Feature-based Parsing

Deep Processing for NLP
Ling 571
February 5, 2014

Roadmap

- Features: Motivation
  - Constraint & compactness
- Features
  - Definitions & representations
- Unification
- Application of features in the grammar
  - Agreement, subcategorization
- Parsing with features & unification
  - Augmenting the Earley parser, unification parsing
- Extensions: Types, inheritance, etc
- Conclusion

Constraints & Compactness

- Constraints in grammar
  - S → NP VP
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  - Violate agreement (number), subcategorization

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  - Explosive!, loses key generalizations

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- Augment CF rules with feature constraints
  - Develop mechanism to enforce consistency
  - Elegant, compact, rich representation

Feature Representations

- Fundamentally, Attribute-Value pairs
  - Values may be symbols or feature structures
    - Feature path: list of features in structure to value
    - “Reentrant feature structures”: share some struct
  - Represented as
    - Attribute-value matrix (AVM), or
    - Directed acyclic graph (DAG)

AVM

$$\begin{pmatrix} \text{NUMBER} & \text{PL} \end{pmatrix}$$

$$\begin{pmatrix} \text{PERSON} & 3 \end{pmatrix}$$

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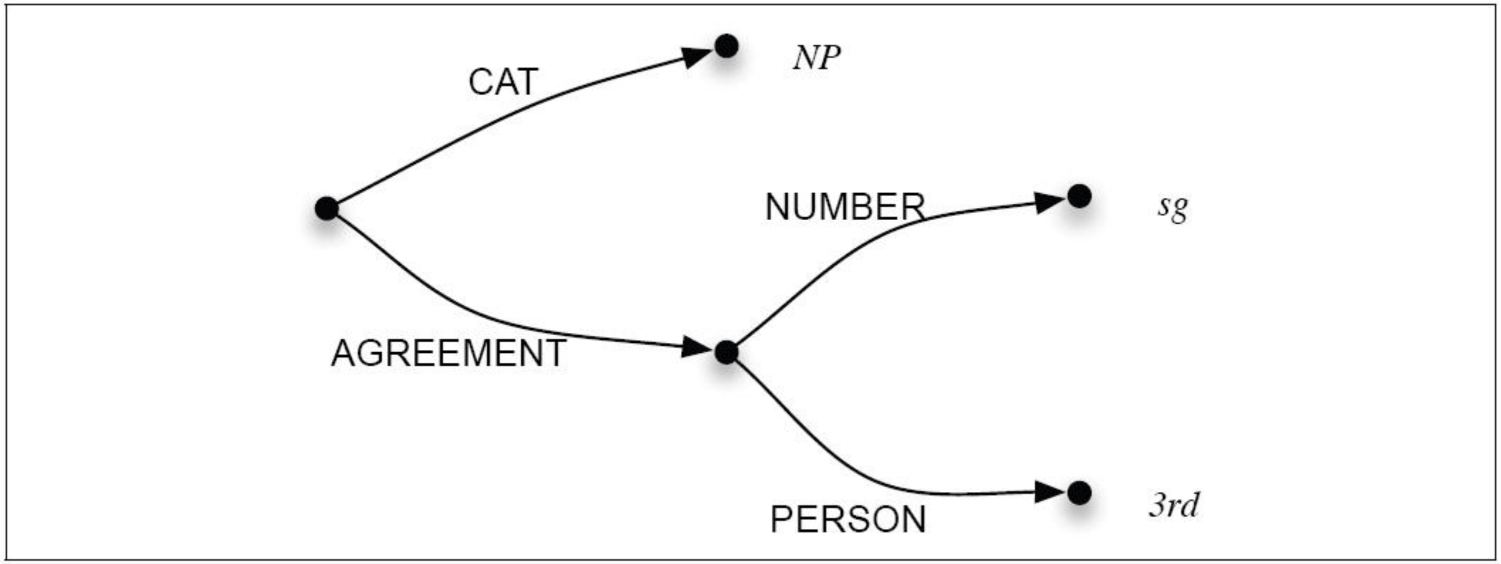
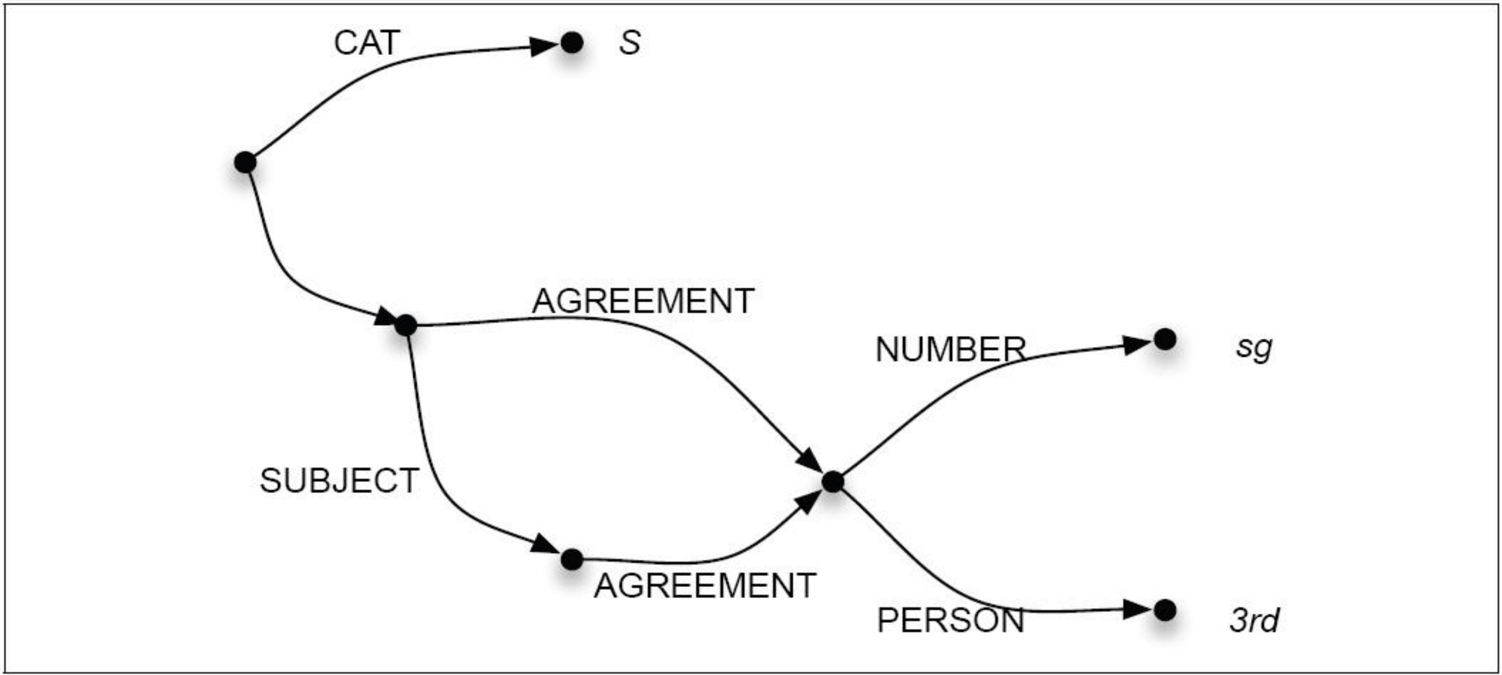
$$\begin{pmatrix} \text{CAT} & \text{NP} \\ \text{NUMBER} & \text{PL} \\ \text{PERSON} & 3 \end{pmatrix}$$

$$\begin{pmatrix} \text{CAT} & \text{NP} \\ \text{AGREEMENT} & \begin{pmatrix} \text{NUMBER} & \text{PL} \\ \text{PERSON} & 3 \end{pmatrix} \end{pmatrix}$$

$$\begin{pmatrix} \text{CAT} & \text{S} \\ \text{HEAD} & \begin{pmatrix} \text{AGREEM'T} & \boxed{1} \begin{pmatrix} \text{NUMBER} & \text{PL} \\ \text{PERSON} & 3 \end{pmatrix} \\ \text{SUBJECT} & \begin{pmatrix} \text{AGREEMENT} & \boxed{1} \end{pmatrix} \end{pmatrix} \end{pmatrix}$$


CAT
NP
NUMBER
sg
AGREEMENT
PERSON
3rd


CAT
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Unification

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  - Feature structures are identical
    - Result in same structure
  - Feature structures match where both have values, differ in missing or underspecified
    - Resulting structure incorporates constraints of both

Subsumption

- Relation between feature structures
  - Less specific f.s. subsumes more specific f.s.
  - F.s. F subsumes f.s. G iff
    - For every feature x in F, F(x) subsumes G(x)
    - For all paths p and q in F s.t. F(p)=F(q), G(p)=G(q)

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- Examples:
  - A: [Number SG], B: [Person 3]
  - C:[Number SG]
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- Examples:
  - A: [Number SG], B: [Person 3]
  - C:[Number SG]
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  - A subsumes C; B subsumes C; B,A don't subsume
    - Partial order on f.s.

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  - [Person 3]
- Mismatched
  - [Number SG] U [Number PL] → Fails!

More Unification Examples

$$\begin{bmatrix} \text{AGREEMENT} & [1] \\ \text{SUBJECT} & \begin{bmatrix} \text{AGREEMENT} & [1] \end{bmatrix} \end{bmatrix} \quad \text{U}$$

$$\begin{bmatrix} \text{SUBJECT} & \begin{bmatrix} \text{AGREEMENT} & \begin{bmatrix} \text{PERSON} & 3 \\ \text{NUMBER} & \text{SG} \end{bmatrix} \end{bmatrix} \end{bmatrix} \quad =$$

$$\begin{bmatrix} \text{AGREEMENT} & [1] \\ \text{SUBJECT} & \begin{bmatrix} \text{AGREEMENT} & [1] \begin{bmatrix} \text{PERSON} & 3 \\ \text{NUMBER} & \text{SG} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Features in CFGs: Agreement

- Goal:
    - Support agreement of NP/VP, Det Nominal
- Approach:
    - Augment CFG rules with features
    - Employ head features
        - Each phrase: VP, NP has head
            - Head: child that provides features to phrase
                - Associates grammatical role with word
                - VP – V; NP – Nom, etc

Agreement with Heads and Features

VP → Verb NP

NP → Det Nominal

Nominal → Noun

Noun → flights

Verb → serves

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Noun → flights
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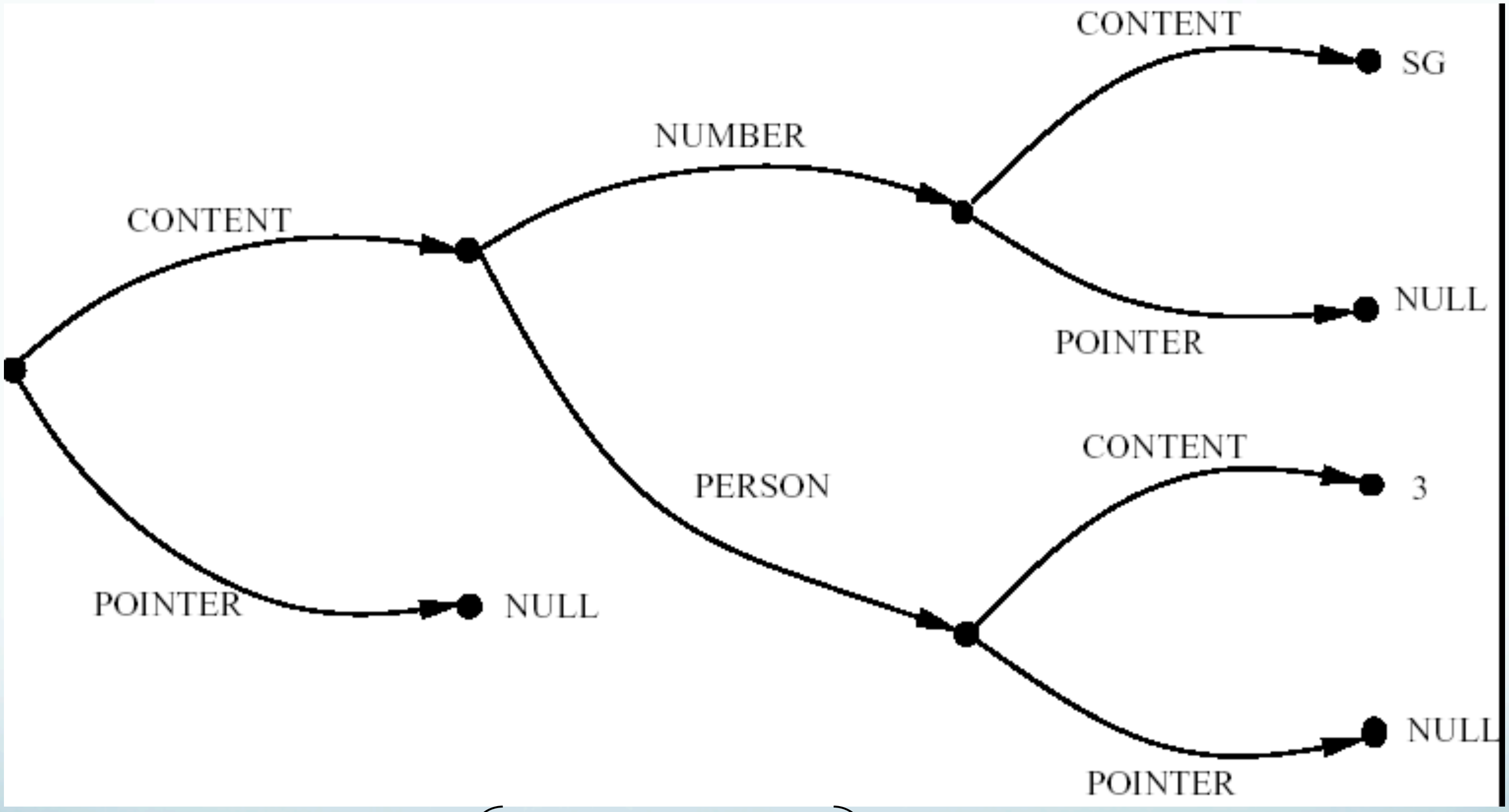
Verb → serves
<Verb HEAD AGREEMENT NUMBER> = SG
<Verb HEAD AGREEMENT PERSON> = 3

Feature Applications

- Subcategorization:
  - Verb-Argument constraints
    - Number, type, characteristics of args (e.g. animate)
    - Also adjectives, nouns
- Long distance dependencies
  - E.g. filler-gap relations in wh-questions, rel

Implementing Unification

- Data Structure:
  - Extension of the DAG representation
  - Each f.s. has a content field and a pointer field
    - If pointer field is null, content field has the f.s.
    - If pointer field is non-null, it points to actual f.s.



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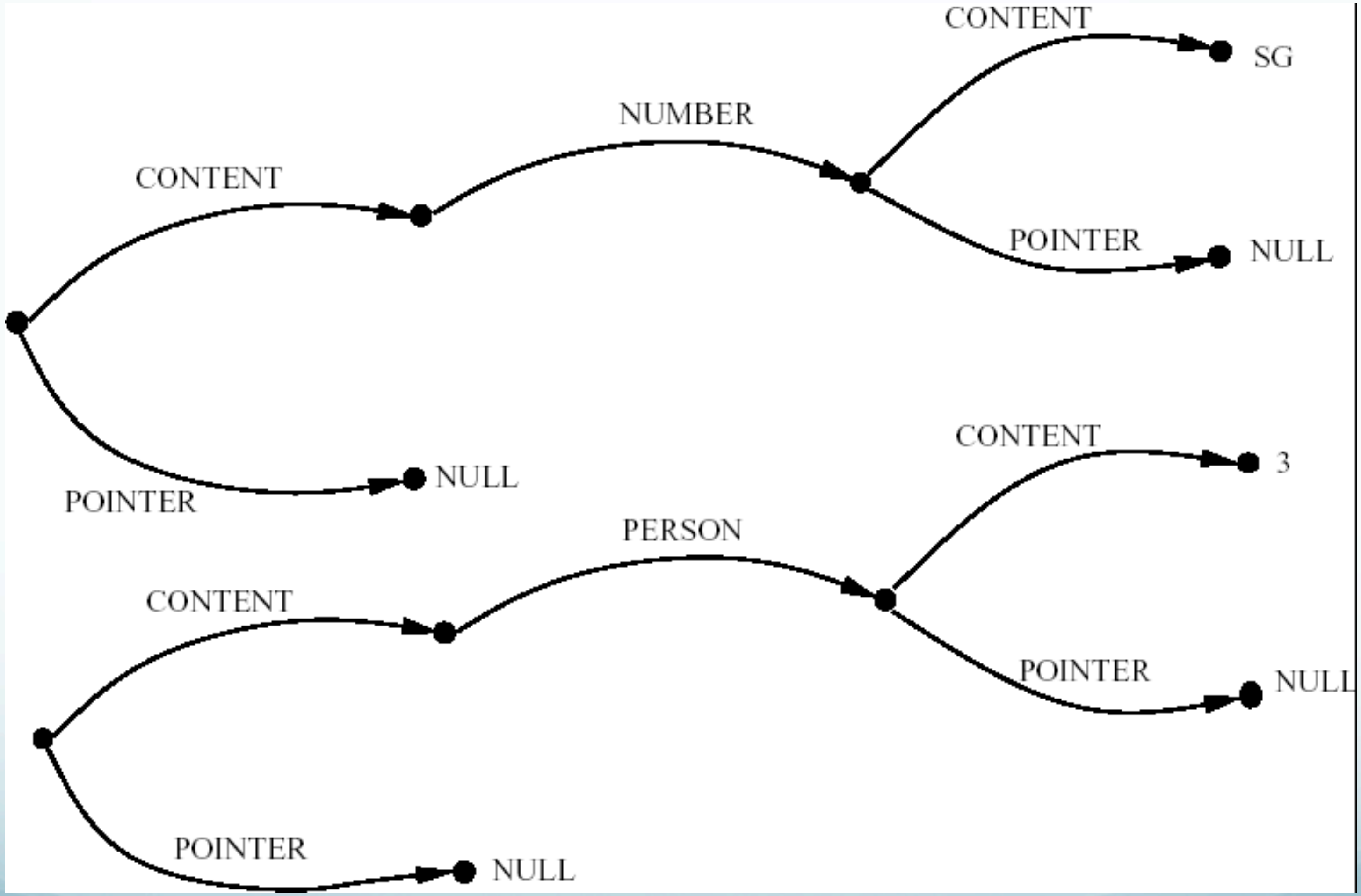
CONTENT
SG
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3
PERSON
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POINTER
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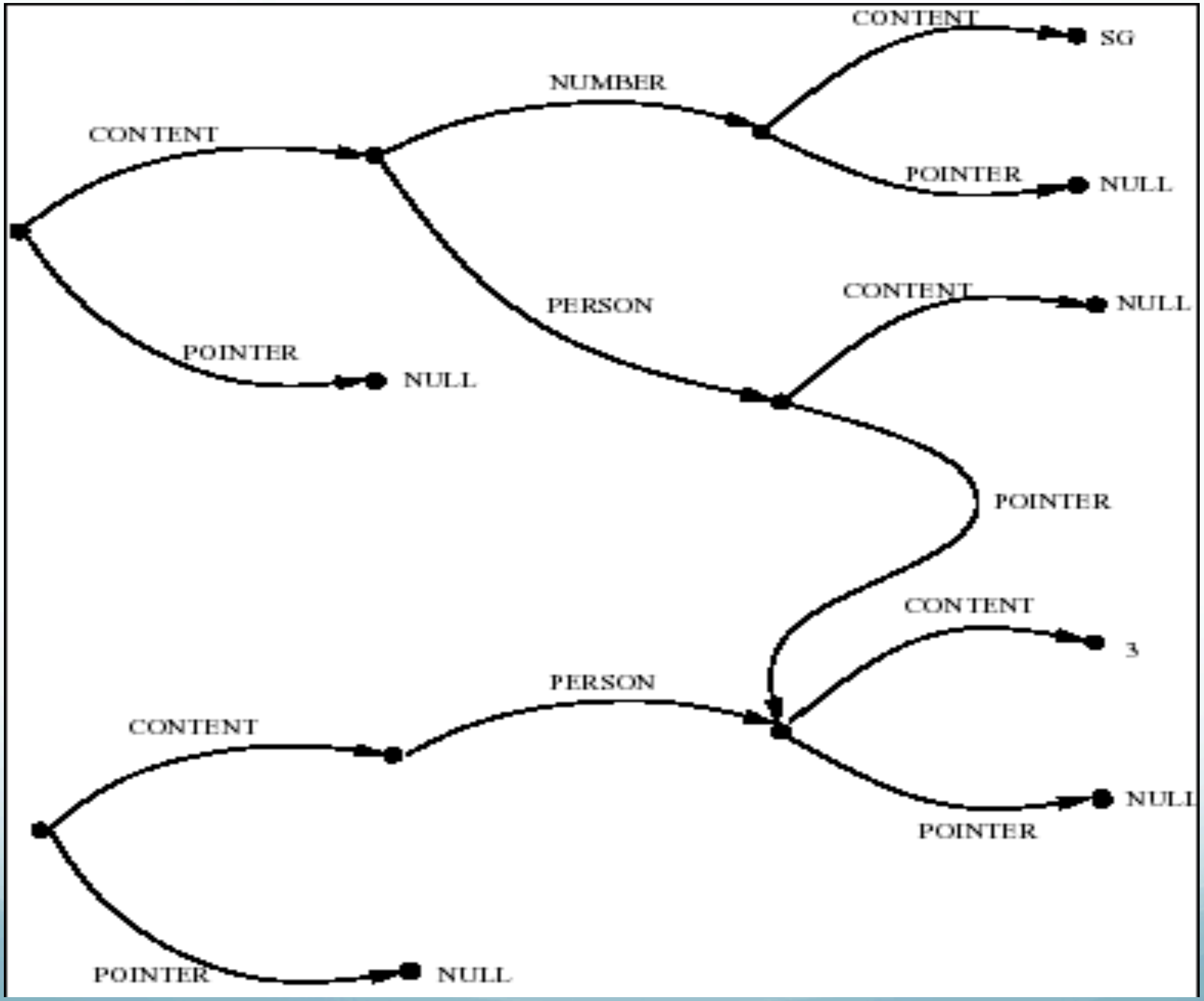
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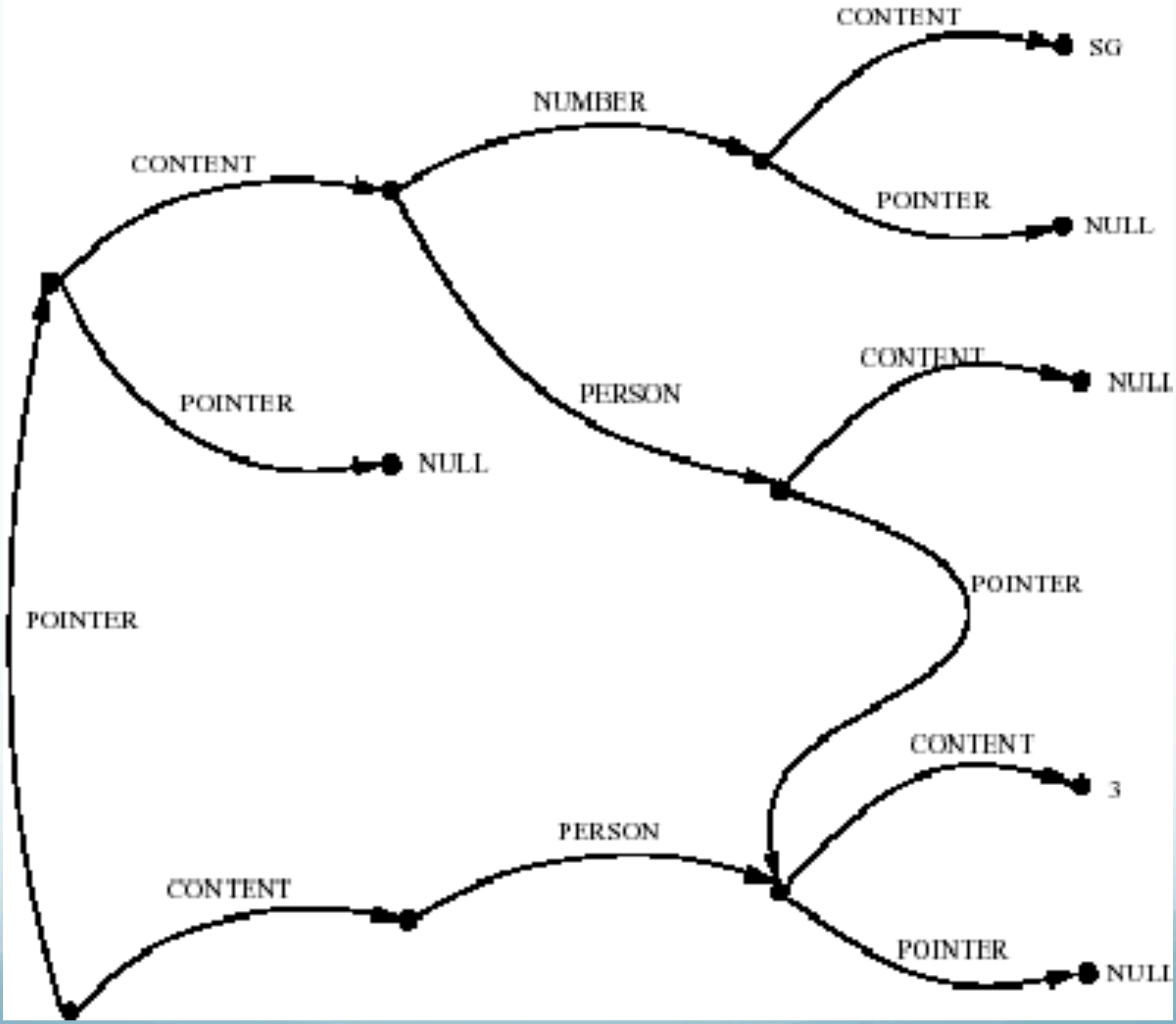
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    - Subsequent updates will update both
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  - If non-identical atomic values, fail!

Implementing Unification: III

- If non-identical, complex structures
  - Recursively traverse all features of fs2
  - If feature in fs2 is missing in fs1
    - Add to fs1 with value null
  - If all unify, point fs2 to fs1 and return fs1

Example

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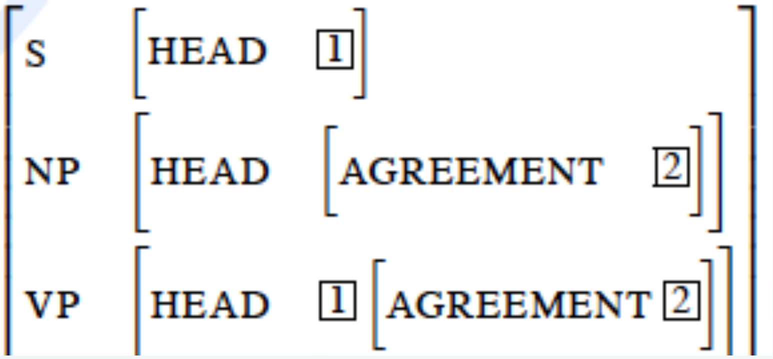
    - Prediction adds DAG from rule
    - Completion applies unification (on copies)
      - Adds entry only if current DAG is NOT subsumed

Example Rule & State

- S → NP VP
  - <NP HEAD AGREEMENT> = <VP HEAD AGREEMENT>
  - <S HEAD> = <VP HEAD>

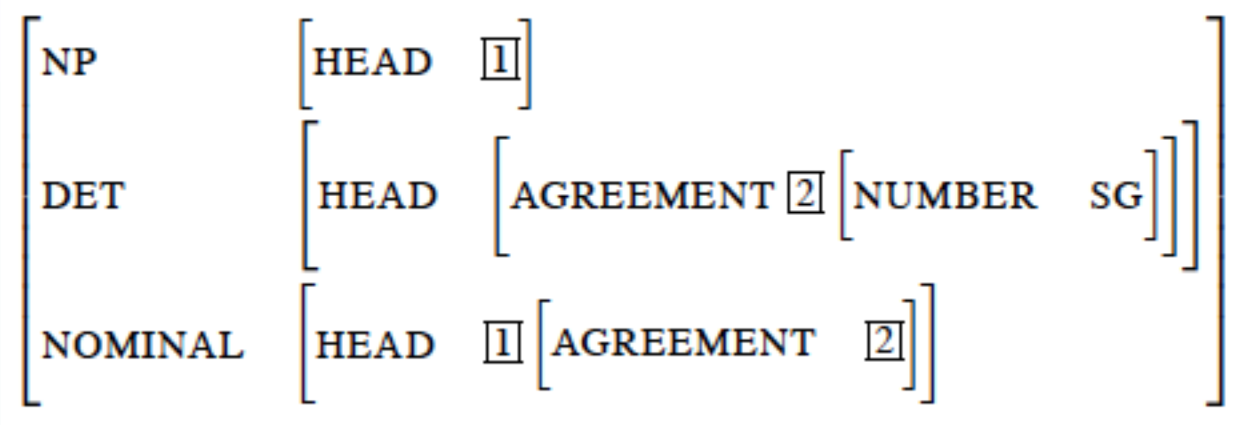


$$\begin{bmatrix} \text{S} & \begin{bmatrix} \text{HEAD} & \boxed{1} \end{bmatrix} \\ \text{NP} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{AGREEMENT} & \boxed{2} \end{bmatrix} \end{bmatrix} \\ \text{VP} & \begin{bmatrix} \text{HEAD} & \boxed{1} \begin{bmatrix} \text{AGREEMENT} & \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

- Prediction: S→• NP VP, [0,0],[],Dag

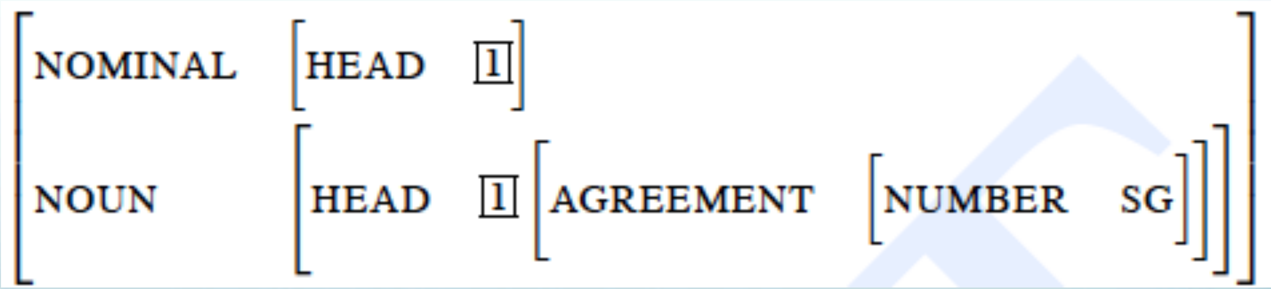
Example Completion

- Existing state: NP → Det • Nominal, [0,1],[S_{det}],Dag_1
- Dag_1:



$$\begin{bmatrix} \text{NP} & \begin{bmatrix}\text{HEAD} & \boxed{1}\end{bmatrix} \\ \text{DET} & \begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{AGREEMENT} & \boxed{2}\begin{bmatrix}\text{NUMBER} & \text{SG}\end{bmatrix}\end{bmatrix}\end{bmatrix} \\ \text{NOMINAL} & \begin{bmatrix}\text{HEAD} & \boxed{1}\begin{bmatrix}\text{AGREEMENT} & \boxed{2}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

- Completed state: Nominal → Noun•,[1,2],[S_{noun}],Dag_2
- Dag_2:



$$\begin{bmatrix} \text{NOMINAL} & \begin{bmatrix}\text{HEAD} & \boxed{1}\end{bmatrix} \\ \text{NOUN} & \begin{bmatrix}\text{HEAD} & \boxed{1}\begin{bmatrix}\text{AGREEMENT} & \begin{bmatrix}\text{NUMBER} & \text{SG}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

Unification Parsing

- Abstracts over categories
  - S → NP VP →
    - X0 → X1 X2; <X0 cat> = S; <X1 cat>=NP;
    - <X2 cat>=VP
  - Conjunction:
    - X0 → X1 and X2; <X1 cat> = <X2 cat>;
    - <X0 cat>=<X1 cat>
- Issue: Completer depends on categories
- Solution: Completer looks for DAGs which unify with the just-completed state' s DAG

Extensions

- Types and inheritance
  - Issue: generalization across feature structures
    - E.g. many variants of agreement
      - More or less specific: 3rd vs sg vs 3rdsg

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  - Approach: Type hierarchy
    - Simple atomic types match literally
    - Multiple inheritance hierarchy
      - Unification of subtypes is most general type that is more specific than two input types
    - Complex types encode legal features, etc

Conclusion

- Features allow encoding of constraints
  - Enables compact representation of rules
  - Supports natural generalizations

- Unification ensures compatibility of features
  - Integrates easily with existing parsing mech.

- Many unification-based grammatical theories