CS227 Homework 4

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1 Right Of Way On Mountain Roads [p.29]

1.1 Text

[1] When two vehicles meet on a steep road where neither can pass, the vehicle facing downhill must yield the right-of-way by backing up until the vehicle going uphill can pass. [2] The vehicle facing downhill has the greater amount of control when backing.

1.2 Interpretation

The first sentence is operationally relevant so it needs to be represented and is fairly self-explanatory from the classes/relations. The second sentence merely gives an explanation for the rule provided by the first so it doesn't need to be represented.

1.3 Ontology

1.3.1 Class Heirarchy

- General class: *Thing*

- Subclasses of *Thing*: *Entity, Action, Event, Direction*

- Subclasses of *Entity*: *DrivingEntity, DrivingSurface*

- Subclass of *DrivingEntity*: *Vehicle*

- Subclass of *DrivingSurface*: *HazardousDrivingSurface*

- Subclasses of *HazardousDrivingSurface*: *NarrowDrivingSurface, SteepDrivingSurface*

- Subclass of *Action*: *Drive*

- Subclass of *Drive*: *Reverse*

- Subclass of *Event*: *DrivingSituation*

- Subclass of *DrivingSituation*: *Impasse*

1.3.2 Instances

- Instances of *Direction*: *Uphill, Downhill*

1.3.3 Relations

- *blockedBy*: with domain of *Drive* and range of *Entity*

- *heading*: with domain of *Drive* and range of *Direction*

- *agent*: with domain of *Action* and range of *Entity*

- *surface*: with domain of *Drive* and range of *DrivingSurface*

- *participant*: with domain of *Event* and range of *Entity*

- *response*: with domain of *Event* and range of *Action*

- *rightOfWay*: with domain of *DrivingSituation* and range of *Entity*

1.4 Flora

```
Entity::Thing.
Action::Thing.
Event::Thing.
Direction::Thing.

DrivingEntity::Entity.
Vehicle::DrivingEntity.
DrivingSurface::Entity.

Drive::Action.
Reverse::Drive.

DrivingSituation::Event.
Impasse::DrivingSituation.

HazardousDrivingSurface::DrivingSurface.
NarrowDrivingSurface::HazardousDrivingSurface.
SteepDrivingSurface::HazardousDrivingSurface.

Uphill:Direction.
Downhill:Direction.

Entity::Thing[blockedBy *=> Entity].
Action::Thing[agent *=> Entity].
Drive::Entity[heading => Direction].
Drive::Action[surface => DrivingSurface].
Event::Thing[participant *=> Entity].
Event::Thing[response *=> Action].
DrivingSituation::Event[rightOfWay *=> Entity].
```

```
?I:Impasse[rightOfWay -> ?V1] :-
  ?V1:Vehicle,
  ?V2:Vehicle,
  ?_:Drive[agent -> ?V1, surface -> ?S1, heading -> Uphill, blockedBy -> ?V2],
  ?_:Drive[agent -> ?V2, surface -> ?S1, heading -> Downhill, blockedBy -> ?V1],
  ?S1:(NarrowDrivingSurface, SteepDrivingSurface),
  ?I:DrivingSituation[participant -> ?V1, participant -> ?V2],
  not ?V1 :=: ?V2.


?I:Impasse[response -> ?R1] :-
  ?I:Impasse[participant -> ?_, participant -> ?V2],
  ?R1:Reverse[agent -> ?V2].
```

1.5 Basic Tests

```
V1:Vehicle.
V2:Vehicle.
_:Drive[agent -> V1, surface -> S1, heading -> Uphill, blockedBy -> V2].
_:Drive[agent -> V2, surface -> S1, heading -> Downhill, blockedBy -> V1].
S1:(NarrowDrivingSurface, SteepDrivingSurface).
R1:Reverse[agent -> V2].
I1:DrivingSituation[participant -> V1, participant -> V2].

flora2 ?- I:Impasse.

Yes
```

$R1$ should be the correct response to the situation:

```
flora2 ?- I1[response -> ?x].

?x = R1

1 solution(s) in 0.0040 seconds

Yes
```

$V1$ should have right of way:

```
flora2 ?- I1[rightOfWay -> ?x].

?x = V1

1 solution(s) in 0.0000 seconds
```

Yes

2 Speed Limits [p.29]

2.1 Text

[1] California has a "Basic Speed Law." [2] This law means you may never drive faster than is safe for current conditions. [3] For example, if you are driving 45 mph in a 55 mph speed zone during a dense fog, you could be cited for driving "too fast for conditions." [4] You may never legally drive faster than the posted speed limit, even if you think it is safe to do so.

[5] Regardless of the posted speed limit, your speed should depend on:

- *[6] The number and speed of other vehicles on the road.*

- *[7] Whether the road surface is smooth, rough, graveled, wet, dry, wide, or narrow.*

- *[8] Bicyclists or pedestrians walking on the road's edge or crossing the street.*

- *[9] Whether it is raining, foggy, snowy, windy, or dusty.*

2.2 Interpretation

Sentence [4] states that driving faster than the posted speed limit is illegal and needs to be represented. All other sentences express the idea that speed should be adjusted depending on conditions. Sentences [2], [5], [6], [7], [8] and [9] are all operationally relevant to this idea and need to be represented.

We will represent speeding using multiple rules: when a driver exceeds the limit of a speed zone [4]; when a driver fails to reduce speed in response to rough, graveled, wet, narrow or crowded roads or rainy, foggy, snowy, windy or dusty weather conditions [2, 5, first part of 6, 7, 9]; and when a driver fails to reduce speed when a pedestrian or bicyclist is ahead in the lane [8]. The second part of [6] about speed depending on the speed of other vehicles will be represented in section 4.

2.3 Ontology

2.3.1 Class Heirarchy

- Subclass of *Entity*: *SpatialEntity*

- Subclass of *SpatialEntity*: *SpeedZone*

- Subclasses of *Drive*: *IllegalDrive, ReduceSpeed*

- Subclass of *IllegalDrive*: *Speeding*

- Subclass of *DrivingSituation*: *HazardousConditions*

- Subclasses of *HazardousConditions*: *Raining, Snowing, Foggy, Windy, Dusty, DenseTraffic*

- Subclasses of *HazardousDrivingSurface* and *HazardousConditions*: *RoughDrivingSurface, GravelDrivingSurface, WetDrivingSurface*

- Subclass of *Entity*: *Person*

- Subclass of *Person*: *Pedestrian*

- Subclass of *Person* and *DrivingEntity*: *Bicyclist*

2.3.2 Relations

- *speed*: with domain of *Drive* and range of *Integer*

- *inSpeedZone*: with domain of *Drive* and range of *SpeedZone*

- *speedLimit*: with domain of *SpeedZone* and range of *Integer*

- *aheadInLane*: with domain of *Drive* and range of *Entity*

2.4 Flora

```
SpatialEntity::Entity.
SpeedZone::SpatialEntity.


IllegalDrive::Drive.
Speeding::IllegalDrive.


HazardousConditions::DrivingSituation.
Raining::HazardousConditions.
Snowing::HazardousConditions.
Foggy::HazardousConditions.
Windy::HazardousConditions.
Dusty::HazardousConditions.
DenseTraffic::HazardousConditions.


RoughDrivingSurface::(HazardousDrivingSurface, HazardousConditions).
GravelDrivingSurface::(HazardousDrivingSurface, HazardousConditions).
WetDrivingSurface::(HazardousDrivingSurface, HazardousConditions).


Person::Entity.
Pedestrian::Person.
Bicyclist::(DrivingEntity, Person).


Drive::Action[speed *=> _integer, inSpeedZone *=> SpeedZone, aheadInLane *=> Entity].
SpeedZone::SpatialEntity[speedLimit *=> _integer].
```

For the basic form of speeding (exceeding the posted speed limit):

```
?S:Speeding :-
  ?D1:DrivingEntity,
  ?S:Drive[agent -> ?D1, speed -> ?X, inSpeedZone -> ?Z],
```

```
?Z:SpeedZone[speedLimit -> ?Y],
?X > ?Y.
```

For not responding to poor conditions by reducing speed:

```
?S:Speeding :-
  ?D1:DrivingEntity,
  ?S:Drive[agent -> ?D1],
  ((?_:HazardousConditions[participant -> ?D1, response -> ?R],
not ?R:ReduceSpeed[agent -> ?D1]);
  ?_:HazardousConditions[participant -> ?D1]).
```

For not responding to the presence of bicyclists or pedestrians crossing the street or walking on the road's edge by reducing speed:

```
?S:Speeding :-
  ?D1:DrivingEntity,
  ?P1:(Pedestrian; Bicyclist),
  ?S:Drive[agent -> ?D1, aheadInLane -> ?P1],
  ((?_:DrivingSituation[participant -> ?D1, participant -> ?P1, response -> ?R],
not ?R:ReduceSpeed[agent -> ?D1]);
  ?_:DrivingSituation[participant -> ?D1, participant -> ?P1]).
```

2.5   Basic Tests

Basic test for the first rule, that exceeding the speed limit of a speed zone is a form of speeding:

```
D1:DrivingEntity.
DR1:Drive[agent -> D1, speed -> 51, inSpeedZone -> Z].
Z:SpeedZone[speedLimit -> 50].

flora2 ?- DR1:Speeding.

Yes
```

Basic test for the second rule, that not reducing speed in hazardous conditions is a form of speeding:

```
D2:DrivingEntity.
DR2:Drive[agent -> D2].
R2:ReduceSpeed[agent -> D2].
H:HazardousConditions[participant -> D2, response -> {not R2}].

flora2 ?- DR2:Speeding.

Yes
```

7

Basic test for the third rule, that not reducing speed when a pedestrian is in your lane is a form of speeding:

```
D3:DrivingEntity.
P1:Pedestrian.
DR3:Drive[agent -> D3, aheadInLane -> P1].
R3:ReduceSpeed[agent -> D3].
D:DrivingSituation[participant -> D3, participant -> P1, response -> {not R3}].

flora2 ?- DR3:Speeding.

Yes
```

If the road is wet, there is a bicyclist in the lane and the driver does not reduce speed while exceeding the speed limit:

```
D5:DrivingEntity.
P2:Bicyclist.
DR5:Drive[agent -> D5, aheadInLane -> P2, speed -> 37, inSpeedZone -> Z2].
R5:ReduceSpeed[agent -> D5].
H:WetDrivingSurface[participant -> D5, participant -> P2, response -> {not R5}].
Z2:SpeedZone[speedLimit -> 30].

flora2 ?- DR5:Speeding.

Yes
```

3 Maximum Speed Limit [p.29]

3.1 Text

[1] The maximum speed limit on most California highways is 65 mph. [2] You may drive 70 mph where posted. [3] Unless otherwise posted, the maximum speed limit is 55 mph on two-lane undivided highways and for vehicles towing trailers. [4] Other speed limit signs are posted for the type of roads and traffic in each area. [5] All speed limits are based on ideal driving conditions. [6] Construction zones usually have reduced speed zones. [7] Driving faster than the posted speed limit or than is safe for current conditions, on any road, is dangerous and illegal. [8] High speed increases your stopping distance. [9] The faster you go, the less time you have to avoid a hazard or collision. [10] The force of a 60 mph crash is not just twice as great as a 30 mph crash, it's four times as great!

3.2 Interpretation

For sentence [1], we can represent highways as a speed zone with a default speed limit of 65mph. [2] has mostly been represented above with speeding rules. We will, however, set *SpeedZone* to have a default speed of 70mph since it appears to be the absolute maximum possible limit. Similarly, for [3], two-lane undivided highways will have a default speed limit of 55mph. Vehicles towing trailers cannot legally travel faster than 55mph so that value will be a default limit. [4] has been represented above with the *SpeedZone* class. [5] has also been represented already. [6] can be represented by adding construction zones as hazardous areas. [7] has already been represented. [8], [9] and [10] are not operationally relevant.

3.3 Ontology

3.3.1 Class Heirarchy

- Subclass of *DrivingSurface*: *Road*

- Subclass of *SpeedZone* and *Road*: *Highway*

- Subclasses of *Highway*: *TwoLaneHighway*, *UndividedHighway*

- Subclass of *TwoLaneHighway* and *UndividedHighway*: *TwoLaneUndividedHighway*

- Subclass of *Vehicle*: *VehicleTowingTrailer*

- Subclass of *SpeedZone* and *HazardousConditions*: *ConstructionZone*

3.3.2 Relations

- *speedLimit*: with domain of *DrivingEntity* and range of *Integer*

3.4 Flora

```
Road::DrivingSurface.

Highway::(SpeedZone, Road).
```

```
Highway[speedLimit *-> 65].

SpeedZone[speedLimit *-> 70].

TwoLaneHighway::Highway.
UndividedHighway::Highway.

TwoLaneUndividedHighway::(TwoLaneHighway, UndividedHighway).
TwoLaneUndividedHighway[speedLimit *-> 55].

VehicleTowingTrailer::Vehicle.
DrivingEntity::Entity[speedLimit *=> _integer].

VehicleTowingTrailer[speedLimit *-> 55].

?S:Speeding :-
  ?D:DrivingEntity[speedLimit -> ?Y],
  ?S:Drive[agent -> ?D, speed -> ?X],
  ?X > ?Y.

ConstructionZone::(SpeedZone, HazardousConditions).
```

3.5   Basic Tests

Default speed for a highway should be 65 and it is:

```
Z6:Highway.

flora2 ?- Z6[speedLimit -> ?x].

?x = 65

1 solution(s) in 0.0000 seconds

Yes
```

Default speed limit for a speed zone should be 70 and it is:

```
Z7:SpeedZone.

flora2 ?- Z7[speedLimit -> ?x].

?x = 70
```

```
1 solution(s) in 0.0000 seconds
```

Yes

Default speed limit for a two lane, undivided highway should be 55 and it is:

```
Z8:TwoLaneUndividedHighway.

flora2 ?- Z8[speedLimit -> ?x].

?x = 55

1 solution(s) in 0.0360 seconds
```

Yes

Default speed limit for a vehicle towing a trailer should be 55 and it is:

```
D6:VehicleTowingTrailer.

flora2 ?- D6[speedLimit -> ?x].

?x = 55

1 solution(s) in 0.0640 seconds
```

Yes

A vehicle towing a trailer is speeding if it exceeds 55mph:

```
DR6:Drive[agent -> D6, speed -> 60].

flora2 ?- DR6:Speeding.
```

Yes

Failing to reduce speed in a construction zone is considered speeding:

```
DR7:Drive[agent -> D5, inSpeedZone -> Z2].
R7:ReduceSpeed[agent -> D5].
H:ConstructionZone[participant -> D5, response -> {not R7}].

flora2 ?- DR7:Speeding.
```

Yes

4 Reduced Speeds: Heavy Traffic or Bad Weather [p.29/30]

4.1 Text

[1] You must drive slower when there is heavy traffic or bad weather. [2] However, if you block the normal and reasonable movement of traffic by driving too slowly, you may be given a ticket. [3] If you choose to drive slower than other traffic, do not drive in the Number 1 (fast) lane. (See page 33.) [4] When traveling below the speed limit always move to the right when another driver is close behind you and wishes to drive faster, unless you are already in the extreme right lane.

4.2 Interpretation

Sentence [1] has already been represented. [2] is difficult to represent since it uses vague terms like "normal" and "reasonable". We will make an estimate that driving 5mph less than vehicles behind you in your lane constitutes "driving too slowly". [3], [4] adds that "driving too slowly" is only an issue when you are not to the right. So to represent [2], [3] and [4] we will make it illegal to drive 5mph slower than drivers behind you and not move to the right-most lane (assuming both are below the speed limit). We introduce a new subclass of *Road*: *RoadHalf*, to represent the two 'halves' of the road, as well as marked and unmarked lanes; both are mainly for use in the next section.

4.3 Ontology

4.3.1 Class Heirarchy

- Subclass of *IllegalDrive*: *BlockTraffic*

- Subclass of *DrivingSurface*: *RoadParts*

- Subclasses of *RoadParts*: *RoadHalf*, *RoadLane*

- Subclasses of *RoadLane*: *MarkedLane*, *UnmarkedLane*

- Subclass of *UnmarkedLane*: *RightMostLane*

4.3.2 Relations

- *lane*: with domain of *Drive* and range of *RoadLane*

- *inFront*: with domain of *Drive* and range of *Entity*

4.4 Flora

```
BlockTraffic::IllegalDrive.

RoadParts::DrivingSurface.
RoadHalf::RoadParts.
RoadLane::RoadParts.
MarkedLane::RoadLane.
UnmarkedLane::RoadLane.
```

```
RightMostLane::UnmarkedLane.

Drive::Action[lane *=> RoadLane].
Drive::Action[inFront *=> Entity].

?B:BlockTraffic :-
  ?D1:DrivingEntity,
  ?D2:DrivingEntity,
  ?B:Drive[agent -> ?D1, speed -> ?X1, inSpeedZone -> ?Z, lane -> ?L],
  ?_:Drive[agent -> ?D2, speed -> ?X2, inSpeedZone -> ?Z, inFront -> ?D1],
  ?L:(RoadLane - RightMostLane),
  ?Z:SpeedZone[speedLimit -> ?X],
  ((?_:DrivingSituation[participant -> ?D1, participant -> ?D2, response -> ?M],
not ?M:MoveRight[agent -> ?D1]);
  ?_:DrivingSituation[participant -> ?D1, participant -> ?D2]),
  ?X1 < ?X,
  ?X2 < ?X,
  (?X1 + 5) < ?X2,
  not ?D1 :=: ?D2.
```

4.5 Basic Tests

Simple case of a driving entity blocking traffic:

```
D8:DrivingEntity.
D9:DrivingEntity.
DR8:Drive[agent -> D8, speed -> 30, inSpeedZone -> Z8, lane -> L8].
DR9:Drive[agent -> D9, speed -> 40, inSpeedZone -> Z8, inFront -> D8].
L8:UnmarkedLane.
Z8:SpeedZone[speedLimit -> 50].
S8:DrivingSituation[participant -> D8, participant -> D9, response -> {not M8}].
M8:MoveRight[agent -> D8].

flora2 ?- DR8:BlockTraffic.

Yes
```

5 Reduced Speeds: Towing Vehicles, Buses, or Large Trucks [p.30]

5.1 Text

[1] When you tow a vehicle or trailer, or drive a bus or three or more axle truck, you must drive in the right hand lane or in a lane specially marked for slower vehicles. [2] If no lanes are marked and there are four lanes or more in your direction, you may only drive in either of the two lanes closest to the right edge of the road.

5.2 Interpretation

Both sentences will be represented as a new subclass of *IllegalDrive*: *IllegalLaneUse*. Both [1] and [2] are then fairly self-explanatory.

5.3 Ontology

5.3.1 Class Heirarchy

- Subclass of *IllegalDrive*: *IllegalLaneUse*

- Subclasses of *Vehicle*: *Bus*, *Truck*, *VehicleTowingVehicle*

- Subclass of *RoadHalf*: *RoadHalfAllUnmarked*

- Subclass of *MarkedLane*: *SlowLane*

- Subclass of *UnmarkedLane*: *SecondRightMostLane*

5.3.2 Relations

- *laneCount*: with domain of *RoadHalf* and range of *Integer*

- *axleCount*: with domain of *Truck* and range of *Integer*

5.4 Flora

```
IllegalLaneUse::IllegalDrive.

Bus::Vehicle.
Truck::Vehicle.
VehicleTowingVehicle::Vehicle.

RoadHalfAllUnmarked::RoadHalf.
SlowLane::MarkedLane.
SecondRightMostLane::UnmarkedLane.

RoadHalf::RoadParts[laneCount *=> _integer].
Truck::Vehicle[axleCount *=> _integer].

?I:IllegalLaneUse :-
```

```
  ?D:(VehicleTowingVehicle; VehicleTowingTrailer; Bus),
  ?I:Drive[agent -> ?D, lane -> ?L, surface -> ?S],
  ?L:(RoadLane - (RightMostLane; SlowLane)),
  (?S:RoadHalf[laneCount -> ?C], ?C < 4; ?S:Road[laneCount -> ?C], ?C < 8).


?I:IllegalLaneUse :-
  ?D:Truck[axleCount -> ?A],
  ?I:Drive[agent -> ?D, lane -> ?L, surface -> ?S],
  ?L:(RoadLane - (RightMostLane; SlowLane)),
  (?S:RoadHalf[laneCount -> ?C], ?C < 4; ?S:Road[laneCount -> ?C], ?C < 8),
  ?A >= 3.

?I:IllegalLaneUse :-
  ?D:(VehicleTowingVehicle; VehicleTowingTrailer; Bus),
  ?I:Drive[agent -> ?D, surface -> ?S, lane -> ?L],
  ?L:(RoadLane - (RightMostLane; SecondRightMostLane)),
  (?S:RoadHalfAllUnmarked[laneCount -> ?C], ?C >= 4; ?S:Road[laneCount -> ?C], ?C >= 8).

?I:IllegalLaneUse :-
  ?D:Truck[axleCount -> ?A],
  ?I:Drive[agent -> ?D, surface -> ?S, lane -> ?L],
  ?L:(RoadLane - (RightMostLane; SecondRightMostLane)),
  (?S:RoadHalfAllUnmarked[laneCount -> ?C], ?C >= 4; ?S:Road[laneCount -> ?C], ?C >= 8),
  ?A >= 3.
```

5.5   Basic Tests

Testing the first/second rule:

```
D10:Truck[axleCount -> 3].
DR10:Drive[agent -> D10, lane -> L10].
L10:UnmarkedLane.

flora2 ?- DR10:IllegalLaneUse.

Yes
```

Testing the third/fourth rule:

```
D11:Bus.
DR11:Drive[agent -> D11, surface -> S, lane -> L10].
S:RoadHalfAllUnmarked[laneCount -> 4].

flora2 ?- DR11:IllegalLaneUse.

Yes
```

6 Reduced Speeds: Around Children (First Section) [p.30]

6.1 Text

[1] When driving within 500 to 1,000 feet of a school while children are outside or crossing the street, the speed limit is 25 mph unless otherwise posted. [2] Also, if the school grounds have no fence and children are outside, never drive faster than 25 mph. [3] Some school zones may have speed limits as low as 15 mph. [4] Always drive more carefully near schools, playgrounds, parks, and residential areas because children may suddenly dart into the street. [5] Also, many children have not yet developed the ability to judge speeds and distances well enough to cross streets safely when cars are moving fast.

6.2 Interpretation

[1] and [2] are represented by a new subclass of *SpeedZone*: *SchoolZone* with a default speed limit of 25mph, which functions as a normal speed zone but also applies when within 500 to 1,000 feet of the associated school and when children are outside. A boolean value for a relation *outside* is sufficient to indicate the latter since if children are crossing the street they are surely outside. A boolean value for a relation *fence* indicates if there is a fence, in which case any speed over 25mph is considered speeding. [3] is not operationally relevant. For [4] we add more subclasses of *HazardousConditions* to indicate that drivers should reduce speed in these areas. [5] is not operationally relevant.

6.3 Ontology

6.3.1 Class Heirarchy

- Subclasses of *SpatialEntity* and *HazardousConditions*: *School, Playground, Park, ResidentialArea*

- Subclass of *SpeedZone*: *SchoolZone*

6.3.2 Relations

- *distanceTo*: with domain of *Drive*, range of *Integer* and argument *Entity*

- *childrenOut*: with domain of *School* and range of $\{0, 1\}$

- *hasFence*: with domain of *School* and range of $\{0, 1\}$

- *speedZone*: with domain of *School* and range of *SchoolZone*

6.4 Flora

```
School::(SpatialEntity, HazardousConditions).
Playground::(SpatialEntity, HazardousConditions).
Park::(SpatialEntity, HazardousConditions).
ResidentialArea::(SpatialEntity, HazardousConditions).

SchoolZone::SpeedZone.
```

```
SchoolZone[speedLimit *-> 25].

School::SpatialEntity[childrenOut *=> _integer, hasFence *=> _integer,
speedZone *=> SchoolZone].
School[childrenOut *-> 0, hasFence *-> 1].

Drive::Action[distanceTo(School) *=> _integer].

?S:Speeding :-
  ?D:DrivingEntity,
  ?S:Drive[agent -> ?D, speed -> ?X, distanceTo(?SC) -> ?Y],
  ?SC:School[childrenOut -> ?C, hasFence -> ?F, speedZone -> ?Z],
  ?Z:SchoolZone[speedLimit -> ?P],
  ?C =:= 1,
  ?Y < 1000,
  ?Y > 500,
  (?X > ?P; (?F =:= 0, ?X > 25)).

D12:DrivingEntity.
DR12:Drive[agent -> D12, speed -> 30, distanceTo(SC12) -> 650].
SC12:School[childrenOut -> 1, speedZone -> Z12].
Z12:SchoolZone.
```

6.5 Basic Tests

Testing the rule:

```
D12:DrivingEntity.
DR12:Drive[agent -> D12, speed -> 30, distanceTo(SC12) -> 650].
SC12:School[childrenOut -> 1, speedZone -> Z12].
Z12:SchoolZone.

flora2 ?- DR12:Speeding.

Yes

flora2 ?- Z12[speedLimit -> ?x].

?x = 25

1 solution(s) in 0.0000 seconds

Yes

flora2 ?- SC12[fence -> ?x].
```

```
?x = 1

1 solution(s) in 2.7680 seconds

Yes
```

7 Reduced Speeds: Around Children (Second Section) [p.30]

7.1 Text

Near schools, look for:

- [1] Bicyclists and pedestrians.

- [2] School safety patrols or school crossing guards and obey their directions. [3] For the crossing guards safety, allow him or her to safely get to the side of the road before driving ahead.

- [4] Stopped school buses and children crossing the street. [5] Some school buses flash yellow lights when preparing to stop to let children off the bus. [6] The yellow flashing lights warn you to slow down and prepare to stop. [7] When the bus flashes red lights (located at the top front and back of the bus), you must stop from either direction until the children are safely across the street and the lights stop flashing. [8] The law requires you remain stopped as long as the red lights are flashing (CVC 22454). [9] If you fail to stop, you may be fined up to $1,000 and your driving privilege could be suspended for one year. [10] If the school bus is on the other side of a divided or multilane highway (two or more lanes in each direction), you do not need to stop.

7.2 Interpretation

[1] is not operationally relevant. [2] and [3] can be combined to say that drivers must stop when there is a crossing guard on the road. [4], [5] and [6] can be combined to say that drivers must slow down and prepare to stop when a school bus ahead is flashing its yellow lights (but not "when the school bus is on the other side of a divided or multilane highway", i.e. it is illegal not to stop when the bus is on the same side as the vehicle or when the road is undivided or multilane with fewer than 4 lanes (2 in each direction)). [7], [8], [9] and [10] can be combined to say that drivers must stop when the school bus is flashing its red lights (but not "when the school bus is on the other side of a divided or multilane highway") and that failing to do so has a penalty of up to $1000 and a 1 year suspension of driving privilege.

7.3 Ontology

7.3.1 Class Heirarchy

- Subclass of *IllegalDrive*: *IllegalNoStop*

- Subclass of *IllegalNoStop*: *IllegalNoStopOnRed*

- Subclasses of *Drive*: *Stop*, *SlowDown*, *PrepareToStop*

- Subclass of *Thing*: *Penalty*

- Subclasses of *Penalty*: *Fine*, *SuspendedLicense*

- Subclass of *Person*: *CrossingGuard*

- Subclasses of *DrivingSituation*: *CrossingGuardOnRoad*, *SchoolBusAhead*

- Subclass of *Bus*: *SchoolBus*

- Subclass of *Highway*: *DividedHighway*

7.3.2 Relations

- *cost*: with domain of *Fine* and range of *Integer*

- *duration*: with domain of *SuspendedLicense* and range of *Integer* (in months)

- *penalty*: with domain of *IllegalDrive* and range of *Penalty*

- *yellowLightsFlashing*: with domain of *SchoolBus* and range of $\{0, 1\}$

- *redLightsFlashing*: with domain of *SchoolBus* and range of $\{0, 1\}$

- *crossing*: with domain of *Road* and range of *Person*

7.4 Flora

```
IllegalNoStop::IllegalDrive.
IllegalNoStopOnRed::IllegalNoStop.
Stop::Drive.
SlowDown::Drive.
PrepareToStop::Drive.

Penalty::Thing.
Fine::Penalty.
SuspendedLicense::Penalty.

Fine::Penalty[cost *=> _integer].
SuspendedLicense::Penalty[duration *=> _integer].
IllegalDrive::Drive[penalty *=> Penalty].

CrossingGuard::Person.
CrossingGuardOnRoad::DrivingSituation.

SchoolBus::Bus.
SchoolBus::Bus[yellowLightsFlashing *=> _integer, redLightsFlashing *=> _integer].
SchoolBus[yellowLightsFlashing *-> 0, redLightsFlashing *-> 0].
SchoolBusAhead::DrivingSituation.

DividedHighway::Highway.

Road::DrivingSurface[crossing *=> Person].

?IL:IllegalNoStop :-
  ?D:DrivingEntity,
```

```
  ?C:CrossingGuard,
  ?R:Road[crossing -> ?C],
  ?IL:Drive[agent -> ?D, surface -> ?R],
  ((?_:CrossingGuardOnRoad[participant -> ?D, participant -> ?C, response -> ?S],
not ?S:Stop[agent -> ?D]);
  ?_:CrossingGuardOnRoad[participant -> ?D, participant -> ?C]).


?IL:IllegalNoStop :-
  ?D:DrivingEntity,
  ?IL:Drive[agent -> ?D, surface -> ?S],
  ?_:Drive[agent -> ?SB, surface -> ?S],
  (?S:RoadHalf; (?S:(Road - DividedHighway)[laneCount -> ?L], ?L < 4)),
  ?SB:SchoolBus[yellowLightsFlashing -> ?Y],
  ((?_:SchoolBusAhead[participant -> ?D, participant -> ?SB, response -> ?R],
not ?R:(SlowDown, PrepareToStop)[agent -> ?D]);
  ?_:SchoolBusAhead[participant -> ?D, participant -> ?SB]),
  ?Y =:= 1.


?IL:IllegalNoStopOnRed :-
  ?D:DrivingEntity,
  ?IL:Drive[agent -> ?D, surface -> ?S],
  ?_:Drive[agent -> ?SB, surface -> ?S],
  (?S:RoadHalf; (?S:(Road - DividedHighway)[laneCount -> ?L], ?L < 4)),
  ?SB:SchoolBus[redLightsFlashing -> ?Y],
  ((?_:SchoolBusAhead[participant -> ?D, participant -> ?SB, response -> ?R],
not ?R:Stop[agent -> ?D]);
  ?_:SchoolBusAhead[participant -> ?D, participant -> ?SB]),
  ?Y =:= 1.


?IL:IllegalNoStopOnRed[penalty -> ?P] :-
  ?IL:IllegalNoStopOnRed,
  ((?P:Fine[cost -> ?F], ?F < 1000); ?P:(SuspendedLicense[duration -> ?D], ?D < 12)).
```

7.5 Basic Tests

Testing the first rule:

```
D13:DrivingEntity.
C13:CrossingGuard.
R13:Road[crossing -> C13].
DR13:Drive[agent -> D13, surface -> R13].
S13:Drive.
DS13:DrivingSituation[participant -> D13, participant -> C13, response -> S13].


flora2 ?- DR13:IllegalNoStop.
```

```
Yes


Testing the second rule:

D14:DrivingEntity.
DR14:Drive[agent -> D14, surface -> S14].
DR142:Drive[agent -> SB14, surface -> S14].
S14:RoadHalf.
SB14:SchoolBus[yellowLightsFlashing -> 1].
DS14:SchoolBusAhead[participant -> D14, participant -> SB14].


flora2 ?- DR14:IllegalNoStop.

Yes


Testing the third rule:

D15:DrivingEntity.
DR15:Drive[agent -> D15, surface -> S15].
DR152:Drive[agent -> SB15, surface -> S15].
S15:RoadHalf.
SB15:SchoolBus[redLightsFlashing -> 1].
P15:Fine[cost -> 500].
DS15:SchoolBusAhead[participant -> D15, participant -> SB15].

flora2 ?- DR15:IllegalNoStopOnRed.

Yes

flora2 ?- DR15[penalty -> ?x].

?x = P15

1 solution(s) in 32.6590 seconds

Yes
```

8 Roundabouts [p.29]

8.1 Text

[1] For roundabouts with multiple lanes, choose your entry or exit lane based on your destination as shown in the graphic. For example, to:

- [2] Turn right at the intersection, choose the right-hand lane and exit in the right-hand lane (blue car.)

- [3] Go straight through the intersection, choose either lane, and exit in the lane you entered (red car.)

- [4] Turn left, choose the left lane, and exit (yellow car.)

8.2 Interpretation

[1] is not operationally relevant. Introduce new definitions for *IllegalLaneUse* which will be defined as turning right from a lane other than the right lane [2], exiting the roundabout in a different lane from the one you entered in [3] and turning left from a lane other than the left lane [4].

8.3 Ontology

8.3.1 Class Heirarchy

- Subclass of *Drive*: *UseRoundabout*

- Subclasses of *UseRoundabout*: *LeftRoundaboutTurn*, *RightRoundaboutTurn*

- Subclass of *SpatialEntity*: *Roundabout*

- Subclass of *Unmarked Lane*: *LeftMostLane*

8.3.2 Relations

- *roundabout*: with domain of *UseRoundabout* and range of *Roundabout*

- *entrylane*: with domain of *UseRoundabout* and range of *Roundabout*

- *exitlane*: with domain of *UseRoundabout* and range of *Roundabout*

8.4 Flora

```
UseRoundabout::Drive.
LeftRoundaboutTurn::UseRoundabout.
RightRoundaboutTurn::UseRoundabout.

Roundabout::SpatialEntity.

LeftMostLane::UnmarkedLane.
```

```
UseRoundabout::Drive[roundabout *=> Roundabout, entryLane *=> RoadLane,
exitLane *=> RoadLane].

?IL:IllegalLaneUse :-
  ?D:DrivingEntity,
  ?R:Roundabout,
  ?IL:RightRoundaboutTurn[agent -> ?D, roundabout -> ?R, entryLane -> ?E1,
exitLane -> ?E2],
  (not ?E1:RightMostLane; not ?E2:RightMostLane).

?IL:IllegalLaneUse :-
  ?D:DrivingEntity,
  ?R:Roundabout,
  ?IL:LeftRoundaboutTurn[agent -> ?D, roundabout -> ?R, entryLane -> ?E1,
exitLane -> ?E2],
  (not ?E1:LeftMostLane; not ?E2:LeftMostLane).

?IL:IllegalLaneUse :-
  ?D:DrivingEntity,
  ?R:Roundabout,
  ?IL:UseRoundabout[agent -> ?D, roundabout -> ?R, entryLane -> ?E1, exitLane -> ?E2],
  not ?E1 :=: ?E2.
```

8.5   Test Questions

Testing the first rule:

```
D16:DrivingEntity.
R16:Roundabout.
E161:RightMostLane.
E162:LeftMostLane.
DR16:RightRoundaboutTurn[agent -> D16, roundabout -> R16, entryLane -> E161,
exitLane -> E162].

flora2 ?- DR16:IllegalLaneUsage.

Yes
```

Testing the second rule:

```
DR17:LeftRoundaboutTurn[agent -> D16, roundabout -> R16, entryLane -> E162,
exitLane -> E161].

flora2 ?- DR17:IllegalLaneUsage.

Yes
```

Testing the third rule:

```
DR18:UseRoundabout[agent -> D16, roundabout -> R16, entryLane -> E162, exitLane -> E161].

flora2 ?- DR18:IllegalLaneUsage.

Yes
```

9 Tests

9.1 Sample Questions

If it's snowing and the driver does not reduce speed, is the driver speeding?

```
D4:DrivingEntity.
DR4:Drive[agent -> D4].
R4:(Drive - ReduceSpeed[agent -> D4]).
H:Snowing[participant -> D4, response -> R4].

flora2 ?- DR4:Speeding.

Yes
```

If a truck is going up a steep, narrow road and a bus is coming down, who has right of way?

```
D191:Truck.
D192:Bus.
_:Drive[agent -> D191, surface -> S19, heading -> Uphill, blockedBy -> D192].
_:Drive[agent -> D192, surface -> S19, heading -> Downhill, blockedBy -> D191].
S19:(NarrowDrivingSurface; SteepDrivingSurface).
I19:DrivingSituation[participant -> D191, participant -> D192].

flora2 ?- I19[rightOfWay -> ?x].

?x = D191

1 solution(s) in 0.0000 seconds

Yes
```

If a vehicle is driving in the left most lane at 48mph in a 50pmh zone and a bus is behind it driving at 55mph and the car doesn't move right, is it blocking traffic?

```
D201:Vehicle.
D202:Bus.
DR201:Drive[agent -> D201, speed -> 48, inSpeedZone -> Z20, lane -> L20].
DR202:Drive[agent -> D202, speed -> 55, inSpeedZone -> Z20, inFront -> D201].
L20:LeftMostLane.
Z20:SpeedZone[speedLimit -> 50].
DS20:DrivingSituation[participant -> D201, participant -> D202].

flora2 ?- DR201:BlockTraffic.

No
```

as expected, since the bus is speeding:

```
flora2 ?- DR202:Speeding.

Yes
```

If a school bus is flashing its red lights on a highway with 3 lanes and a truck is present, must the truck stop?

```
D211:Truck.
D212:SchoolBus[redLightsFlashing -> 1].
DR211:Drive[agent -> D211, surface -> S21].
DR211:Drive[agent -> D212, surface -> S21].
S21:Highway[laneCount -> 3].
R21:(Drive - Stop).
SB:SchoolBusAhead[participant -> D211, participant -> D212, response -> R21].

flora2 ?- DR211:IllegalNoStopOnRed.

Yes
```

as expected since the only time a vehicle does not have to stop is if the school bus is on the other side of a 4+ lane, divided highway.

If a vehicle is driving at 30mph 800 feet from a school with no children outside, is the vehicle speeding?

```
D22:Vehicle.
DR22:Drive[agent -> D22, speed -> 30, distanceTo(SC22) -> 800].
SC22:School[childrenOut -> 0, speedZone -> Z22],
Z22:SchoolZone.

flora2 ?- DR22:Speeding.

No
```

as expected since children are not outside.

If a vehicle towing a trailer is driving 60mph on a standard highway, is the vehicle speeding?

```
D23:VehicleTowingTrailer.
DR23:Drive[agent -> D23, speed -> 60, surface -> S23].
S23:Highway.

flora2 ?- D23:Speeding.

Yes
```

as expected since vehicles towing trailers have a speed limit of 55mph by default despite a default speed limit of 65mph on highways.

A truck with 5 axles is driving in the second right most lane on the highway. Is this illegal?

```
D24:Truck[axleCount -> 5].
DR24:Drive[agent -> D24, lane -> L24, surface -> S24].
L24:SecondRightMostLane.
S24:Highway.

flora2 ?- DR24:IllegalLaneUse.

Yes
```

as expected since trucks with 3+ axles must use the right most lane unless there are 4+ unmarked lanes, in which case it can also use the second right most:

```
DR25:Drive[agent -> D24, lane -> L24, surface -> S25].
S25:RoadHalfAllUnmarked[laneCount -> 4].

flora2 ?- DR25:IllegalLaneUse.

No
```

9.2 Novel Questions

1. Can you ever be cited for driving slower than the speed limit? [Yes]

```
D271:DrivingEntity.
D272:DrivingEntity.
DR271:Drive[agent -> D271, speed -> 35, lane -> L27].
DR272:Drive[agent -> D272, speed -> 45, lane -> L27, inFront -> D271].
L27:(RoadLane - RightMostLane).

flora2 ?- DR271:BlockTraffic.

Yes
```

The KB is correct that you can be cited for driving slower than the speed limit, under certain circumstances. It's not, however, a direct answer to the question. It requires suggesting a possible scenario and asking if that scenario is legal. An unfamiliar user would struggle to answer this question using the KB.

2. On a highway with no posted speed limit, what is the maximum legal speed for a vehicle towing a trailer? [55 mph]

```
D26:VehicleTowingTrailer.
DR26:Drive[agent -> D26, surface -> S26].
S26:Highway.

flora2 ?- D26[speedLimit -> ?x].

?x = 55

1 solution(s) in 0.1520 seconds

Yes
```

The KB is correct.

3. If you are traveling below the speed limit, are not in the rightmost lane, and another driver wishes to pass, is it legal to stay in your lane? [No]

Use the same scenario as question 1:

```
D271:DrivingEntity.
D272:DrivingEntity.
DR271:Drive[agent -> D271, speed -> 35, lane -> L27].
DR272:Drive[agent -> D272, speed -> 45, lane -> L27, inFront -> D271].
```

29

```
L27:(RoadLane - RightMostLane).

flora2 ?- DR271:BlockTraffic.

Yes
```

The KB is correct that it is not legal to stay in your lane. This question required some manipulation, for two reasons. First: the KB represents speeds using integers so to convey the idea that someone is traveling below the speed limit requires an integer for the driver's speed as well as a speed zone with a given integer speed limit. And second: as mentioned in the *BlockTraffic* section, the handbook uses vague terms like 'normal' and 'reasonable' which are difficult to represent. The decision was made to make the assumption that driving 5mph less than someone behind you while not in the right hand lane was illegal, assuming that both drivers are driving below the speed limit.

Now the question itself is lacking details necessary for it to be answered. It is not the case that it is illegal to stay in your lane if you are below the speed limit and someone wishes to pass. It is only illegal if the driver wishing to pass is also below the speed limit. For instance, if you are driving 49mph in a 50mph zone and someone driving 55mph wants to pass, then you have no legal obligation to move over since they are speeding. Furthermore, if the driver wishing to pass was driving at 50mph, you would still have no legal obligation to move over since you are not driving slow enough to 'block the normal and reasonable flow of traffic.' So as presented, the question does not have a definite answer. To get an answer it was necessary to fill in speed values that the question left out.

4. If you are driving within 1000 feet of a school while children are outside with no posted school-zone speed limit, what is your maximum legal speed? [25 mph]

```
D28:DrivingEntity.
DR28:Drive[agent -> D28, distanceTo(SC28) -> 1000].
SC28:School[childrenOut -> 1, speedZone -> Z28].
Z28:SchoolZone.

flora2 ?- Z28[speedLimit -> ?x].

?x = 25

1 solution(s) in 0.0080 seconds

Yes
```

The KB is correct.

5. What factors influence the driving speed limit?

The KB cannot easily handle this question. There are situations (rain, fog, wind etc.) for which it is recommended that you reduce your speed. But there is no way of directly answering the question. The KB would probably need a class of *Factors* that affect speed with subclasses like *Weather* and *SurfaceCondition* but even then you would need to individually create instances and test whether they were instances of *Factors*.

6. If you are driving a bus, large truck, or towing a vehicle or trailer on a road with three lanes, which lanes may you drive in (left, middle, and/or right)? [Right (you may not drive in the middle or left lanes)]

```
D301:VehicleTowingVehicle.
DR301:Drive[agent -> D301, surface -> S30, lane -> L301].
DR302:Drive[agent -> D301, surface -> S30, lane -> L302].
DR303:Drive[agent -> D301, surface -> S30, lane -> L303].
L301:LeftMostLane.
L302:(UnmarkedLane - (LeftMostLane; RightMostLane)).
L303:RightMostLane.
S30:Road[laneCount -> 3].

flora2 ?- ?D:IllegalLaneUse[lane -> ?x].

?D = DR301
?x = L301

?D = DR302
?x = L302

2 solution(s) in 0.0000 seconds

Yes
```

The KB is correct that the right lane is the only legal option (and the answer is the same for all the vehicles, where a large truck is defined in the KB as one with 3 or more axles). The KB, however, fails when you specify an instance of (*VehicleTowingTrailer*; *VehicleTowingVehicle*; *Bus*; *Truck[axlecount−> 3]*) as the question specifies. An instance of each, tested individually, gives the same result as above.

7. Can you be fined more than $1000 for passing a school bus with flashing red lights? [No (you may be fined up to $1000)]

```
D31:DrivingEntity.
DR311:Drive[agent -> D31, surface -> S31].
DR312:Drive[agent -> SB31, surface -> S31].
S31:Road[laneCount -> 2].
```

```
SB31:SchoolBus[redLightsFlashing -> 1].
SBA31:SchoolBusAhead[participant -> D31, participant -> SB31].
F31:Fine[cost -> 1001].

flora2 ?- DR311:IllegalNoStopOnRed.

Yes

flora2 ?- ?DR311[penalty -> ?x].

No
```

The KB is correct that it is illegal but you cannot be fined more than $1000. The representation required some extra details, such as the road and its lane count. It would have been better to define it in the KB in such a way that if no road was specified, then it assumed a general 2 lane road.

8. Is it legal to drive in the opposite direction past a school bus with flashing red lights on a road without a divider? [No]

```
D32:DrivingEntity.
DR321:Drive[agent -> D32, surface -> S32].
DR322:Drive[agent -> SB32, surface -> S32].
S32:UndividedHighway[laneCount -> 2].
SB32:SchoolBus[redLightsFlashing -> 1].
SBA32:SchoolBusAhead[participant -> D32, participant -> SB32].

flora2 ?- DR321:IllegalNoStopOnRed.

Yes
```

The KB is correct but it required a small amount of manipulation. The KB does not explicitly define the *IllegalNoStopOnRed* rule as checking which side of the road a *DrivingEntity* is on. It merely assumes that if the *DrivingEntity* is on the same side of the road or if the road is undivided and has fewer than 4 lanes, then not stopping is illegal. It would have been better to explicitly check which side of the road each *DrivingEntity* is on. A lane count for the road also had to be added because it not possible to answer the question definitively otherwise.

9. Can your maximum legal speed be lower than the posted speed limit if it is raining, foggy, snowing, windy, or dusty? [Yes]

The KB cannot easily handle this question. The KB would say it's not illegal to reduce speed when it is raining, which implies that you can travel at less than the speed limit but it's neither direct nor obvious.

10. Is it legal to drive faster than the posted speed limit? [No]

```
D34:DrivingEntity.
DR34:Drive[agent -> D34, inSpeedZone -> Z34, speed -> 41].
Z34:SpeedZone[speedLimit -> 40].

flora2 ?- DR34:Speeding.

Yes
```

The KB is correct that it is illegal to exceed the posted speed limit but again it requires putting sample values into place. This is not ideal since it doesn't answer the question in a general sense but rather only concludes that driving 41 in a 40 zone is illegal.

9.3 Analysis Summary

The KB performed reasonably well overall. It performs best on questions that are precisely defined. This seems to be true of the system as a whole. For instance, defining the rule that driving faster than the speed limit is considered speeding is simple because it is precisely defined. And answering questions like 'if I am driving at 40mph in a 50mph zone, am I speeding?' are easily answered for the same reason. It becomes more difficult with more general questions like 'is it legal to drive faster than the posted speed limit?'. All the KB can do is answer queries with specific numbers so the user must simply providing scenarios and ask 'is this legal?'. When there are only a small number of possibilities, trying each of them is not a great hassle but in this case there are arbitrarily many possible speeds and speed limit combinations and it is not feasible to try them all. Ideally you want to be able to say 'if I am driving at some speed x and the speed limit is some y, am I speeding?'. It would be better if the KB could handle more general questions but it is not immediately obvious how to do so.

Similarly, the KB does not handle 'answer extraction' questions like 6. The system seems to be suited to answering 'yes' or 'no' questions or being supplied with instances and checking if they apply. For instance, in 6, instead of simply creating multiple lanes and checking each in turn, it would be ideal if we could ask 'if I am driving a bus, which lane should I drive in?' and have it response with an instance of, say, *RightMostLane*. Questions like 5, are even more difficult to handle since there isn't even an obvious way to translate it into appropriate KB vocabulary and even then you would likely still have to create instances and ask if they matched or not, as opposed to it supplying you with instances.

The KB could have been improved by defining more general situations. For instance, instead of defining *IllegalNoStopOnRed* as one big rule, it would be better to define the situation of a school bus flashing its red lights and then defining *IllegalNoStopOnRed* as an instance of the situation without the correct response. Separating things out in this fashion could allow the KB to answer more questions since it would have a larger number of simpler rules. E.g. at present it could not say whether a given situation matches one where a school bus is flashing its lights; it could only say that it is illegal not to stop if that situation is occurring.

Overall the KB performed reasonably well. Many of the limitations in answering general questions and extracting answers seems to be a challenge of the system as a whole rather than this KB specifically. Still, improvements could have been made by separating and simplifying rules.