On Learning Planning Goals for Traffic Control

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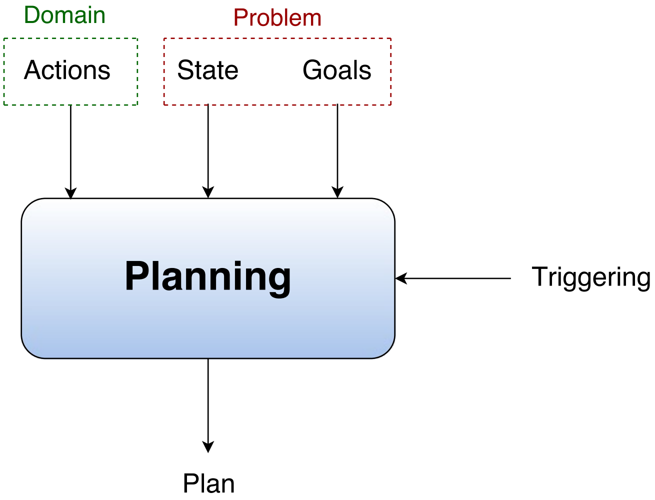
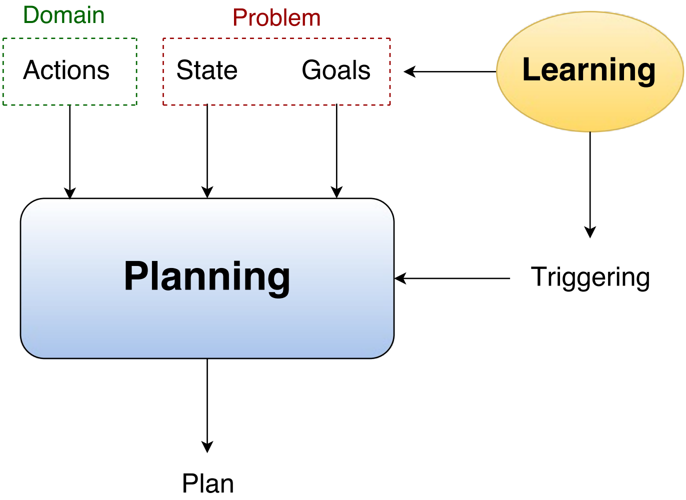
Goal reasoning

- Goal directed behavior is a hallmark of intelligence
- Most of the times goals do not remain static
- In some domains, predicting goal's appearance can increase system's autonomy and performance

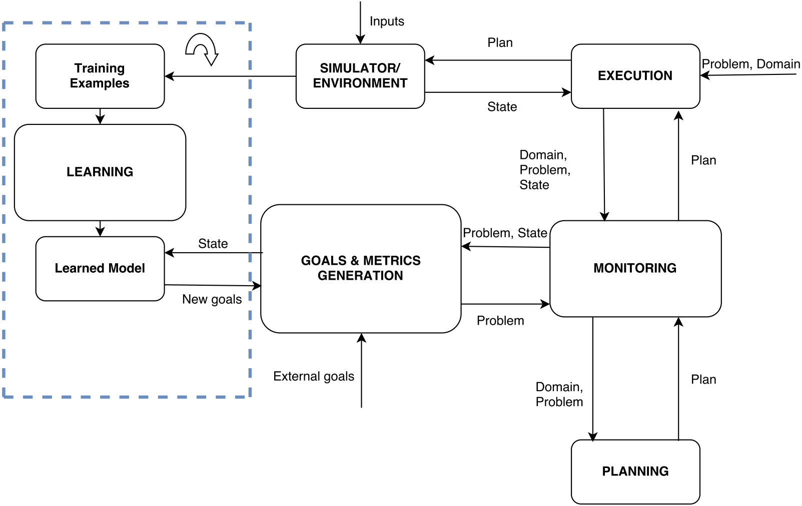
Automated Planning



Motivation


Domain
Actions
Problem
State
Goals
Learning
Planning
Triggering
Plan

Architecture



Traffic Control

Automated Planning

- **State** → static and dynamic state of the city
- **Goals** → achieve low density in streets with high density
- **Actions** → set traffic lights to green or red
- **Triggering** → when a street has high density [Gulić et al., 2015]

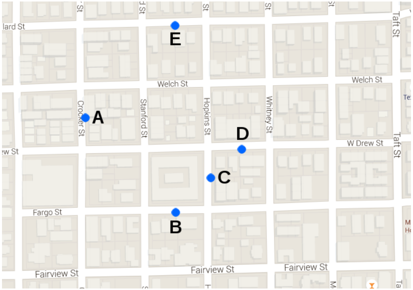
Relational Learning

- **Predict** the density → given previous N time steps densities, predict when the density is going to be high
- **Triggering** → if a high density is predicted in any street, then a goal for decreasing its density is raised

Learning task

- Algorithm: TILDE, generates relational decision trees
- Time series prediction approach
- Subset of the planning domain predicates
- **Target concept**: density(street, level)
- **Background knowledge**:
  - connection(street, street)
  - green-*Step*(traffic-light, street)
  - density-*Level*-*Step*(street)

Predicting goals

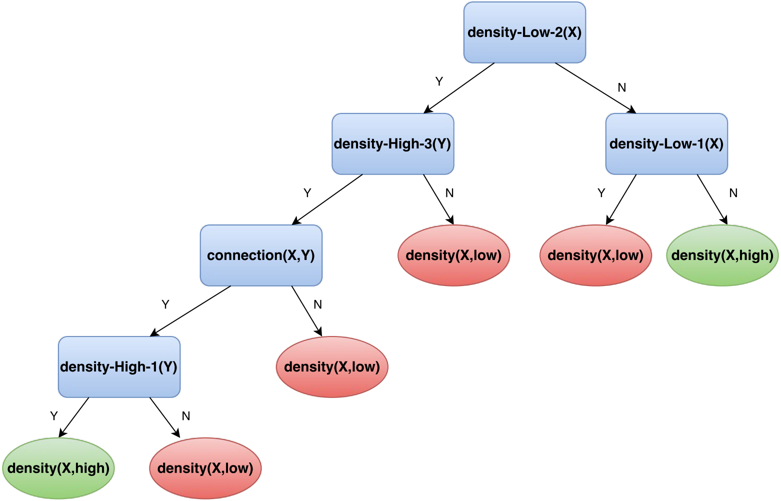


Houston downtown

2 density levels - Accuracy

Training/Test	A	B	C	D	E
A	0.99	0.94	0.99	0.97	0.99
B	0.99	0.95	0.99	0.98	0.99
C	0.96	0.93	0.99	0.97	0.99
D	0.96	0.93	0.99	0.98	0.99
E	0.96	0.93	0.99	0.97	0.99

Predictive model



Traffic management

Experimental setting

Systems to compare

	AP	Reactive goals	Predicted goals
Static			
Planning	✓	✓	
Learning	✓		✓

Metrics

- CO_2
- Number of **steps** all the cars reach their destination
- Average waiting time (**AWT**)
- Average travel time (**ATT**)
- Planner executions (**PE**)

Traffic management

Results

Uncongested city - 5300 cars in one hour

	Steps	$C0_2$	AWT	ATT	PE
Static	3969	1103	93	172	
Planning	4070	1117	95	175	22
Learning	**3881**	**1090**	**88**	**167**	**15**

Traffic management
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Congested city - 6000 cars in one hour

	Steps	$C0_2$	AWT	ATT	PE
Static	-	2553	582	638	
Planning	-	2187	435	506	48
Learning	**4070**	**1265**	**121**	**204**	**46**

Conclusions

- Autonomous system that generates its own goals, predicting their appearance
- Relational Learning works well with Automated Planning
- Promising results in the traffic domain

Current and Future work

- Integrate Anticipatory Planning
- Carry out online learning
- Apply multi-agent approach

Thank you

"Urban Traffic Control Assisted by AI Planning and Relational Learning"

Workshop on Agents in Traffic and Transportation

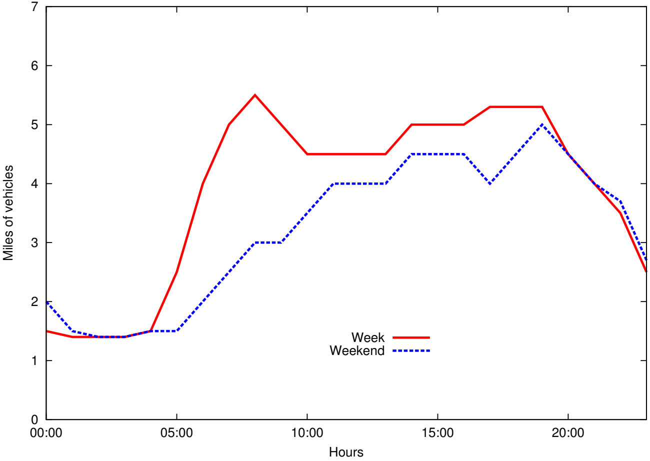
July, 10 @ Madison Room

Planning domain

```
(:action hm-green-to-all-ways
 :parameters (?t - traffic-light ?c - crossing ?sin - street
              ?sout1 - street ?sout2 - street ?sout3 - street)
 :precondition (and (goes-into ?sin ?c)
                    (goes-out ?sout1 ?c)
                    (traffic-lights-from-street ?t ?c ?sin)
                    (not (opposite-direction ?sin ?sout1))
                    (densityLevel ?sout1 moderate)...)
 :effect (and (not (state-to-street ?t ?sout1 red))
              (densityLevel ?sin low)...)
```

Planning problem

```
(define (problem traffic1) (:domain traffic)
  (:objects s1 ... s566 - street
            c1 ... c30 - crossing
            tl1 ... tl10 - traffic-light)
  (:init (goes-into s1 c3)
         (opposite-directions s5 s7)
         (state-from-street tl1 s7 green)
         (densityLevel s1 high)...)
  (:goal (and (densityLevel s4 low)
              (densityLevel s35 low) ...)))
```


Miles of vehicles
0
1
2
3
4
5
6
7
00:00
05:00
10:00
15:00
20:00
Hours
Week
Weekend