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

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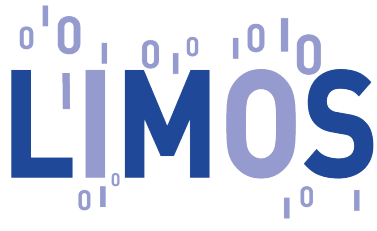


**Context**: The strategic reasoning of virtual agents is often poor

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## Game AI behavioural techniques state of the art[1]

- Ad hoc algorithms (Hard-coded, poor reusability)
- Finite-State Machines (Hard-coded, poor scaling)
- Behavioural Trees (Hard-coded, poor scaling)
- Utility-based AI (Tuning utilities can be laborious)
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**Obversation**: Logic-based methods are almost absent from SOTA

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Declarative logic programming helps intuitive rules representation:

## Transformation of a game rule

From our game prototype: "A **human** in the same room as a **monster** or a **pit**, dies"

Listing 1: The same rule in Prolog

```
1 dies(Agent):-
2     human(Agent),
3     human(X, Y),
4     (
5         monster(X, Y) ; pit(X, Y)
6     ).
```

1. $X$ is an element if $X$ is an object or a being
2. $X$ is a being if $X$ is an animal or a monster
3. $X$ is a monster if $X$ is a dragon
4. $X$ is an animal if $X$ is a dog

Listing 2: Simple Ontology in Prolog

```
1 element(X):- object(X). %1
2 element(X):- being(X). %1
3
4 being(X):- animal(X). %2
5 being(X):- monster(X). %2
6
7 monster(X):- dragon(X). %3
8 animal(X) :- dog(X). %4
```

# Stable Model Semantics

For representing the agents knowledge, we can use the *Stable Model Semantics* from Gelfond and Lifschitz [1988] with Negation as Failure (NAF):

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## Truth Table

| $p$ | $q$ | $r$ | $s$ |
|---|---|---|---|
| True | False | False | True |

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But how do we represent represent partial or negative knowledge?

# Well-Founded Semantics

- The *Well-Founded Semantics* (WFS) from Van Gelder et al. [1991] is a 3-valued version of the *Stable Model Semantics*
- In the WFS a proposition can be *true*, *false* or *undefined*
- *Undefined* values are used for ignorance or contradictory info

Listing 3: Use of the Well-Founded Semantics in SWI-Prolog

```
1 is_true(Atom):- call_delays(Atom, true).
2 is_false(Atom):- \+ Atom.
3 is_undefined(Atom):-
4     call_delays(Atom, Condition),
5     Condition \== true.
```

# WFS with Partial Knowledge

## With partial knowledge of the truth values of atoms

- Propositions with *true* atoms are *true*
- Propositions with *false* atoms are *false*
- If $p$ is *true* then $\neg p$ is *false*
- Conversely, if $p$ is *false* then $\neg p$ is *true*

## Assume *undefined* propositions *false* and see what holds

- Any proposition symbols not in the resulting set must be *false*
- We can then make them false in the well-founded model
- This operation can be repeated until no value changes

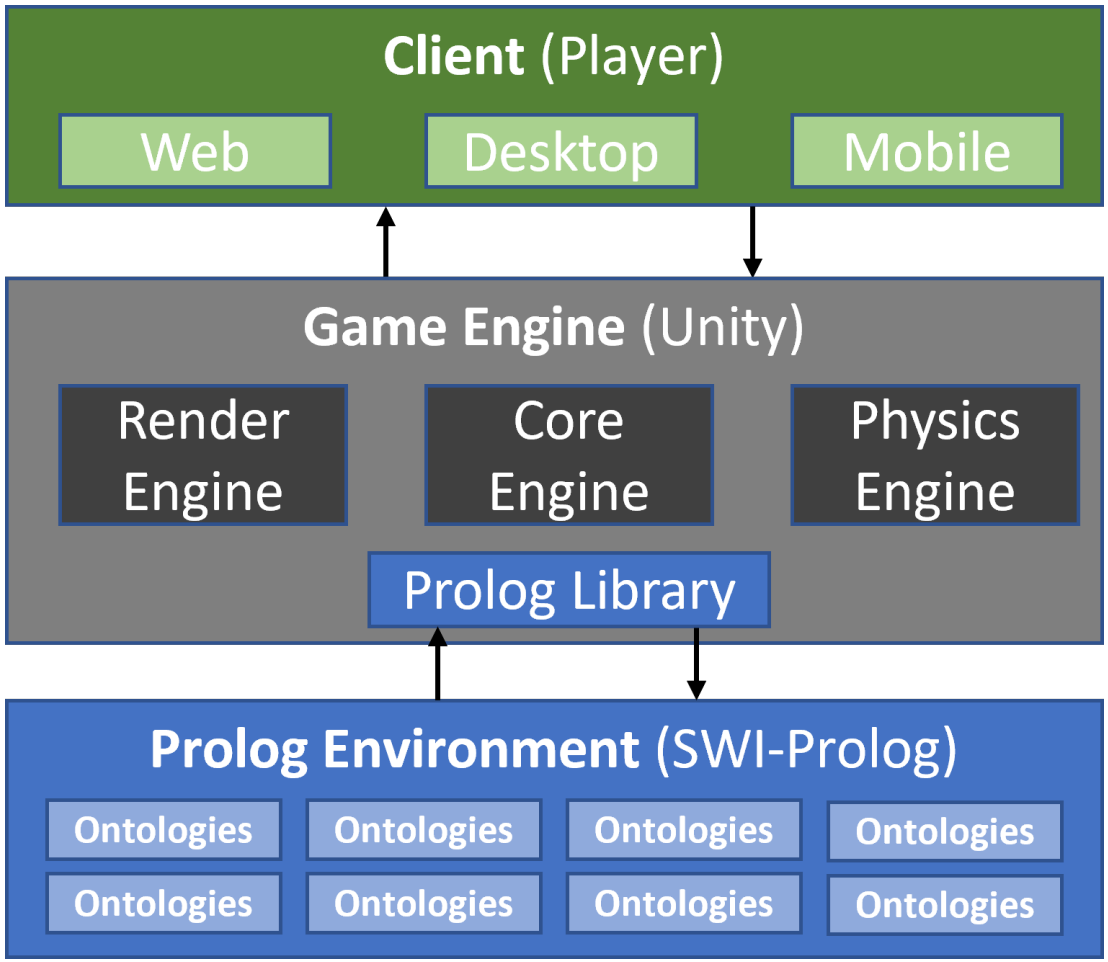
# WFS Example

Listing 4: Representing False Facts in SWI-Prolog

```
1  monster(X,Y):-
2      pos_monster(X,Y),
3      tnot(neg_monster(X,Y)).
4
5  monster(X,Y):- % Positive Contradiction
6      pos_monster(X,Y),
7      neg_monster(X,Y),
8      tnot(monster(X,Y)).
9
10 monster(X,Y):- % Negative Contradiction
11     tnot(pos_monster(X,Y)),
12     tnot(neg_monster(X,Y)),
13     tnot(monster(X,Y)).
```

*Tnot* denotes *Tabled Negation*, it checks if there is an atom whose truth cannot be proven without making a call to a non-ground negative literal (i.e. floundering)

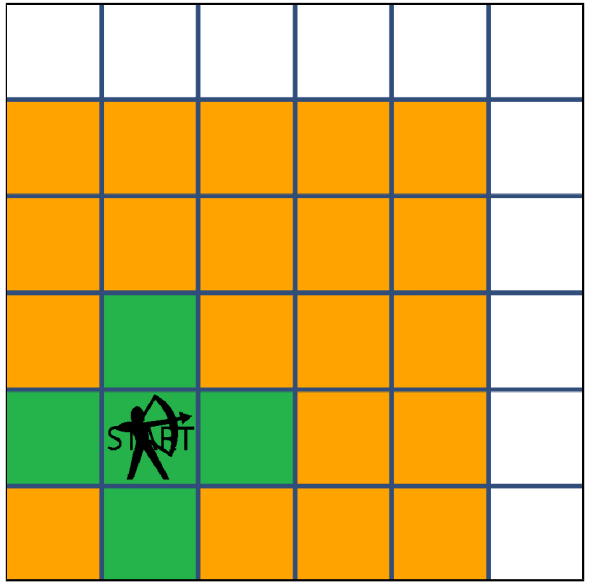
# Global Architecture




Architecture of the integration of a logic programming environment in a game engine

# Prototype: Wumpus World[2]


(a) View of the world




(b) View of the Agent

## Principle of Wumpus World

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

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

# Small Example of a Wumpus World Game Situation

Listing 5: Human agent knowledge of the world

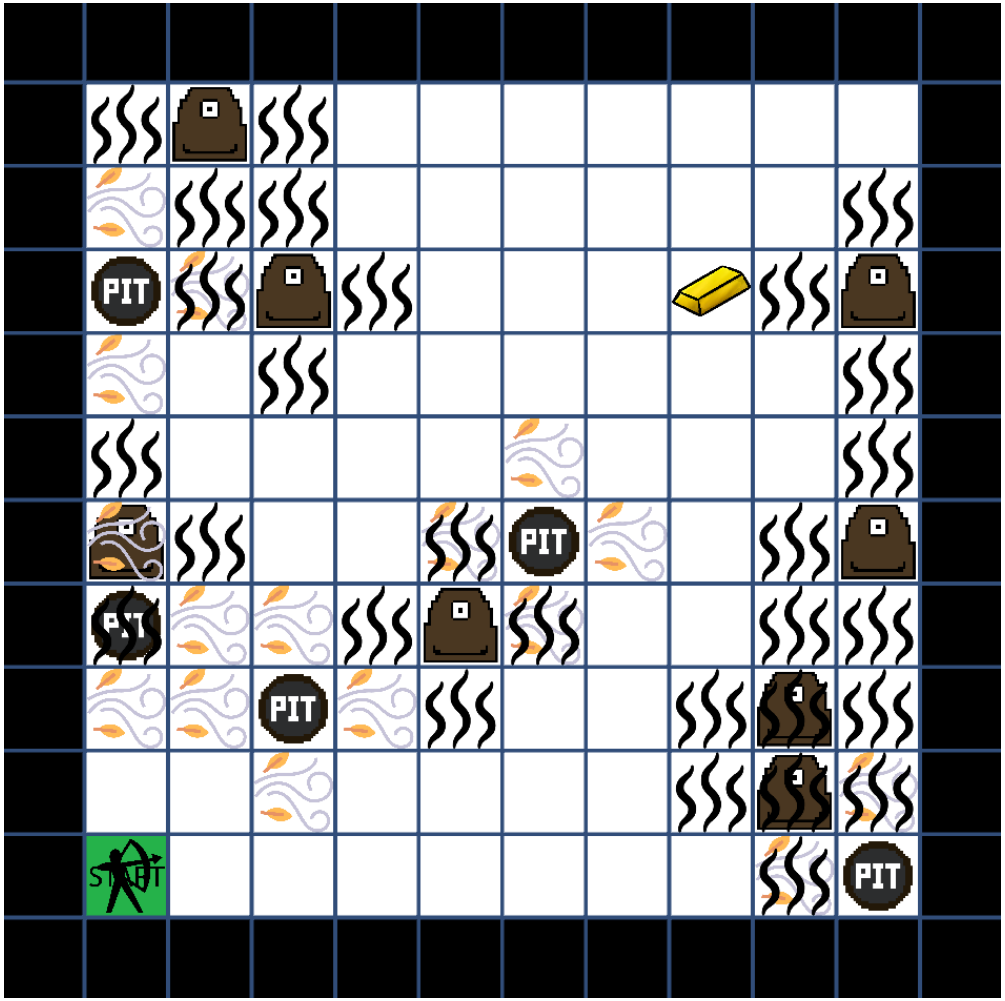
```
visited(1, 1). visited(1, 2). visited(2, 1).
visited(2, 2). stench(2, 2).

safe(X, Y):- tnot(monster(X, Y)).
safe(X, Y):- tnot(pit(X, Y)).
safe(X, Y):- visited(X, Y).
safe(X, Y):- neighbor(X, Y, X2, Y2),
             visited(X2, Y2),
             no_breeze(X2, Y2),
             no_stench(X2, Y2).
```

Listing 6: Prolog query for monster given new knowledge

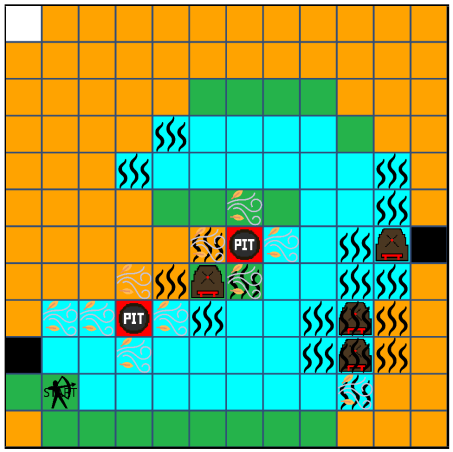
```
?- monster(3, 2).
true.
```

# Adding Complexity




A more complex configuration of the Wumpus World game

# Introducing Behaviours




(a) Default behaviour

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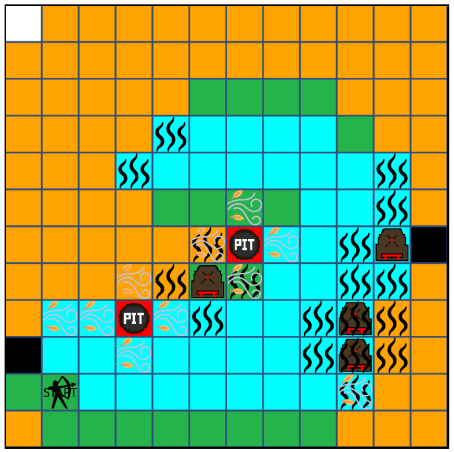


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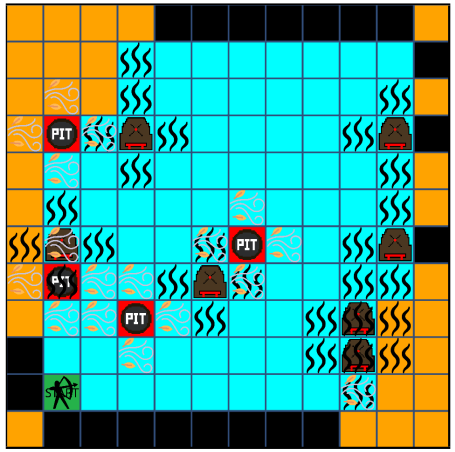


(b) Explorer behaviour

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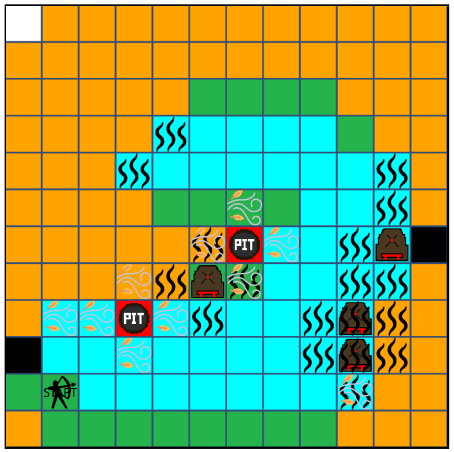


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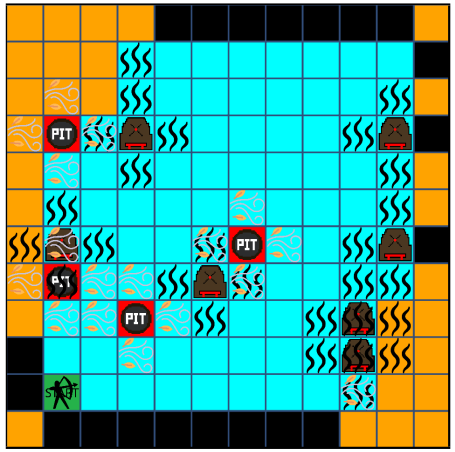


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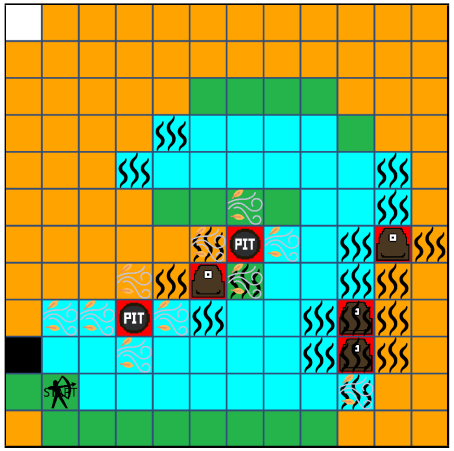


(c) Pacifist behaviour

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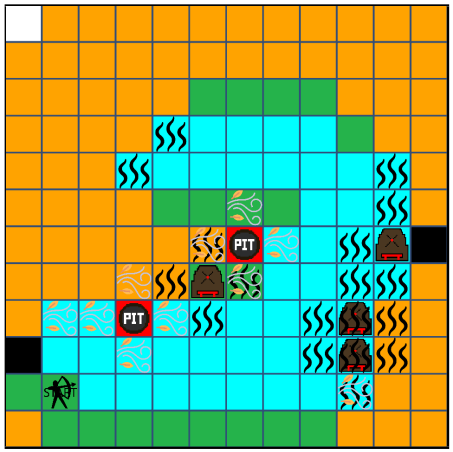


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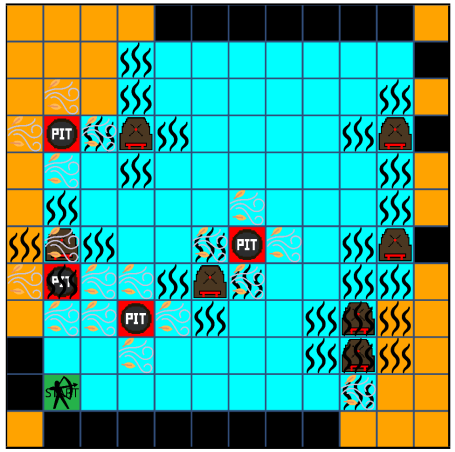


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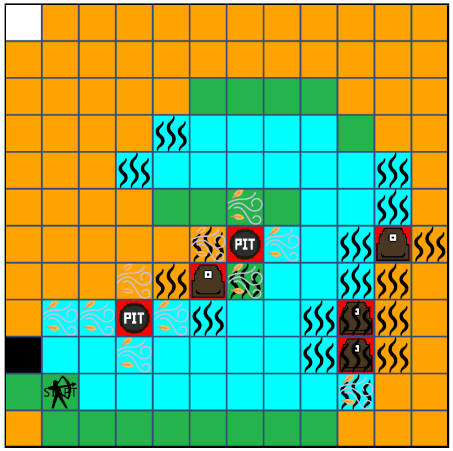


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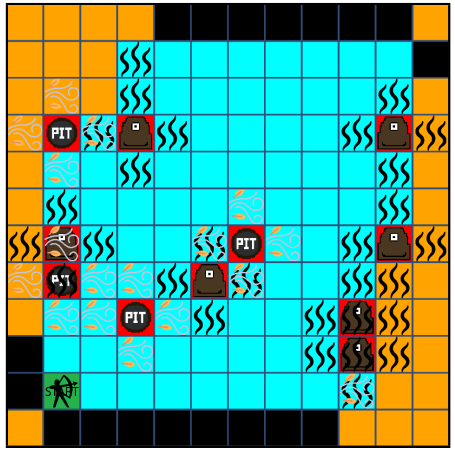


(d) Pacifist AND Explorer behaviour

# Current and Future Works

## Current work

- Improve the prototype to enable even more complex behaviour
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# Thank You!

# References I


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