



In Closing

More on ASP

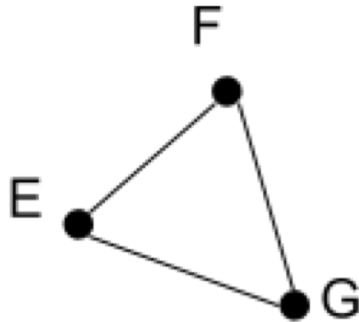
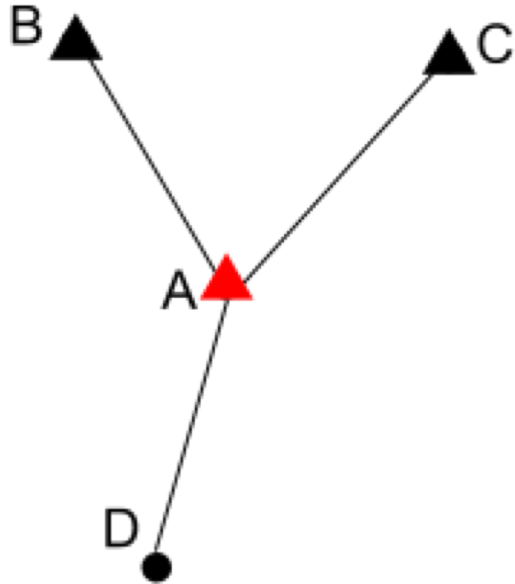


Learning in LPMLN

(Lee and Wang, “Weight Learning in a Probabilistic Extension of Answer Set Programs,” 2018)

Weight Learning from Data

```
carries_virus("A").  
contact("A", "B").    contact("B", "C"). ...  
@w(1) has_disease(X) :- carries_virus(X).  
@w(2) carries_virus(Y) :- contact(X, Y), carries_virus(X).
```



```
% Training data  
:- not carries_virus("E").  
:- carries_virus("H").  
...  
:- not has_disease("A").  
:- has_disease("H").
```

Learning in LP^{MLN}

| Weight learning is to learn the weights of the rules given the rules (without weights) and the data

- Easy for humans to write rules
- Better for machines to learn the importance of the rules

| The weight learning task for a parameterized LPMLN program is to find the MLE (Maximum likelihood Estimation) of the parameters

$$\operatorname{argmax}_{\mathbf{w}} P_{\hat{\Pi}(\mathbf{w})}(O)$$

| Structure learning is to learn the rules (with / without weights)

Learning Algorithm

| Maximizing the probability of the observation can be done by the gradient descent method:

$$\text{Iterate } w^{t+1} := w^t + \eta \frac{\partial}{\partial w} \log P_w(O)$$

| Computing the expected value can be done by MCMC sampling and other methods

```
@w(1) has_disease(X) :- carries_virus(X).
```

```
@w(2) carries_virus(Y) :- contact(X, Y), carries_virus(X).
```

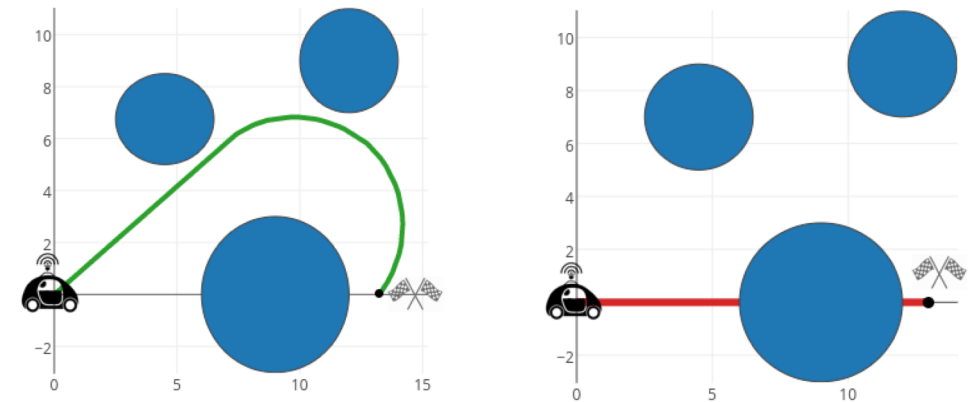
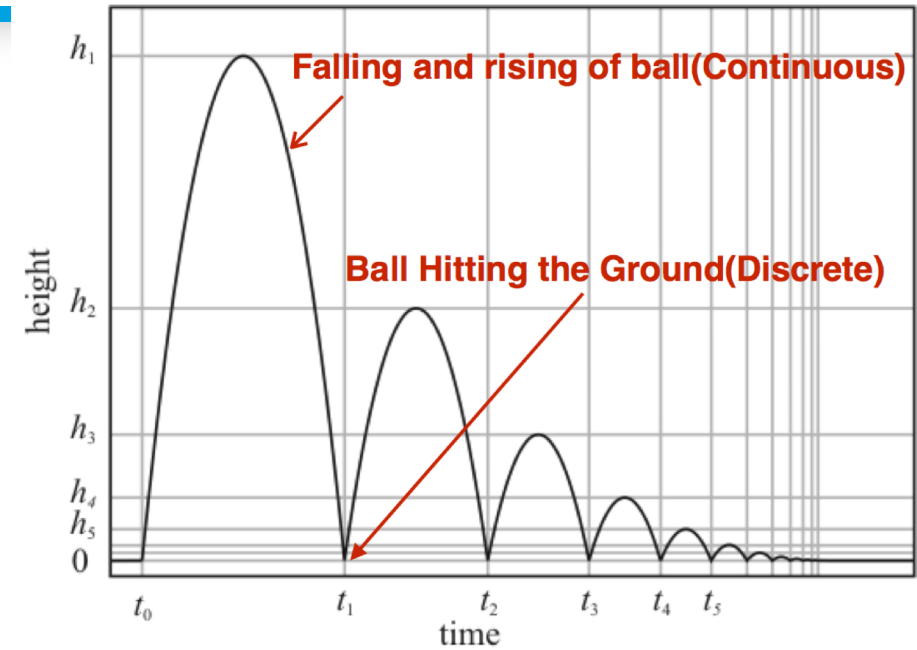


Answer Set Programming Modulo Theories

(Bartholomew and Lee, “First-Order Stable Model Semantics with Intensional Functions,” 2019)

Hybrid Systems

- A hybrid system is a dynamic system that exhibits both continuous and discrete dynamic behavior
- ASP is not suitable for modeling hybrid systems because
 - They are propositional (no support for reals) and lack of general functions to represent non-linear polynomials, trigonometric functions, and differential equations
 - They do not consider invariants during continuous transitions
 - Related to the challenge in integrating high-level task planning and low-level motion planning

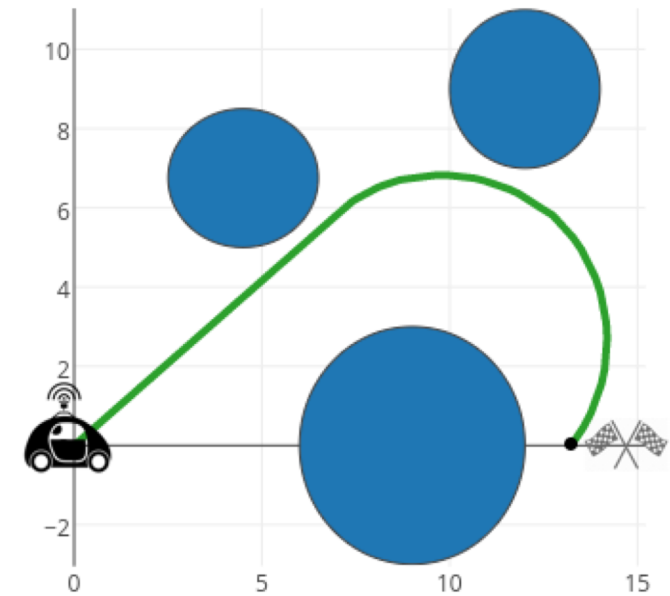
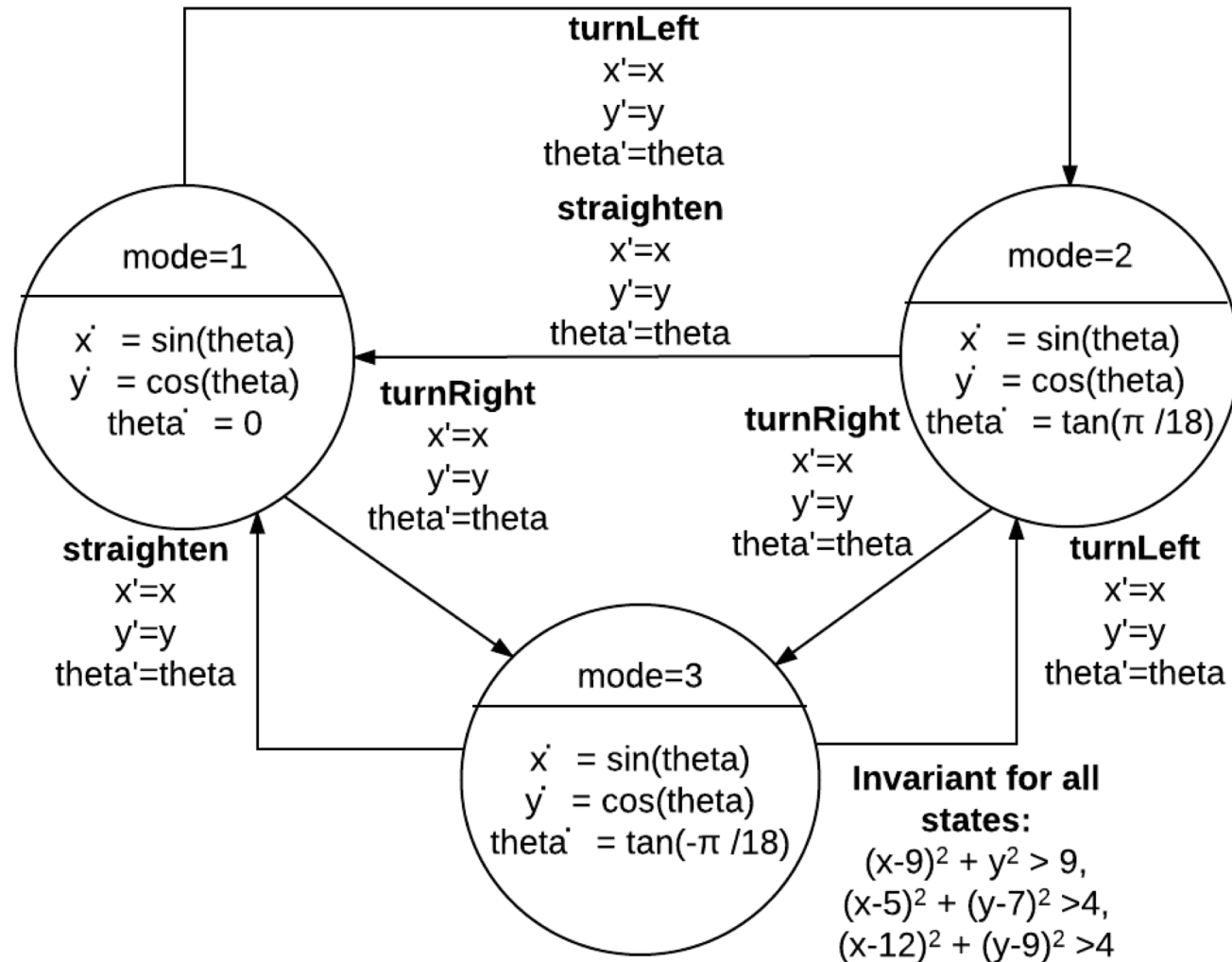


ASP vs. SMT



- | ASP is a successful nonmonotonic declarative programming paradigm, but is limited in handling first-order reasoning involving functions due to its propositional setting
- | SMT is a successful approach to solving some specialized first-order reasoning, but is limited in handling expressive nonmonotonic reasoning
- | Answer Set Programming Modulo Theories (ASPMT) is a tight integration of ASP and SMT

Representing Hybrid Automata in ASPMT



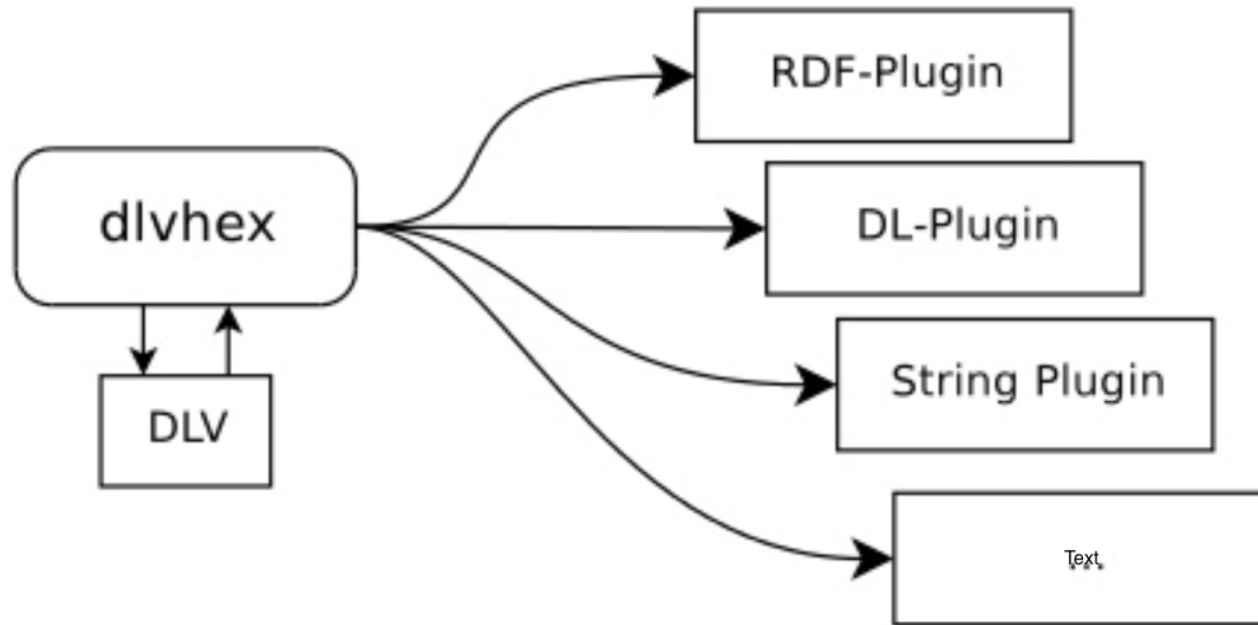


DLVHEX

(Eiter et al., “Combining answer set programming with description logics for the Semantic Web,” 2008)

DLVHEX

| HEX (Higher-order logic programs with EXternal atoms)



| The program can interface with multiple external sources of knowledge via so called external atoms implemented as “plugins”.

DLVHEX: Example

```
triple(X,Y,Z) :- &rdf[uri1](X,Y,Z)
```

```
triple(X,Y,Z) :- &rdf[uri2](X,Y,Z)
```

```
proposition(P) :- triple(P,rdf:type,rdf:Statement)
```

`&rdf` is an external predicate intended to extract knowledge from a given URI.

Wrap-Up

