GRASP: RANDOMISED SEMIRING PARSING

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WHAT'S GRASP ABOUT?

Open source

- semiring parsing
- weighted deduction
- approximate forest rescoring
- inference by **sampling**

https://github.com/wilkeraziz/grasp

DEDUCTIVE PARSING

Abstracts away from implementation details.

- **items** represent intermediate results in the deduction process
- $\frac{A_1 \ldots A_k}{B} C_1 \ldots C_j$ is a deduction rule
- **item derivations**
  - $D = \langle r \rangle$ where r is a **grammar rule**
  - $D = \langle b : D_{a_1}, \ldots, D_{a_k} \rangle$ where $\frac{a_1 \ldots a_k}{b} c_1 \ldots c_j$ is an instantiation of $\frac{A_1 \ldots A_k}{B} C_1 \ldots C_j$ and $D_{a_1}, \ldots, D_{a_k}$ are item derivations

Hypergraph representation

- *items* are mapped to **nodes**
- $\frac{a_1 \ldots a_k}{b} c_1 \ldots c_j$ are mapped to **edges**
  - b is mapped to a **head** node
  - $a_1 \ldots a_k$ are mapped to **tail** nodes

SEMIRING PARSING

The same deductive parser, multiple tasks!

FOREST	parse forest
VITERBI	max
INSIDE	sum
BOOLEAN	recognition
COUNTING	counting
1-BEST	argmax
K-BEST	top derivations

Value recursion

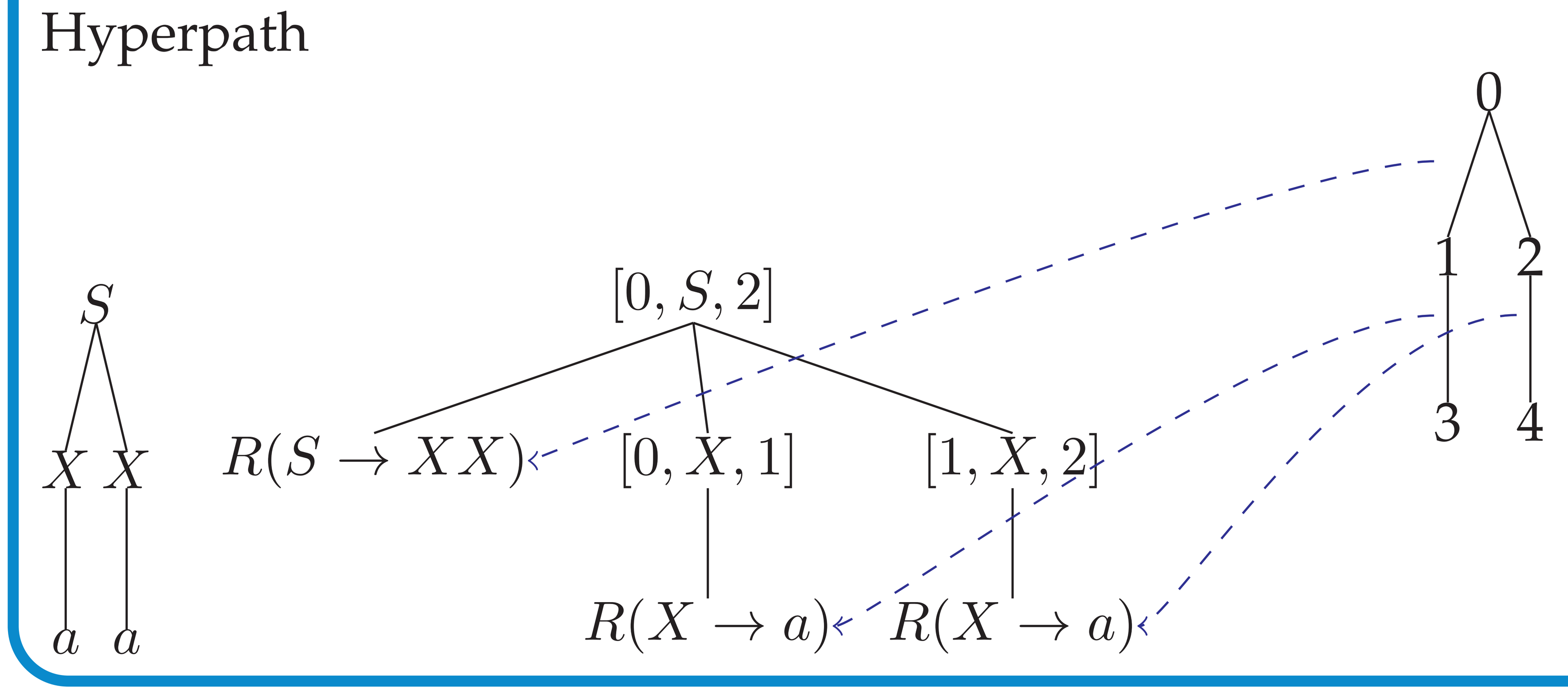
$$V(D) = \bigotimes_{i=1}^{j} R(d_i)$$

- where D is an item derivation
- $\text{yield}(D) = d_1 \ldots d_j$ is a grammar derivation
- $R(r)$ is the value of grammar rule r

$$V(D) = \begin{cases} R(r) & \text{if } D = \langle r \rangle \\ \bigotimes_{i=1}^{k} V(D_i) & \text{if } D = \langle b : D_1 \ldots D_k \rangle \end{cases}$$

DERIVATIONS

Grammar derivation
Item derivation
Hyperpath



SLICE SAMPLING

Sample probabilistically from a distribution proportional to $f(\mathbf{d})$

- **non-negative** function over derivations $\mathbf{d} \in \mathcal{D}$
- $\langle \mathcal{D}, f(\mathbf{d}) \rangle$ is represented by a **hypergraph**
- a derivation $\mathbf{d} = \langle e_1, \ldots, e_m \rangle$ is a sequence of m steps (edges)
- $r_h \in \mathbf{d}$ refers to an edge headed by h whose underlying rule is r

$$f(\mathbf{d}) = \psi(\mathbf{d}) \times \theta(\mathbf{d}) = \psi(\mathbf{d}) \times \prod_{r_h \in \mathbf{d}} \theta_{r_h}$$

Data augmentation and *slice sampling*

$$f(\mathbf{d}, \mathbf{u}) = \psi(\mathbf{d}) \prod_{u_h : r_h \in \mathbf{d}} \delta_{(0, \theta_{r_h})}(u_h) \prod_{u_h \in r_h \notin \mathbf{d}} \phi(u_h; \boldsymbol{\alpha})$$

u: one auxiliary variable per item

Gibbs sampling

$$f(u_s | \mathbf{d}) = \begin{cases} \frac{\delta_{(0,\theta_{r_h})}(u_h)}{\theta_{r_h}} & \text{if } r_h \in \mathbf{d} \\ \phi(u_h; \boldsymbol{\alpha}) & \text{otherwise} \end{cases}$$

$$f(\mathbf{d}|\mathbf{u}) \propto \psi(\mathbf{d}) \prod_{r_h \in \mathbf{d}} \frac{\delta_{(0,\theta_{r_h})}(u_h)}{\phi(u_h; \boldsymbol{\alpha})}$$

Sampling from the $f(\mathbf{d}|\mathbf{u})$

- rescore the slice exactly (if $\psi(\mathbf{d})$ is simple enough)
- estimate an empirical distribution
  - uniform sampling
  - importance sampling

SLICE: SUBSET OF $\mathcal{D}$ WHERE $f(\mathbf{d}|\mathbf{u}) > 0$

ITEM FORMS	$R(X \to \alpha)$, $T\left(q \xrightarrow{x} r\right)$, $[X \to \alpha \bullet \beta, q, s]$ and $\langle X; q, r \rangle$
GOAL	$\langle S'; q, r \rangle \quad q \in I, r \in F$
AXIOMS	$\frac{}{[S' \to \bullet S, q, q]} \quad q \in I$
PREDICT	$\frac{R\left(Y \xrightarrow{\theta} \gamma\right)}{\left[Y \xrightarrow{\theta} \bullet\gamma, r, r\right]} \quad [X \to \alpha \bullet Y\beta, q, r]$
SCAN	$\frac{T\left(r \xrightarrow{x/\omega} s\right) \quad \left[X \xrightarrow{\theta} \alpha \bullet x\beta, q, r\right]}{\left[X \xrightarrow{\omega \otimes \theta} \alpha x \bullet \beta, q, s\right]}$
COMPLETE	$\frac{\left[X \xrightarrow{\theta} \alpha \bullet Y\beta, q, r\right] \quad \langle Y; r, s \rangle}{\left[X \xrightarrow{\theta} \alpha Y_{r,s} \bullet \beta, q, s\right]}$
CONVERT	$\frac{\left[X \xrightarrow{\theta} \alpha\bullet, q, r\right]}{\langle X; q, r \rangle} \quad \theta > u_{X_{q,r}}$

Key: auxiliary variables are **lazily sampled** $u_h \sim f(u_h|\mathbf{d})$

FEATURES

Grammar formalism	epsilon-free CFG
Weighted deduction	bottom-up and top-down (exact and sliced)
Forest rescoring	top-down (exact and sliced)
Real-valued semirings	BOOLEAN, COUNTING, VITERBI, INSIDE
Value recursion	robust to cycles
Derivation semirings	1-BEST, k-BEST, SAMPLE, FOREST, SLICE
Sampling algorithms	ancestral sampling, slice sampling
LM queries	kenlm
Applications	constituency parsing, decoding for hiero models

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