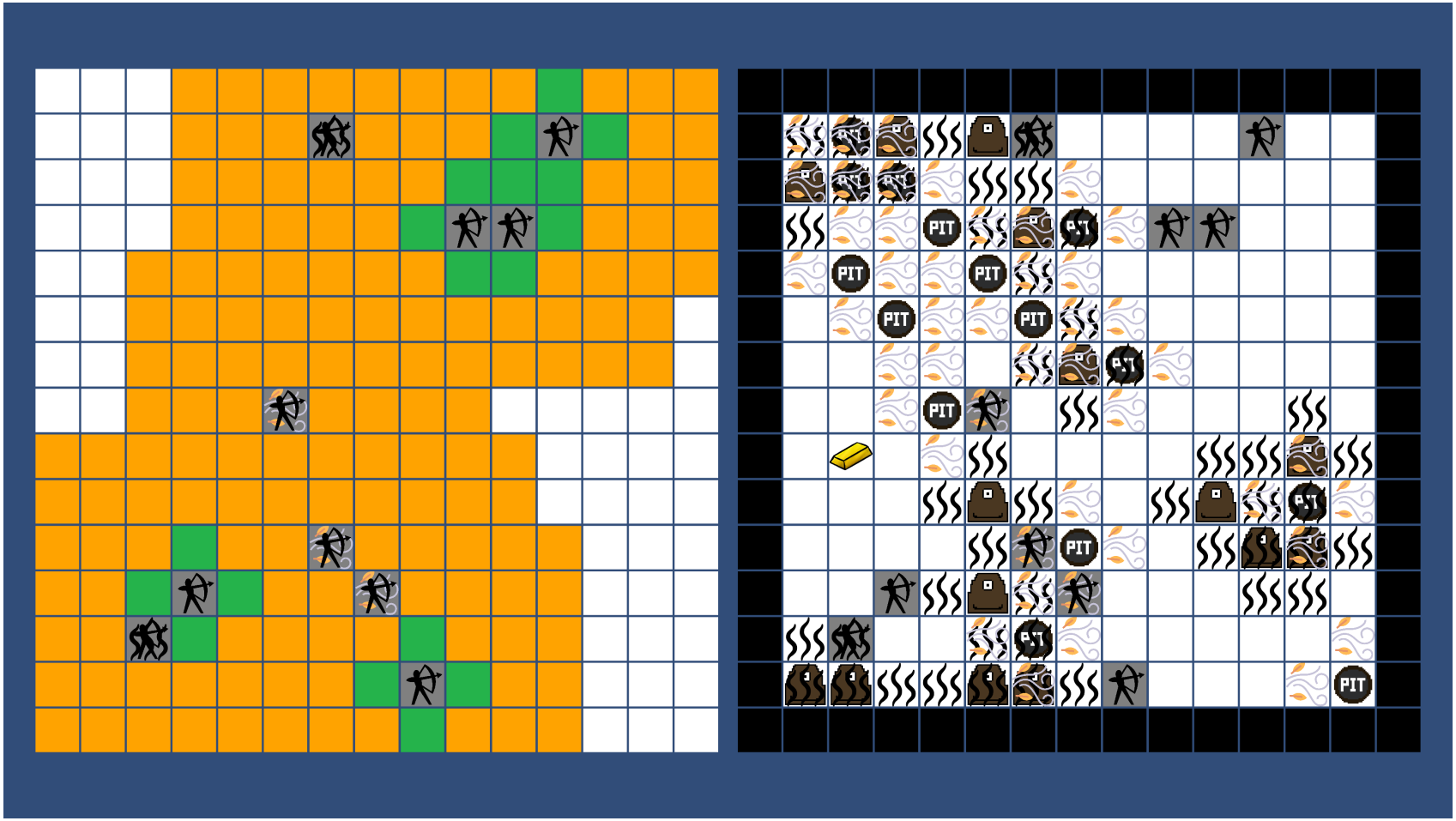


Figure 3: Turn 18.

Prototype: Wumpus World Multi-agent example



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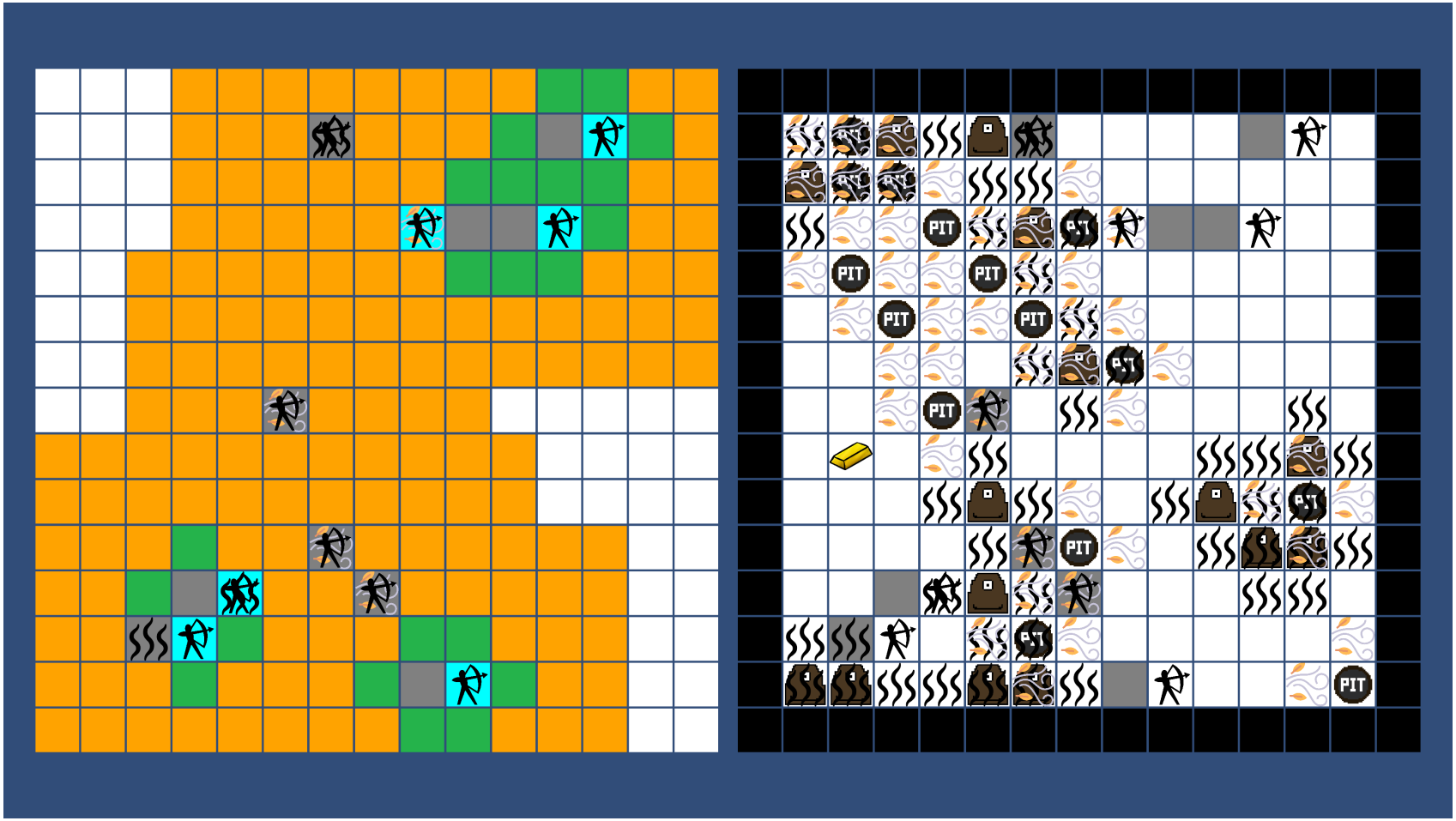

Figure 4: Turn 2.

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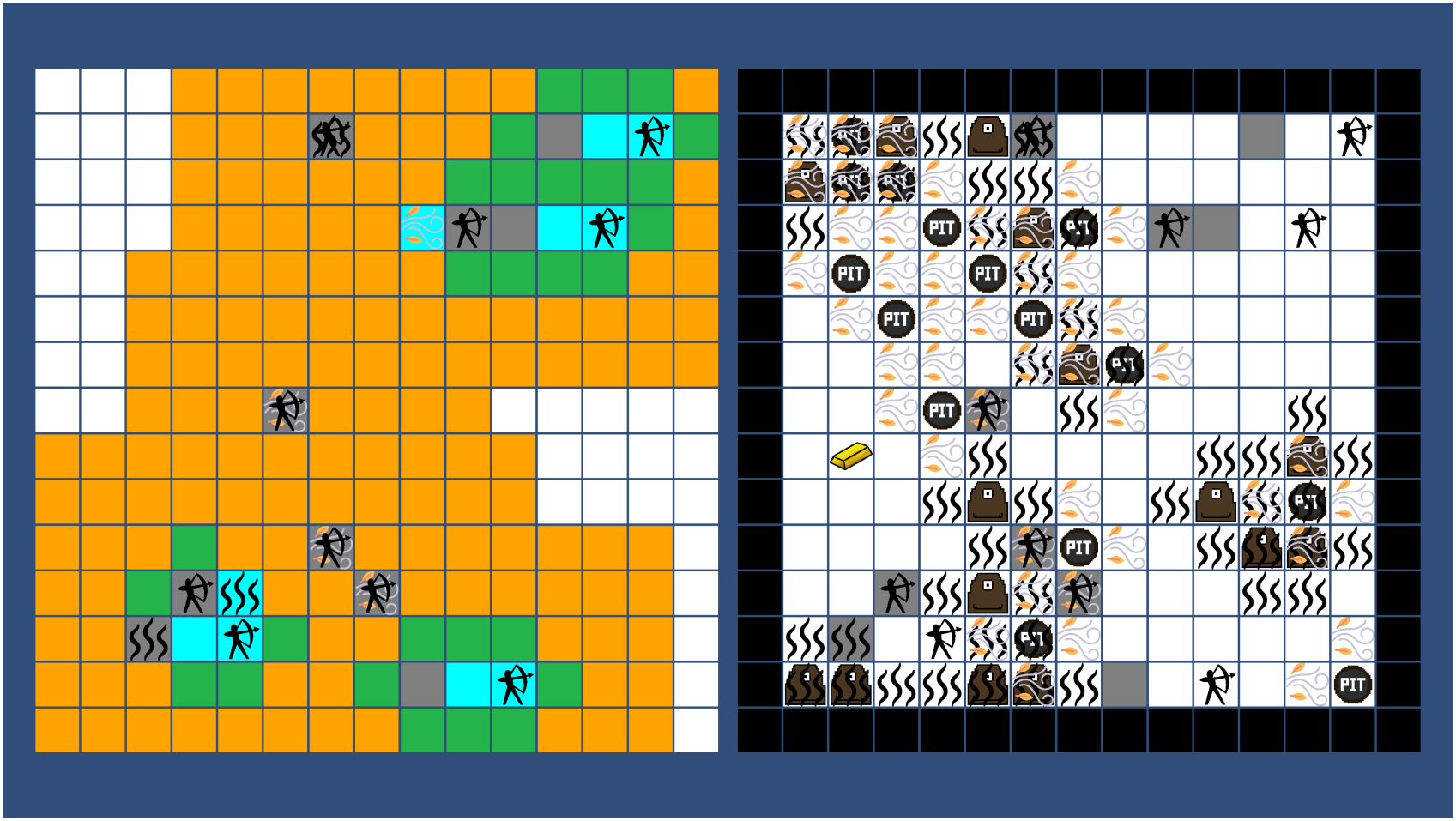

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Thank You!

sylvain.lapeyrade@uca.fr

References I

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