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

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

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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)
- Action Planning (Difficult to use, can be expensive)
- Learning-based AI (Resource intensive, black box)

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Obversation: Logic-based methods are almost absent from SOTA

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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]
- **VEsNA**, Gatti and Mascardi [2022]
- **ThinkEngine**, Angilica et al. [2022]

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Obversation: This is not yet adopted by the general industry.

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     location(Agent, [X, Y]),
3     (
4         location(pit, [X, Y]) ;
5         location(monster, [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
```

Representing Uncertainty

The *Well-Founded Semantics* (WFS) from Van Gelder et al. [1991] is a 3-valued version of the *Stable Model Semantics* from Gelfond and Lifschitz [1988] which uses *Negation as Failure (NAF)*.

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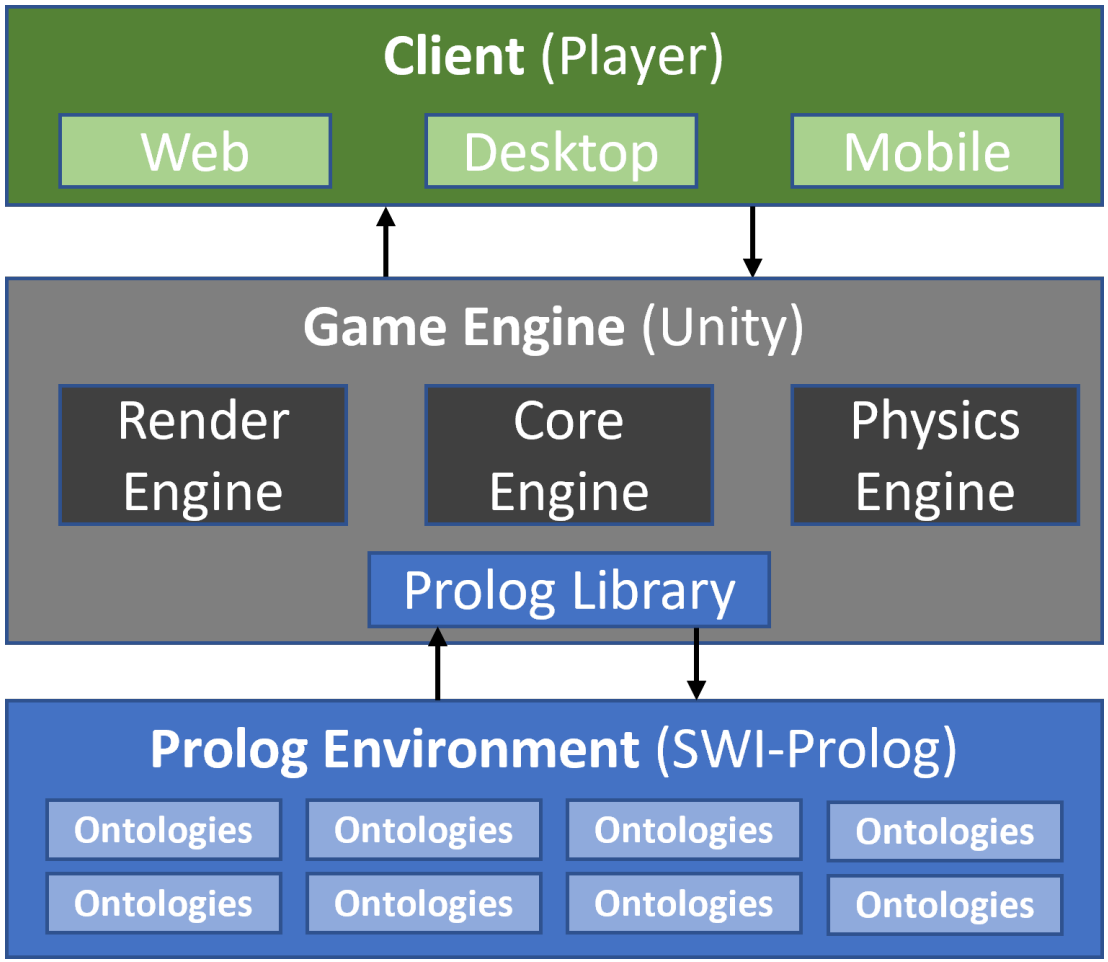
Listing 5: Use of the Well-Founded Semantics in SWI-Prolog

```
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.
```

Global Architecture



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

Interface between Prolog & Game Engine

Connecting Prolog to Unity seems like a recurring endeavour:

- **SwiPlCs** – "official" SWI-Prolog interface, *last updated 2013*
  `github.com/SWI-Prolog/contrib-swiplcs`
- **UnityProlog** – Ian Horswill, *last updated 2017*
  `github.com/ianhorswill/UnityProlog`
- **BackTraQ** – *"Prolog like", last updated 2019*
  `github.com/FacticiusVir/BacktraQ`
- **Yield Prolog** – *"Prolog like", last updated 2019*
  `sourceforge.net/projects/yieldprolog`
- **CSharpProlog** – J.Pool & J.Sakamoto, *last updated 2020*
  `github.com/jsakamoto/CSharpProlog`
- **Pengines.Client** – *F# alternative, last updated 2021(!)*
  `github.com/ninjarobot/Pengines.Client`

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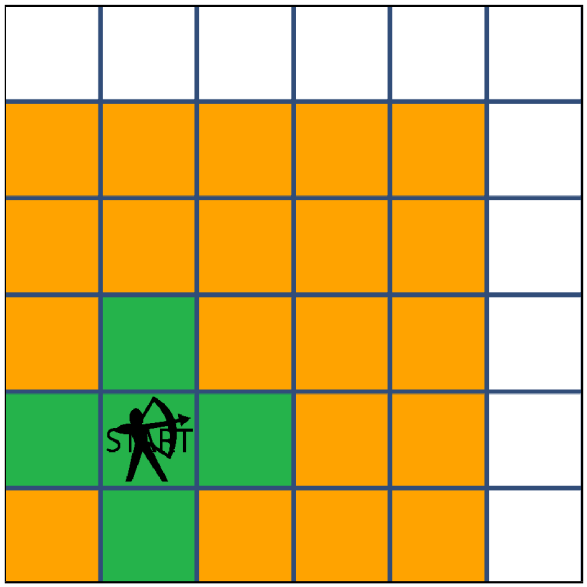
No entirely satisfying solution... so we build our own interface:
`github.com/sylvainlapeyrade/mqi_csharp`

Prototype: Wumpus World[2]



(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.

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

Small Example of a Wumpus World Game Situation

Listing 6: 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 7: Prolog query for monster given new knowledge

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

What's next?

Current work

- Improve the prototype to enable even more complex behaviour, espcially in MAS context
- Better formalise the creation and interaction with ontologies

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Thank You!

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