Department of Computer Science
UNIVERSITY OF COLORADO **BOULDER**

Reinforcement Learning for NLP

Advanced Machine Learning for NLP

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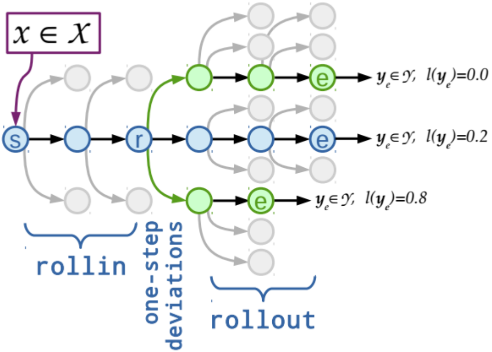
DEEP SHIFT-REDUCE PARSERS

What Makes NLP different from RL?

- Often, best actions are **known**
- We're not just searching for high-reward
- Sometimes actions themselves are known

Roll In vs. Roll Out



- Roll In: Which states does the algorithm see
- Roll Out: What states do you use for training

Known Policy vs. Exploration

roll-out → ↓ roll-in	**Reference**	**Mixture**	**Learned**
Reference	Inconsistent		
Learned	Not locally opt.	Good	RL

- RL only gets reward
- Roll-in with reference gives unrealistic trajectories
- How to incorporate knowledge of true actions?
- Train classifier as proxy for policy

RL for Translation

RL for Translation

Observation

1. Mit dem Zug

RL for Translation

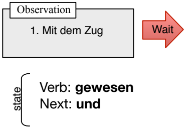
Observation

1. Mit dem Zug

state

Verb: **gewesen**
Next: **und**

RL for Translation



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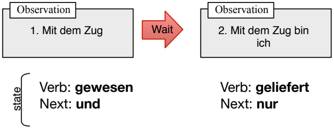

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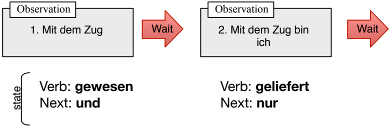

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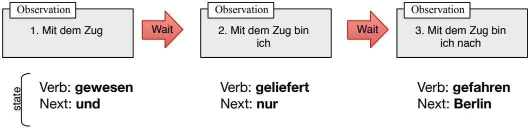

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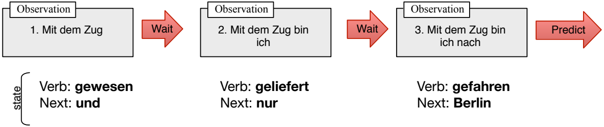

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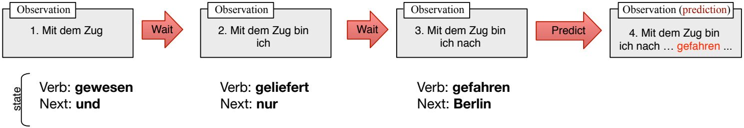

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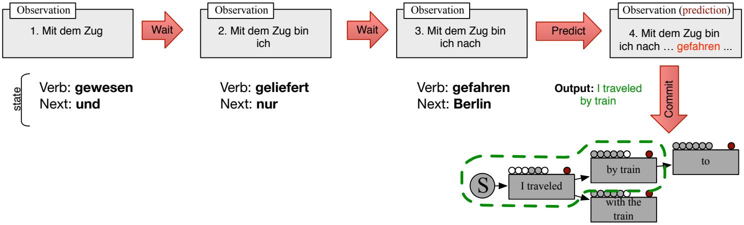

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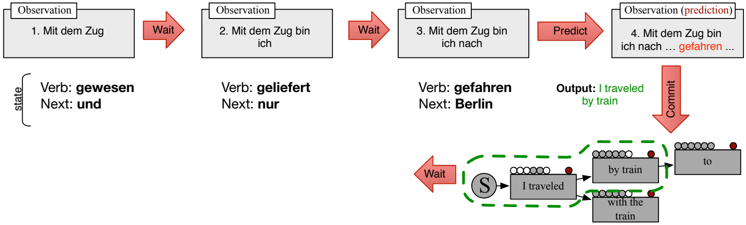

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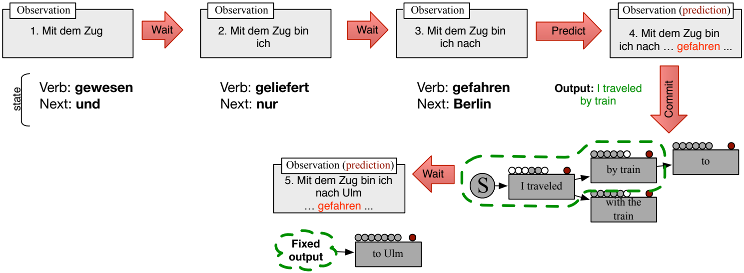

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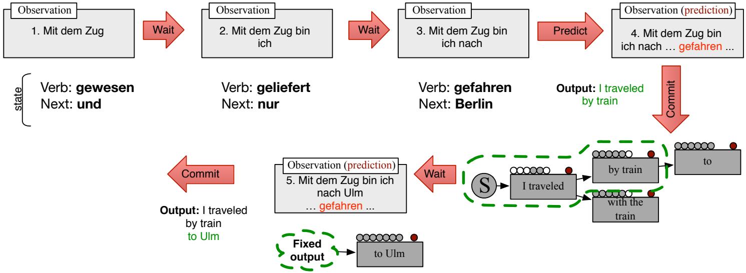

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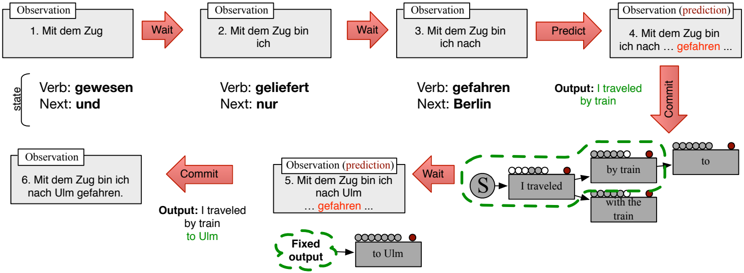

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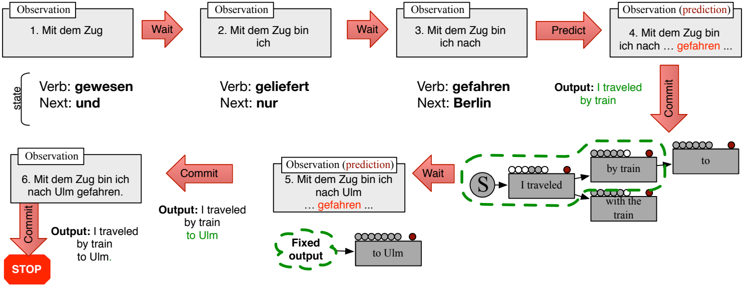

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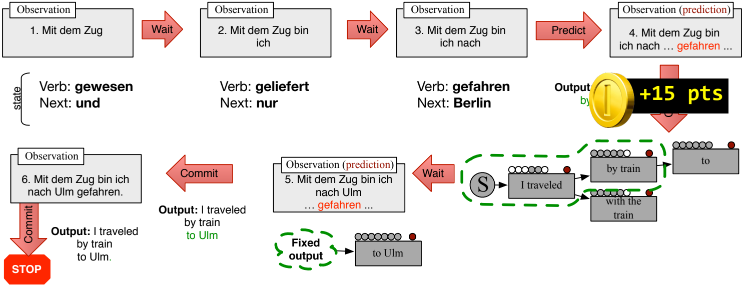

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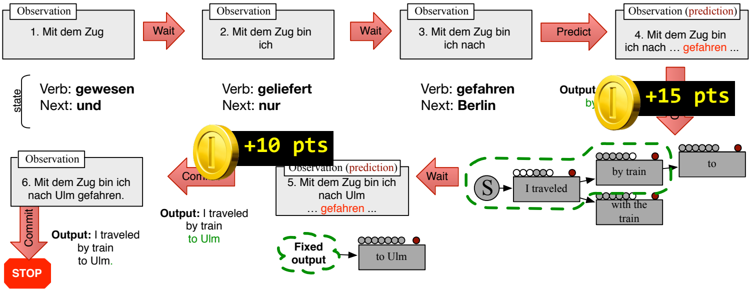

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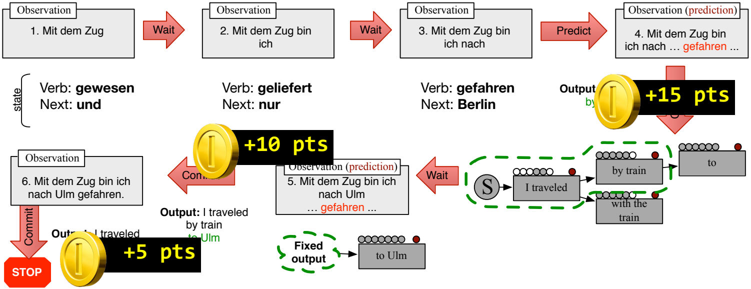
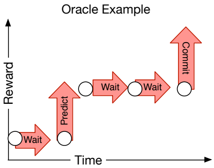


How do we find a good policy?



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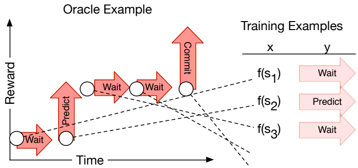

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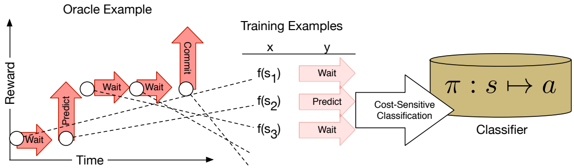

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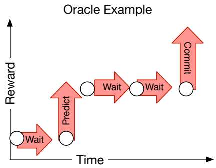

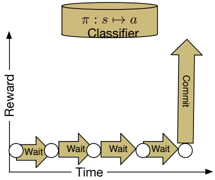

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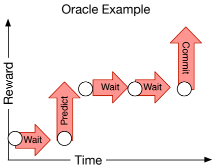

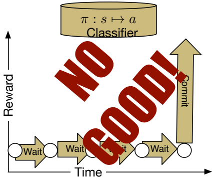

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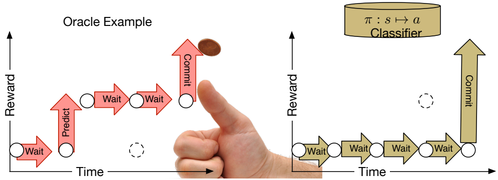

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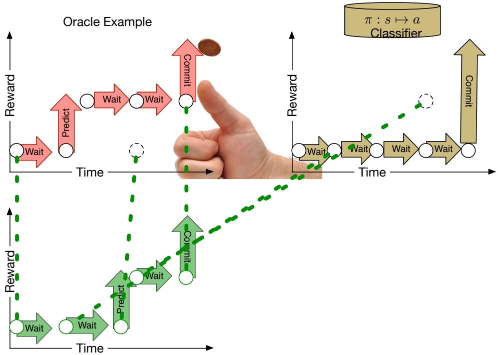

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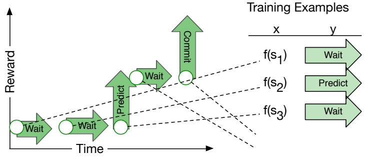

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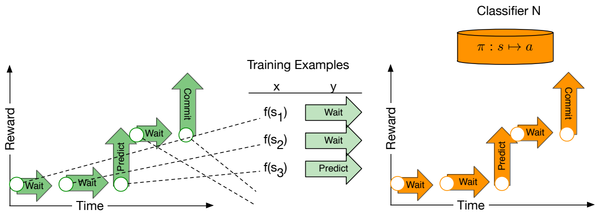


LOLS

Algorithm 1 Locally Optimal Learning to Search (LOLS)

Require: Dataset $\{\boldsymbol{x}_i, \boldsymbol{y}_i\}_{i=1}^N$ drawn from $\mathcal{D}$ and $\beta \geq 0$: a mixture parameter for roll-out.

Initialize a policy π_0.
for all $i \in \{1, 2, \dots, N\}$ (loop over each instance) **do**
    Generate a reference policy π^{ref} based on $\boldsymbol{y}_i$.
    Initialize $\Gamma = \emptyset$.
    for all $t \in \{0, 1, 2, \dots, T-1\}$ **do**
        Roll-in by executing $\pi_i^{\text{in}} = \hat{\pi}_i$ for t rounds and reach s_t.
        for all $a \in A(s_t)$ **do**
            Let $\pi_i^{\text{out}} = \pi^{\text{ref}}$ with probability β, otherwise $\hat{\pi}_i$.
            Evaluate cost $c_{i,t}(a)$ by rolling-out with π_i^{out} for $T - t - 1$ steps.
        end for
        Generate a feature vector $\Phi(\boldsymbol{x}_i, s_t)$.
        Set $\Gamma = \Gamma \cup \{\langle c_{i,t}, \Phi(\boldsymbol{x}_i, s_t)\rangle\}$.
    end for
    $\hat{\pi}_{i+1} \leftarrow \text{Train}(\hat{\pi}_i, \Gamma)$ (Update).
end for
Return the average policy across $\hat{\pi}_0, \hat{\pi}_1, \dots \hat{\pi}_N$.

LOLS on Dependency Parsing

Policy is learning actions for shift-reduce parser

roll-out → ↓ roll-in	**Reference**	**Mixture**	**Learned**
Reference is optimal			
Reference	87.2	89.7	88.2
Learned	**90.7**	90.5	86.9
Reference is suboptimal			
Reference	83.3	87.2	81.6
Learned	87.1	**90.2**	86.8
Reference is bad			
Reference	68.7	65.4	66.7
Learned	75.8	**89.4**	87.5

But what structure is best?

- RecNN not much better than DAN
- But syntax may not be optimal
- Can we learn structure?

But what structure is best?

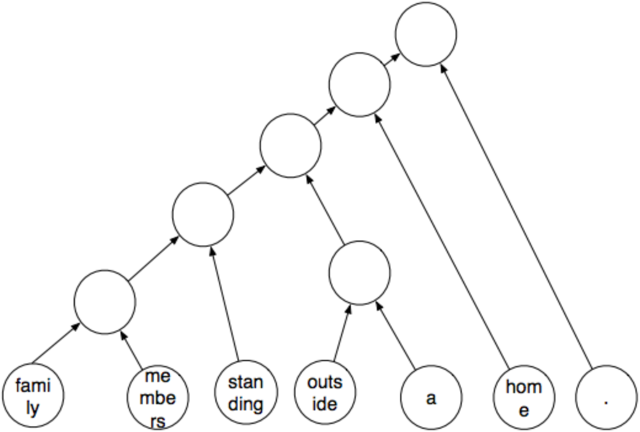
- RecNN not much better than DAN
- But syntax may not be optimal
- Can we learn structure?
    - Policy learns shift-reduce parser
    - TreeLSTM with **learned structure**
    - Reward is performance on downstream task

Performance

Table 4: Classification accuracy on SNLI dataset.

Model	Acc.	# params.
100D-Right to left	79.1	2.3m
100D-Left to right	80.2	2.3m
100D-Bidirectional	80.2	2.6m
100D-Supervised syntax	78.5	2.3m
100D-Semi-supervised syntax	80.2	2.3m
100D-Latent syntax	**80.5**	2.3m

What structures?



Other places of NLP + RL

- Question answering
- Language games
- Dialog systems
- Human learning

Wrapup

- RL allows for algorithms to think about long-term rewards
- And to guide actions of a system
- Important for systems that interact with world
- Discrete action spaces often more difficult