

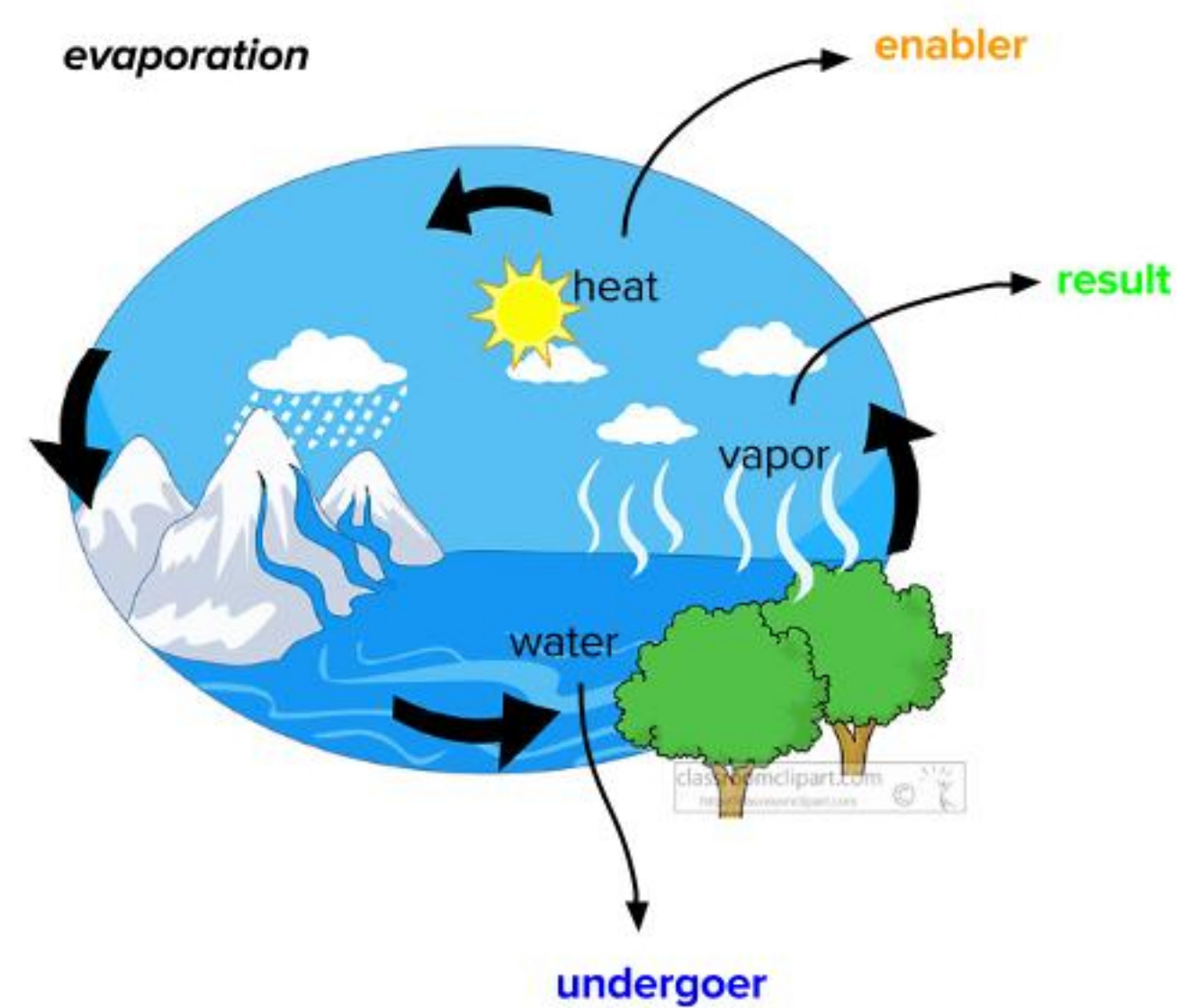
# Cross Sentence Inference for Process Knowledge

## Motivation

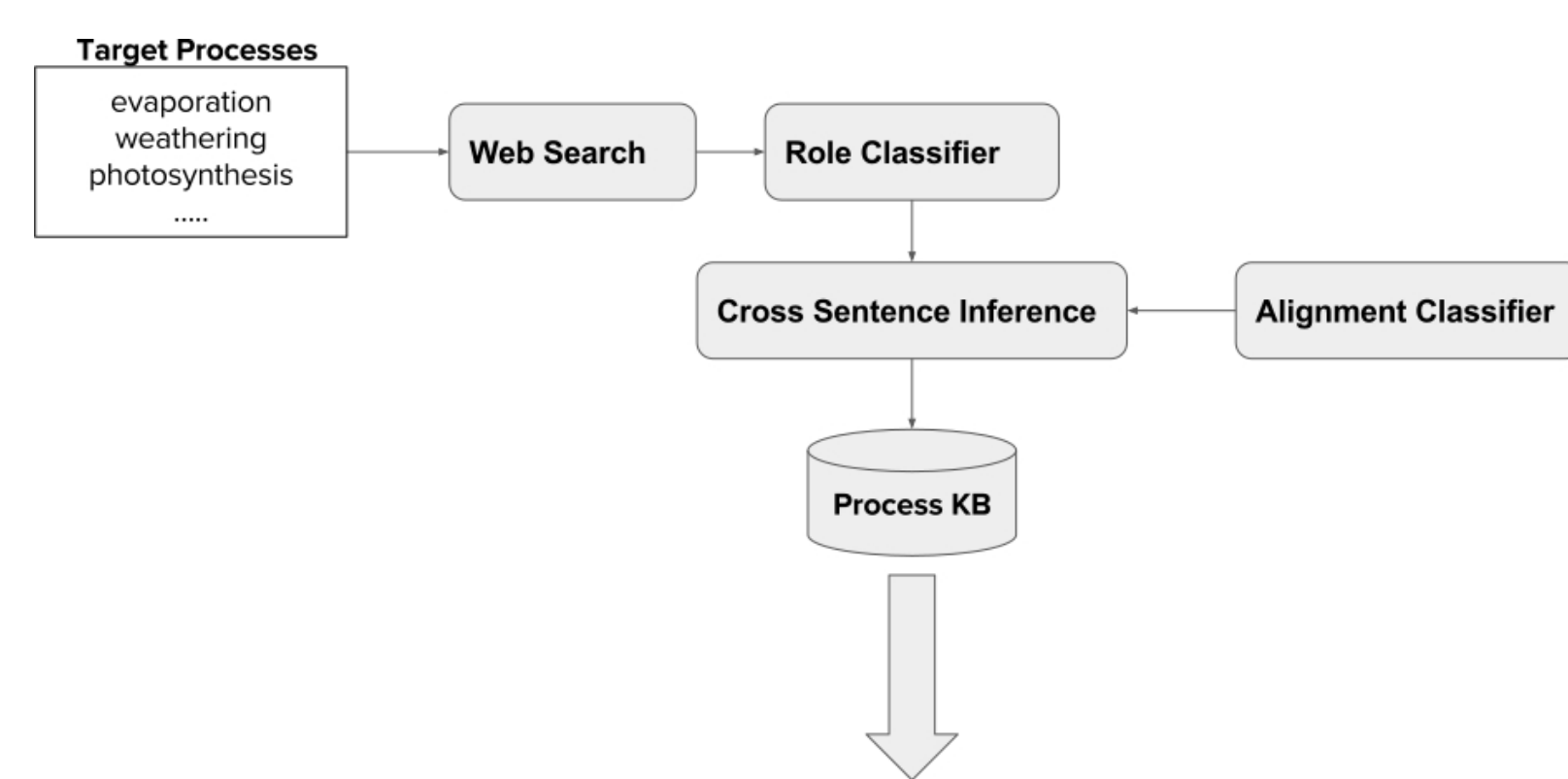
- Knowledge of processes is essential for AI systems to understand and reason about events.
- Role-based representations have been shown to be useful for NLP tasks.

## Macro Level Process Knowledge

- Processes can be characterized from its **undergoer**, **enabler**, **action**, and **result**.



- We seek to aggregate knowledge from multiple descriptions.



Process	Undergoer	Enabler	Action	Result
evaporation	liquid water	heat energy	changes convert	gas water vapor
weathering	rock solid material	weather heating	disintegration breaking down	smaller rocks particles
photosynthesis	carbon dioxide CO2	solar energy light energy	convert transforms	energy food

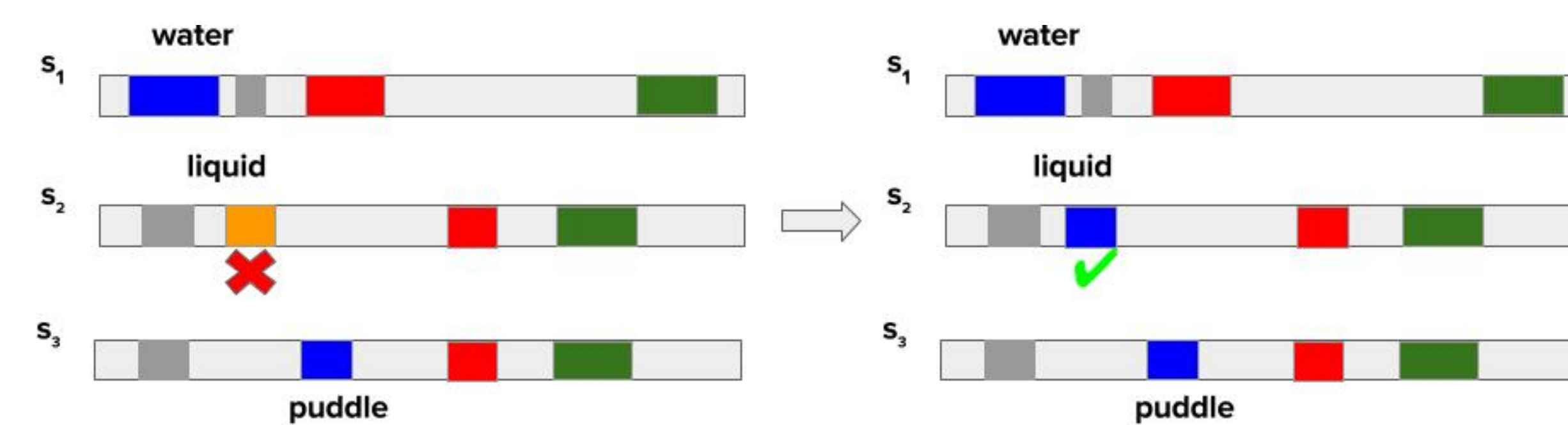
Table 1: Examples of Target Knowledge Roles

## Challenges

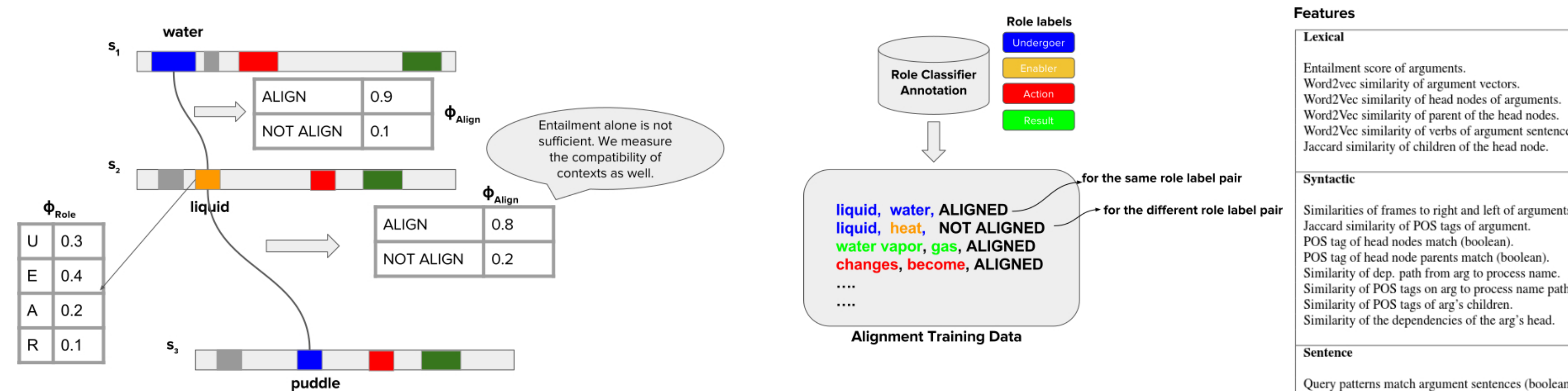
- SRL systems typically perform sentence level interpretation and may not produce globally coherent roles.
- Existing semantic role resources such as FrameNet has poor coverage of the grade science process terms.

## Cross Sentence Inference

- Given a group of sentences that describes the same process, we want to perform consistent role assignments across text spans from different sentences.



- We combine the output of role classifier and alignment classifier to find globally consistent role assignment.



- We formulate the cross sentence inference task using an Integer Linear Program (ILP)

$$\arg \max_{\mathbf{z}} \sum_k \sum_{i,j} z_{ijk} \left( \lambda \overbrace{\phi_{role}(a_{ij}, k)}^{\text{role classifier score}} + (1 - \lambda) \left[ \Delta(a_{ij}, k) - \nabla(a_{ij}, k) \right] \right)$$

$$\Delta(a_{ij}, k) = \frac{1}{\tilde{N}_k} \sum_{l,m} z_{lmk} \phi_{align}(a_{ij}, a_{lm})$$

Average similarity of other spans w/ the same role k

$$\nabla(a_{ij}) = \frac{2}{\tilde{N}_{k'}} \sum_{l,m} \sum_{n \neq k} z_{lmn} \phi_{align}(a_{ij}, a_{lm})$$

Average similarity of other spans / role = k

subject to :

$$\sum_j z_{ijk} \leq 1 \quad \forall a_{ij} \in \text{sentence}_i, k \in \mathbf{R}$$

cannot assign more than one role to an argument span

$$\sum_k z_{ijk} \leq 1 \quad \forall a_{ij} \in \text{sentence}_i$$

a role can only occur once in the sentence

where  $z_{ijk} \in \{0, 1\}$

## Dataset

- Compiled the target processes from New York Regents science exams, helpsteaching.com
- Consist of 537 sentences with 54 processes and 1205 role fillers (manually annotated).
- Data : <https://github.com/StonyBrookNLP/spock>

## Results

- Cross sentence inference provides additional gain beyond within sentence inference

Method	Prec.	Rec.	F1
Role mapping	56.62	59.60	58.07
SEMAFOR	40.72	50.54	45.10
Role class. ( $\phi_{role}$ )	78.48	<b>78.62</b>	78.55
+ within sent.	86.25	73.91	79.60
+ cross sent.	<b>89.84</b>	75.36	<b>81.97++</b>

Table 2: Process role inference performance.

- Argument entailment alone only produces a minor improvement. Alignment classifier scores are much more effective.

Method	Prec.	Rec.	F1
within sent.	86.25	73.91	79.60
+ Entailment			
cross sent. w/ $\Delta + \nabla$	86.62	73.91	79.76
+ Alignment Classifier			
cross sent. w/ $\Delta + \nabla$	<b>89.84</b>	75.36	<b>81.97++</b>

Table 3: Performance impact of inference components.

## Conclusion

- Cross sentence inference using an Integer Linear Program helps improve the accuracy of process knowledge extraction
- Compatibility can be effectively assessed using an alignment classifier built without any additional supervision