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Learning Languages by Contextual Information

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Grammatical Inference

- Algorithmic learning of formal languages
- Mathematical model of language acquisition
- Natural language processing, biological sequences etc...

Multiple Context-Free Languages

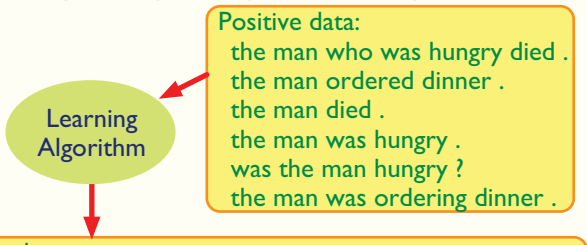
- Mild extension of CFLs
- Polynomial-time parsable
- "Cross serial dependencies" in natural languages
- "Pseudoknots" in RNA sequences

ex. $\{ a^m b^n c^m d^n \mid n,m > 0 \}$, $\{ ww \mid w \in \Sigma^* \}$

Substitutable Context-Free Languages

- Clark & Eyraud (2007)
- Efficiently learnable from positive data

$x_1y_1z_1,\ x_1y_2z_1,\ x_2y_1z_2 \in L \Rightarrow x_2y_2z_2 \in L$



Learning from positive data:

The learner conjectures a language from positive examples from the target language.

Learning from positive data and membership queries:

Besides the learner can ask the teacher whether an arbitrary sentence is in the target language.

MCFL

p-dimensionally substitutable MCFLs (our work)

$w_0x_1w_1\ldots x_kw_k,\ w_0z_1w_1\ldots z_kw_k,\ y_0x_1y_1\ldots x_ky_k \in L$
$\Rightarrow y_0z_1y_1\ldots z_ky_k \in L$ for $k \leqq p$.

ex. $\{ a^m bc^n de^m fg^n \mid n,m \geqq 0 \}$,
$\{ a_1^n b_1 c_1^n d_1 \ldots a_p^n b_p c_p^n d_p \mid n \geqq 0 \}$

Various kinds of MCFLs (our work)

Including all CFLs by Clark et al. ('08) and p-dimensionally SCFLs and other MCFLs.

CFL

k,l-substitutable CFLs (our work)

$x_1uy_1vz_1,\ x_1uy_2vz_1,\ x_2uy_1vz_2 \in L \Rightarrow x_2uy_2vz_2 \in L$

where $|u| = k$, $|v| = l$.

ex. $\{ a^n b^n \mid n > 0 \}$, $\{ a^n cb^n \mid n > 0 \}$,
$\{ wcw^R \mid w \in \{a,b\}^* \}$, $\{ w\bar{w}^R \mid w \in \Sigma^+ \}$

Various kinds of CFLs (Clark et al. '08)

Including all k,l-substitutable CFLs, regular languages, Dyck languages, etc.

Substitutable CFLs (Clark & Eyraud '07)

Regular

k-reversible languages (Angluin '82)

$x_1vy_1,\ x_1vy_2,\ x_2vy_1 \in L \Rightarrow x_2vy_2 \in L$ for $|v| = k$

0-reversible languages (Angluin '82)

$x_1y_1,\ x_1y_2,\ x_2y_1 \in L \Rightarrow x_2y_2 \in L$