

Computational Linguistics

CSC 2501 / 485
Fall 2018

4

Assignment Project Exam Help

4. Extending grammars with features

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Reading: Jurafsky & Martin: 12.3.4–6, 15.0–3;
[Allen: 4.1–5]; Bird et al: 9.

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Agreement and inflection

- Problem: **Agreement** phenomena.

*Nadia {washes/***wash**} the dog.*

*The boys {***washes**/wash} the dog.*

*You {***washes**/wash} the dog.*

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- **Morphological inflection** of verb must match subject noun in person and number.

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Subject–verb agreement 1

Present tense

| | Singular | Plural |
|---|-------------------------|------------------|
| 1 | <i>I wash</i> | <i>we wash</i> |
| 2 | <i>you wash</i> | <i>you wash</i> |
| 3 | <i>he/she/it washes</i> | <i>they wash</i> |
| 1 | <i>I am</i> | <i>we are</i> |
| 2 | <i>you are</i> | <i>you are</i> |
| 3 | <i>he, she, it is</i> | <i>they are</i> |

Subject–verb agreement 2

Past tense

| | Singular | Plural |
|---|---------------------------|--------------------|
| 1 | <i>I washed</i> | <i>we washed</i> |
| 2 | <i>you washed</i> | <i>you washed</i> |
| 3 | <i>he, she, it washed</i> | <i>they washed</i> |
| 1 | <i>I was</i> | <i>we were</i> |
| 2 | <i>you were</i> | <i>you were</i> |
| 3 | <i>he, she, it was</i> | <i>they were</i> |

Agreement features 1

- English agreement rules are fairly simple.
 - Subject : verb w.r.t. person and number.
 - No agreement required between verb and object.
- Many languages have other agreements.
 - *E.g.*, German: Article and adjective ending depends on noun gender and case:

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Agreement features 2

Nominative Case (Subject Case)

| Masculine | Feminine | Neuter | Plural |
|------------|------------|------------|------------|
| der | die | das | die |

der neu**e** Wagen

the new car

die schön**e** Stadt

the beautiful city

das alt**e** Auto

the old car

die neu**en** Bücher

the new books

| Masculine | Feminine | Neuter | Plural |
|------------|-------------|------------|--------------|
| ein | eine | ein | keine |

ein neu**er** Wagen

a new car

eine schön**e** Stadt

a beautiful city

ein alt**es** Auto

an old car

keine neu**en** Bücher

no new books

Ask about.com: German language: Adjective endings I and II.
<http://german.about.com/library/weekly/aa030298.htm> and
[aa033098.htm](http://german.about.com/library/weekly/aa033098.htm)

Agreement features 2

Accusative Case (Direct Object)

| Masculine | Feminine | Neuter | Plural |
|------------|------------|------------|------------|
| den | die | das | die |

den neu**en** Wagen

the new car

die schön**e** Stadt

the beautiful city

das alt**e** Auto

the old car

die neu**en** Bücher

the new books

| Masculine | Feminine | Neuter | Plural |
|--------------|-------------|------------|--------------|
| einen | eine | ein | keine |

einen neu**en** Wagen

a new car

eine schön**e** Stadt

a beautiful city

ein alt**es** Auto

an old car

keine neu**en** Bücher

no new books

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[aa033098.htm](http://german.about.com/library/weekly/aa033098.htm)

Agreement features 3

E.g., Chinese: Numeral classifiers, often based on shape, aggregation,:

| | |
|------|------------------------------------------------------------------|
| 两条鱼 | <i>liang tiao yu</i> ‘two CLASSIF-LONG-ROPELIKE fish’ |
| 两条河 | <i>liang tiao he</i> ‘two CLASSIF-LONG-ROPELIKE rivers’ |
| 两条腿 | <i>liang tiao tui</i> ‘two CLASSIF-LONG-ROPELIKE legs’ |
| 两条裤子 | <i>liang tiao kuzi</i> ‘two CLASSIF-LONG-ROPELIKE pants’ |
| 两只胳膊 | <i>liang zhi gebo</i> ‘two CLASSIF-GENERAL arms’ |
| 两件上衣 | <i>liang jian shangyi</i> ‘two CLASSIF-CLOTHES-ABOVE-WAIST tops’ |
| 两套西装 | <i>liang tao xizhuang</i> ‘two CLASSIF-SET suits’ |

Zhang, Hong (2007). Numeral classifiers in Mandarin Chinese. *Journal of East Asian Linguistics*, 16(1), 43–59. Thanks also to Tong Wang, Vanessa Wei Feng, and Helena Hong Gao.

Agreement features 1

- English agreement rules are fairly simple.
- Many languages have other agreements.
- Some languages have multiple grammatical genders.
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- E.g. Chichewa has genders for men, women, bridges, houses, diminutives, men inside houses, etc. Between 12-18 in total.
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- Some languages overtly realize many of these distinctions.
- E.g. some Hungarian verbs have as many as 4096 inflected forms.

Inflectional morphology

- Word may be inflected ...
 - ... to indicate paradigmatic properties, e.g. singular / plural, past / present, ...
 - ... to indicate some (other) semantic properties
 - ... to agree with inflection of other words.
- Each (open-class) word-type has a **base form / stem / lemma**.
- Each occurrence of a word includes inflection by a (possibly null) morphological change.

Rule proliferation 1

- **Problem:** How to account for this in grammar.
- **Possible solution:** Replace all NPs, Vs, and VPs throughout the grammar.

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$S \rightarrow NP VP$

$VP \rightarrow V NP$

$NP \rightarrow you, dog, dogs, bear, bears,$

$V \rightarrow washes, wash, washed, is,$

...

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$S \rightarrow NP_{3s} VP_{3s}$

$NP_2 \rightarrow you$

$V_{1s} \rightarrow am, was, wash,$

$S \rightarrow NP_{3p} VP_{3p}$

\vdots

$washed, \dots$

$S \rightarrow NP_2 VP_2$

$VP_{3s} \rightarrow V_{3s} NP$

\vdots

$S \rightarrow NP_{1s} VP_{1s}$

\vdots

$S \rightarrow NP_{1p} VP_{1p}$

$V_{3s} \rightarrow is, was,$
 $washes, washed, \dots$

$NP_{3s} \rightarrow dog, bear, \dots$

$V_{3p} \rightarrow are, were,$

$NP_{3p} \rightarrow dogs, bears$

$wash, washed, \dots$

Rule proliferation 2

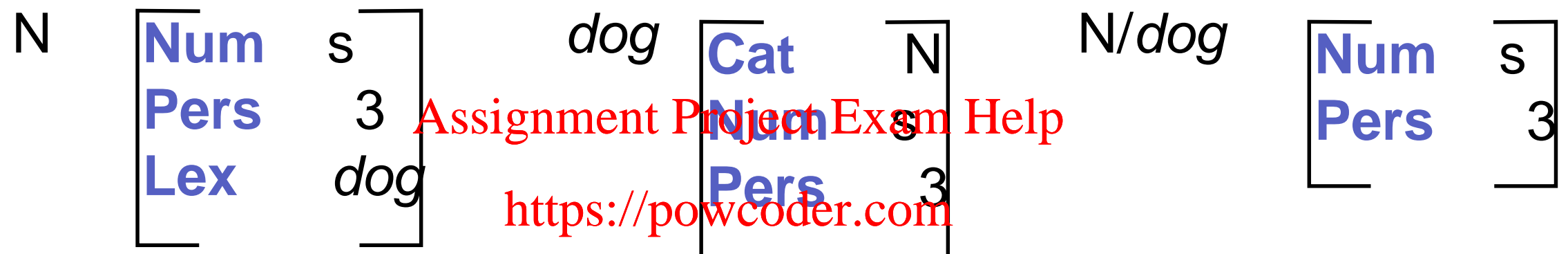
- *Drawback 1:* the result is big ... really big.
- *Drawback 2:* Losing the generalization:
 - All these Ss, NPs, VPs have the same structure.
 - Doesn't depend on particular verb, noun, and number.
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- CF rules collapse together structural and featural information.
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- All information must be completely and directly specified.
 - *E.g.*, can't just say that values must be equal for some feature without saying exactly what values.

Feature structures 1

- *Solution:* Separate feature information from syntactic, structural, and lexical information.
- A **feature structure** is a list of pairs:
[*feature-name* *feature-value*]
- Feature-values may be atoms or feature structures.
- Can consider syntactic category or word to be bundle of features too.
- Can represent syntactic structure.

Feature structures 2

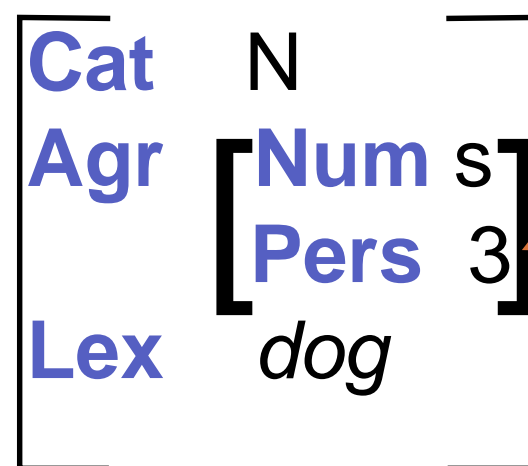
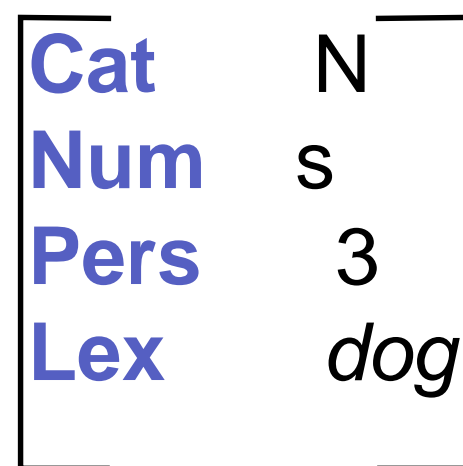
- *Drawback*: many equivalent notations.



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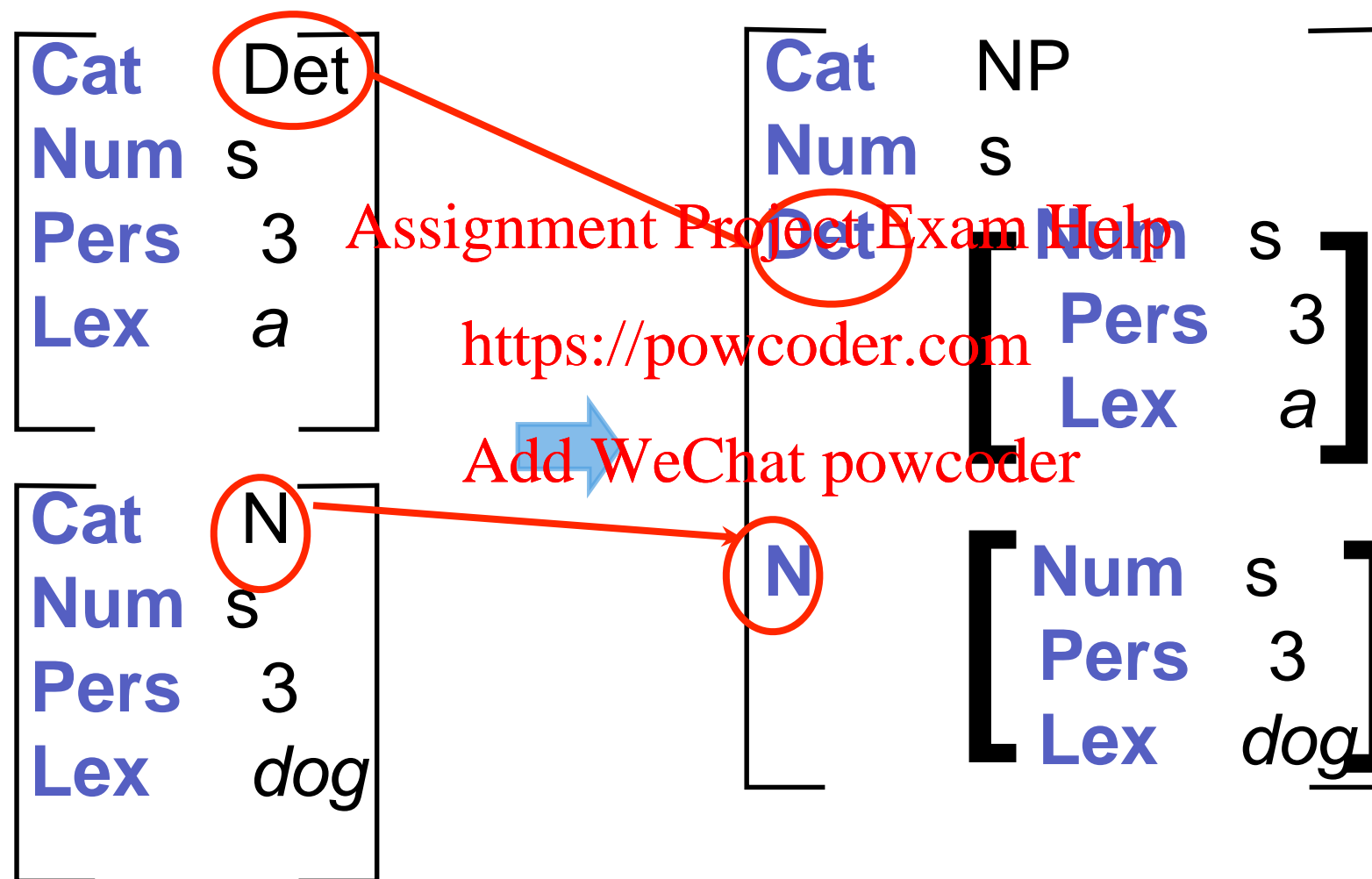
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Feature paths:
features of
features; e.g.,
(Agr Pers 3)

Feature structures 3



NP formed from Det and N.
Feature values in components become
feature names in new constituent.

Components of feature use

- 1. **Lexical specification:**

Description of *properties* of a word:
morphological, syntactic, semantic, ...

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dog: $\begin{bmatrix} \text{Cat} & N \\ \text{Agr} & 3s \end{bmatrix}$ *sleeps:* $\begin{bmatrix} \text{Cat} & V \\ \text{Agr} & 3s \end{bmatrix}$

dogs: $\begin{bmatrix} \text{Cat} & N \\ \text{Agr} & 3p \end{bmatrix}$ *sleep:* $\begin{bmatrix} \text{Cat} & V \\ \text{Agr} & \{1s, 2s, 1p, 2p, 3p\} \end{bmatrix}$

Or: $\wedge 3s$

Or: $N \rightarrow \text{dog}$
 $(N \text{ Agr}) = 3s$

$N \rightarrow \text{dogs}$
 $(N \text{ Agr}) = 3p$

$V \rightarrow \text{sleeps}$
 $(V \text{ Agr}) = 3s$

$V \rightarrow \text{sleep}$
 $(V \text{ Agr}) = \{1s, 2s, 1p, 2p, 3p\}$

Components of feature use

- **2. Agreement:**
 - **Constraints** on co-occurrence in a rule — within or across phrases.
 - Typically are equational constraints.

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NP → Det N
(Det **Num**) = (N **Num**)

S → NP VP
(NP **Agr**) = (VP **Agr**)

Components of feature use

- **3. Projection:**

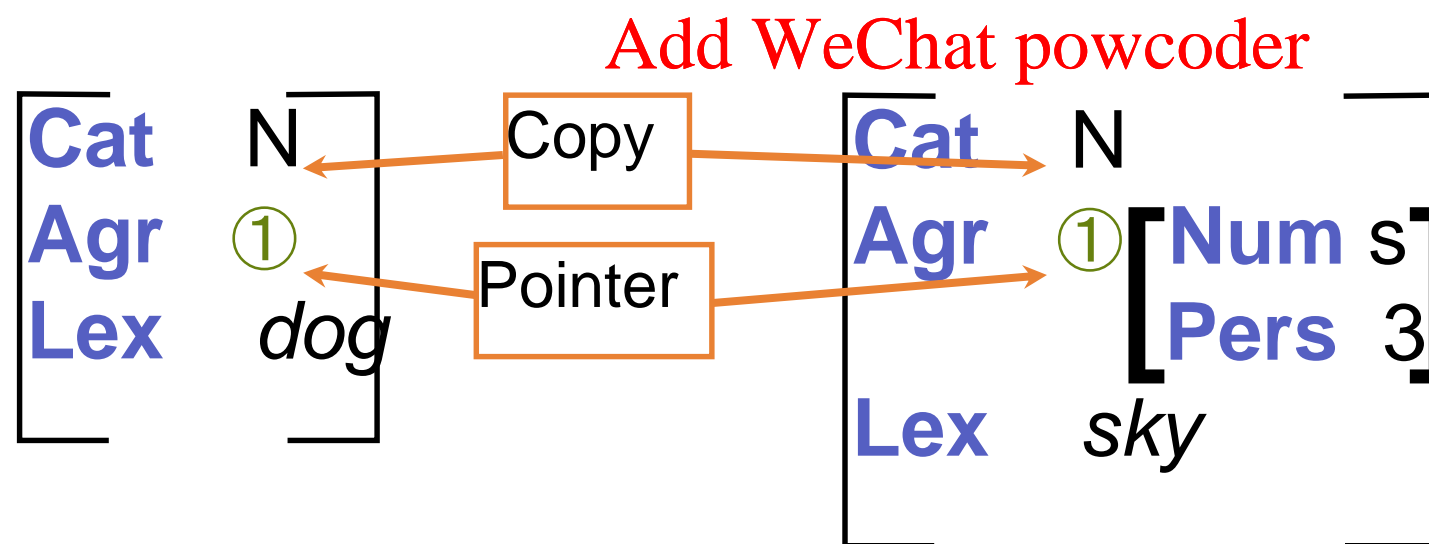
- ***Sharing of features*** between the head of a phrase and the phrase itself.

VP \rightarrow V ...
(VP Agr) = (V Agr)

- Head features:
 - **Agr** is typical, but so is the head-word itself as a feature.
(Common enough that there's usually a mechanism for "declaring" head features and omitting them from rules.)

Constraints on feature values 1

- What does it mean for two features to be “equal”?
- A *copy* of the value or feature structure, or a *pointer* to the same value or feature structure (re-entrancy, shared feature paths).



Constraints on feature values 2

- But: It may be sufficient that two features are not equal, just *compatible* — that they can be *unified*.

- E.g.,

| | |
|------|---|
| Cat | N |
| Pers | 3 |
| Num | s |

 and

| | |
|-------|---|
| Cat | N |
| Pers | 3 |
| Order | F |

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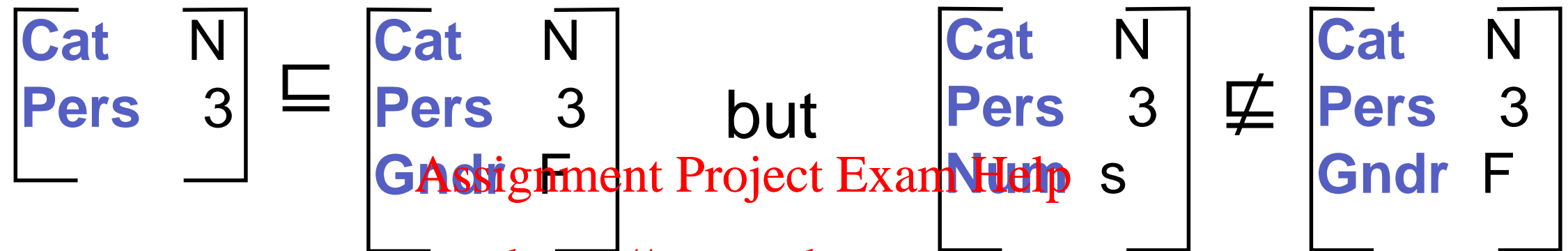
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Subsumption of feature structures 1

- Feature structure X *subsumes* feature structure Y if Y is consistent with, and at least as specific as X .
- Also say that Y *extends* X .
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 Y can add (non-contradictory) features to those in X .
- **Definition:** X *subsumes* Y ($X \sqsubseteq Y$) iff there is a *simulation* of X inside Y , i.e., a function s.t.:
 - $\text{sim}(X) = Y$
 - If X is atomic, so is Y and $X = Y$
 - Otherwise, for all feature values $X.f$: $Y.f$ is defined, and sim simulates $X.f$ inside $Y.f$.

Subsumption of feature structures 2

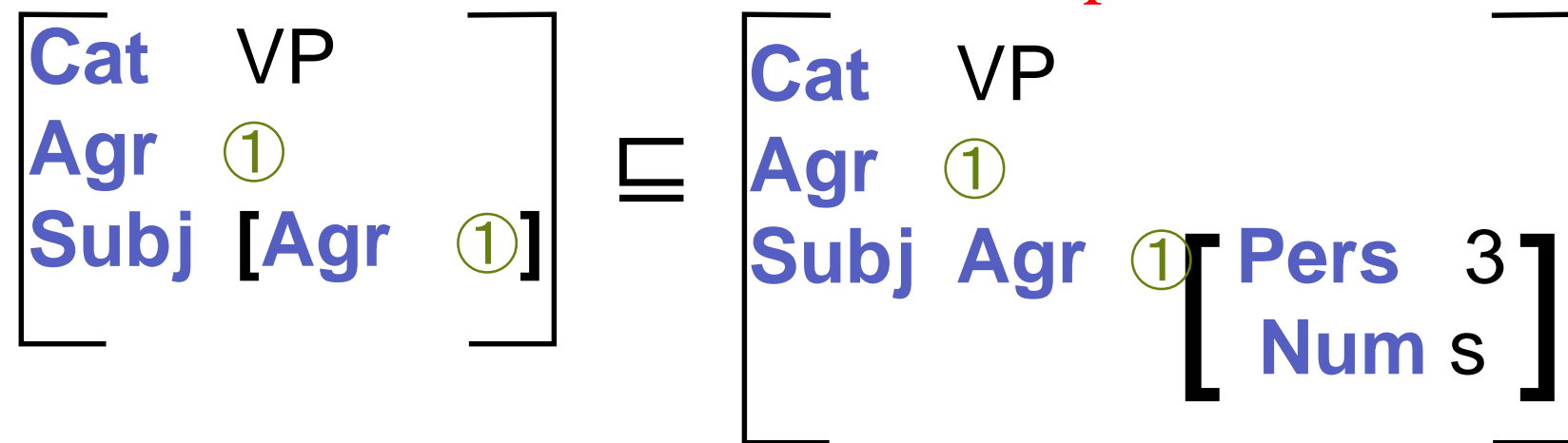
- Examples:



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Unification 1

- The *unification* of X and Y ($X \sqcup Y$) is the most general feature structure Z that is subsumed by both X and Y .
- Z is the smallest feature structure that extends both X and Y . <https://powcoder.com>
- Unification is a constructive operation.
 - If any feature values in X and Y are incompatible, it fails.
 - Else it produces a feature structure that includes all the features in X and all the features in Y .

Unification 2

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$$\begin{bmatrix} \text{Cat} & N \\ \text{Pers} & 3 \\ \text{Num} & s \end{bmatrix} \cup \begin{bmatrix} \text{Cat} & N \\ \text{Pers} & 3 \\ \text{Gndr} & F \end{bmatrix} = \begin{bmatrix} \text{Cat} & N \\ \text{Pers} & 3 \\ \text{Num} & s \\ \text{Gndr} & F \end{bmatrix}$$

Features in chart parsing

- Each constituent has an associated feature structure.
 - Constituents with children have a feature structure for each child.
- Arc addition: <https://powcoder.com>
 - The feature structure of the new arc is initialized with all known constraints.
- Arc extension:
 - The feature structure of the predicted constituent must unify with that of the completed constituent extending the arc.

Sample grammar fragment

$S \rightarrow NP VP$

$(NP \text{ Agr}) = (VP \text{ Agr})$

$NP \rightarrow Det N$

$(NP \text{ Agr}) = (N \text{ Agr})$

$(Det \text{ Agr}) = (N \text{ Agr})$

$VP \rightarrow V$

$(VP \text{ Agr}) = (V \text{ Agr})$

$Det \rightarrow a$

$Det \rightarrow all$

$Det \rightarrow the$

$[Agr \ 3s]$

$[Agr \ 3p]$

$[Agr \ \{3s, 3p\}]$

$N \rightarrow dog$

$N \rightarrow dogs$

$[Agr \ 3s]$

$[Agr \ 3p]$

$V \rightarrow sleep$

$V \rightarrow sleeps$

$[Agr \ ^3s]$

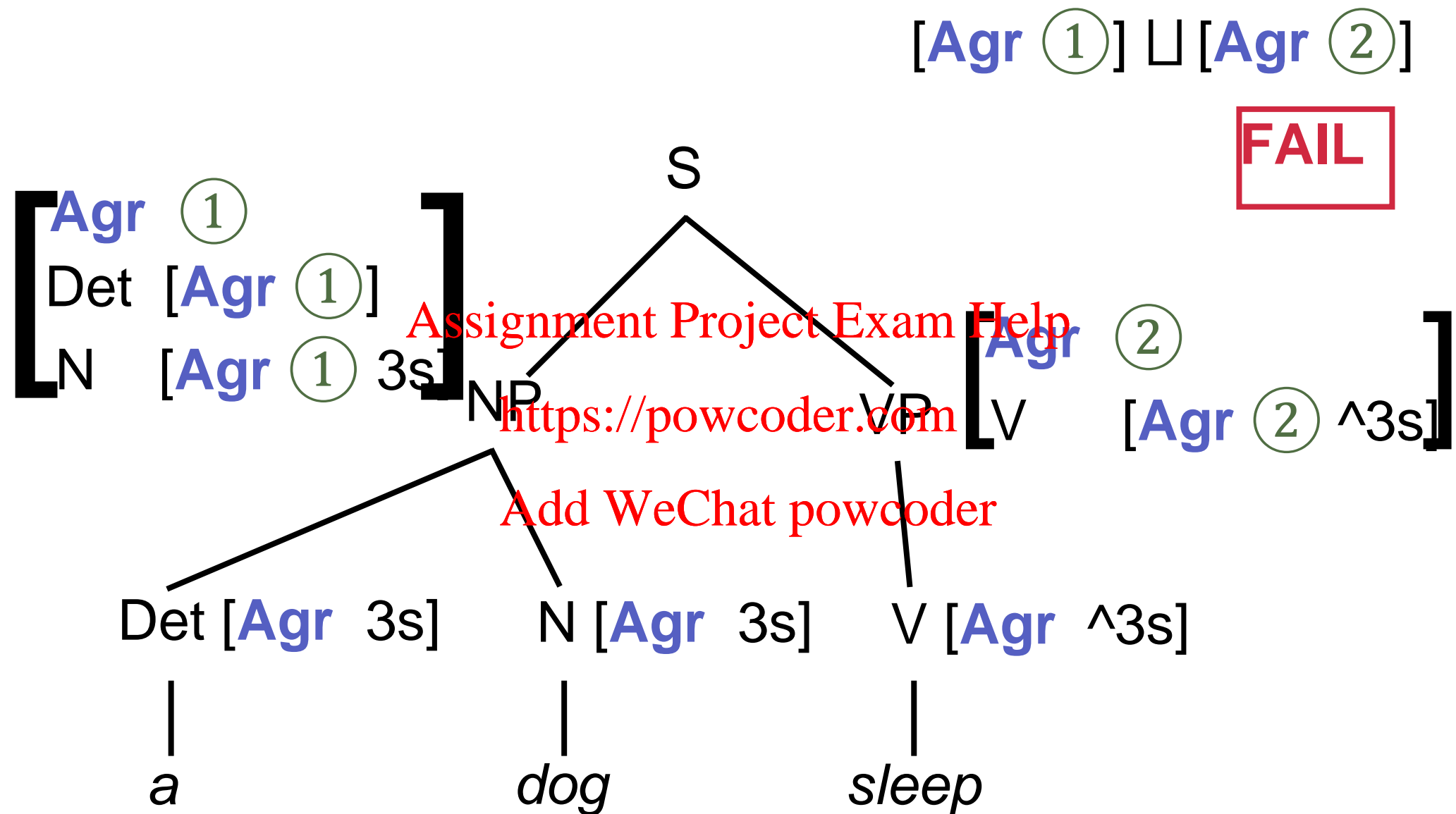
$[Agr \ 3s]$

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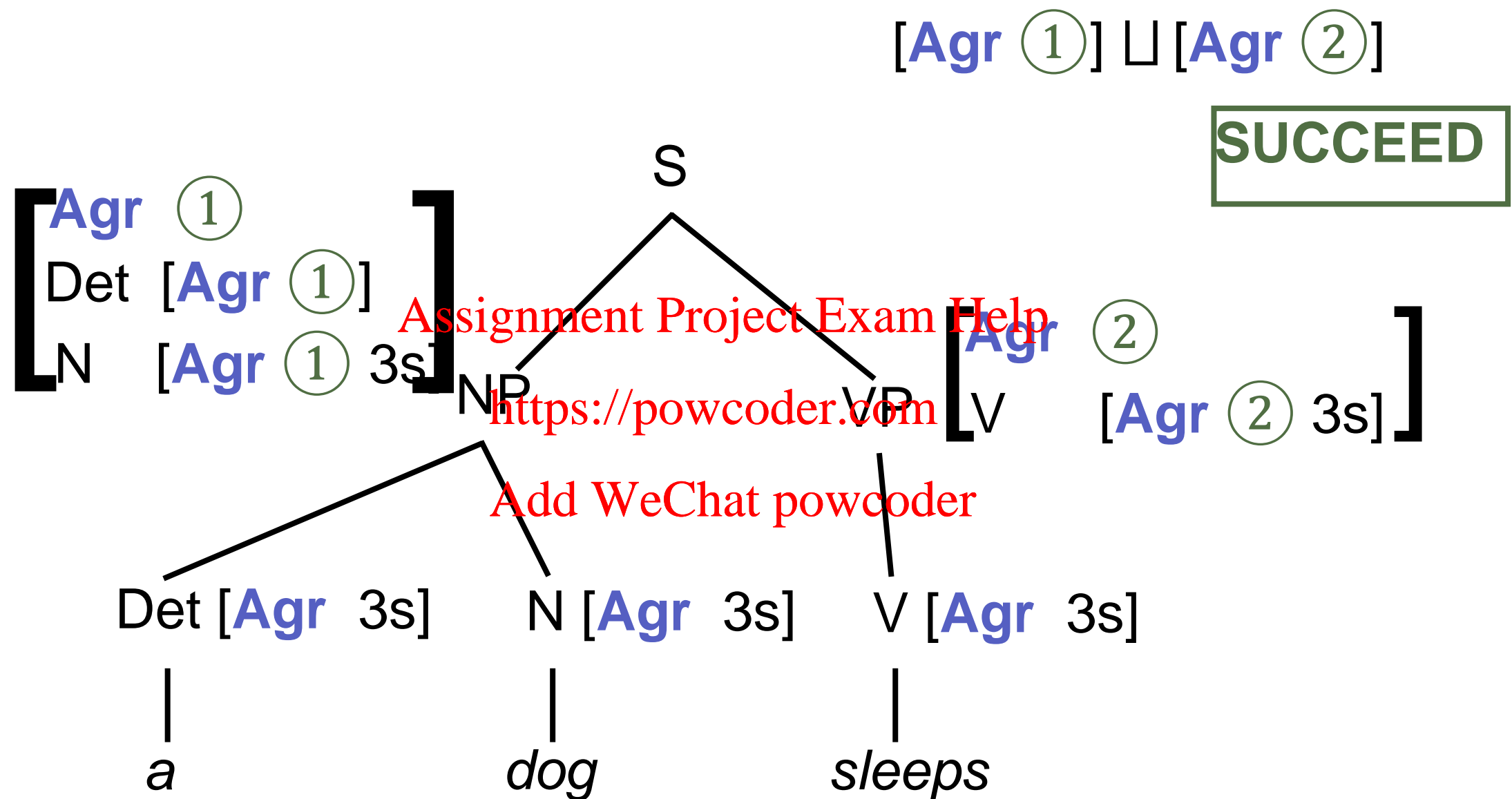
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Mismatched features fail



Unifiable features succeed



Advantages of this approach

- Distinguishes structure from "functional" info.
- Allows for economy of specification:
 - Equations in rules:
$$S \rightarrow NP \text{ Agr} = (VP \text{ Agr})$$

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Must unify with
 - Sets of values in lexicon:
$$N \rightarrow \textit{fish}$$

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(N Agr {3s, 3p})
- Allows for indirect specification and transfer of information, e.g., head features.

Features and the lexicon

- Lexicon may contain each inflected form.
 - Feature values and base form listed.
- Lexicon may contain only base forms.
 - Process of *morphological analysis* maps inflected form to base form plus feature values.
 - Time–space trade-off, varies by language.
- Lexicon may contain *semantics* for each form.

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Morphological analysis

- Morphological analysis is simple in English.
- Reverse the rules for inflections, including spelling changes.

dogs → *dog* [**Agr** 3p] *eats* → *eat* [**Agr** 3s, **Tns** pres]
dog → *dog* [**Agr** 3s] *ripped* → *rip* [**Tns** past]
berries → *berry* [**Agr** 3p] *tarried* → *tarry* [**Tns** past]
buses → *bus* [**Agr** 3p] *running* → *run* [**Tns** pp]

- Irregular forms will always have to be explicitly listed in lexicon.

children → *child* [**Agr** 3p] *sang* → *sing* [**Tns** past]

Morphology in other languages

- Rules may be more complex in other (even European) languages.
- Languages with compounding (e.g., German) or agglutination (e.g., Finnish) require more-sophisticated methods.
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- E.g., *Verdauungsspaziergang*, a stroll that one takes after a meal to assist in digestion.
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Semantics as a lexical feature

- Add a **Sem** feature:

| | |
|-------------|------------|
| Cat | N |
| Num | s |
| Pers | 3 |
| Lex | <i>dog</i> |
| Sem | dog |

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for semantic objects
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- The meaning of *dog* is dog.
The meaning of *chien* and *Hund* are both dog.
The meaning of *dog* is G52790.

Goal of parsing

- A representation of properties relevant to meaning and interpretation:
 - Things
 - Predicates (events)
 - Roles

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Entities (e.g., in a knowledge base)

Relations between things and predicates.
- Syntactic structure helps in:
 - Determining **things** and **predicates**.
 - Determining mapping of **things** to **roles** of **predicates**.

Example

The goalie kicked the ball.

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Event: *kicked*

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Role: Agent
(doer)

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Role: Theme
(thing affected)

Thing: *The goalie* Thing: *the ball*

kick (agent=goalie, theme=ball)

Syntax \leftrightarrow interpretation

- Mapping from structure to *objects of interpretation*
 - Things: NPs, Ss
 - Predicates: verbs, preps, APs
 - Roles: ??
- What are the roles in these examples?

Sara left.

Joan found the treasure in the garage.

Ken put the ball in the garage.

Tim cut the wire with a pair of scissors.

Melissa visited Ottawa with Nadia.

Andrew felt like a failure.

Syntax \leftrightarrow interpretation

- Mapping from structure to *objects of interpretation*
 - Things: NPs, Ss
 - Predicates: verbs, preps, APs
 - Roles: ?? **(thematic roles)**
- What are the roles in these examples?

Sara left.

Joan found the treasure in the garage.

Ken put the ball in the garage.

Tim cut the wire with a pair of scissors.

Melissa visited Ottawa with Nadia.

Andrew felt like a failure.

Grammatical function vs. thematic roles

- Mapping is more or less regular:

Subject \approx Agent / Experiencer

Object \approx Theme

Object of preposition \approx Goal/Location/
Recipient / Instrument

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- This mapping is used to determine appropriate semantic representation.

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Verb subcategorization 1

- **Problem:** Constraints on verbs and their complements.

*Nadia told / instructed / *said / *informed Ross to sit down.*

*Nadia *told / *instructed / said / *informed to sit down.*

*Nadia told / *instructed / *said / informed Ross of the requirement to sit down.*

Nadia gave / donated her painting to the museum.

*Nadia gave / *donated the museum her painting.*

Nadia put / ate the cake in the kitchen.

*Nadia *put / ate the cake.*

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Verb subcategorization 2

- VPs are much more complex than just V with optional NP and/or PP.
- Can include more than one NP.
- Can include clauses of various types:
*that Ross fed the marmoset
to pay him the money*
- **Subcat**: A feature on a verb indicating the kinds of verb phrase it allows:
_np, _np_np, _inf, _np_inf, ...

Write this way to distinguish from constituents.

Verb tense and aspect 1

- **Tense and aspect** markings on verb:
 - Locate the event in time (relative to another time).
 - Mark the event as complete/finished or in progress.

Nadia rides the horse. — In progress now.

Nadia rode the horse. — Completed before now.

Nadia had ridden the horse. — Completed before before now.

Nadia was riding the horse. — In progress before now.

⋮

Verb tense and aspect 2

- Tense: past or present
- Aspect: simple, progressive, or perfect

| | | | | |
|------------------|--------------|----------------------------------------------------------------------------------------------------------------|-------------------|----------------------|
| <i>Nadia ...</i> | | Assignment Project Exam Help https://powcoder.com Add WeChat powcoder | | |
| | | In progress | | |
| | | Complete | | |
| | | Auxiliary verb | | |
| | | Simple | Progressive | Perfect |
| Present | <i>rides</i> | <i>is riding</i> | <i>has ridden</i> | |
| Past | <i>rode</i> | <i>was riding</i> | <i>had ridden</i> | |
| | | Present participle | Past participle | <i>... the horse</i> |

Verb tense and aspect 3

- Tense: past or present
- Aspect: simple, progressive, or perfect

| | | | |
|------------------|--------------|----------------------------------|--|
| <i>Nadia ...</i> | | Auxiliary verbs | |
| | Simple | Perfect progressive (continuous) | |
| Present | <i>rides</i> | <i>has been riding</i> | |
| Past | <i>rode</i> | <i>had been riding</i> | |

... the horse

Modal verbs

- **Modal verbs:** Auxiliary verbs that express degrees of certainty, obligation, possibility, prediction, etc.

Nadia

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{*could, should, must, ought to, might, will, ...*}

{*ride, be riding, have ridden, have been riding*}
the horse.

English auxiliary system

- Structure (so far):
[MODAL] [HAVE] [BE] MAIN-VERB

- General pattern:

VP → AUX VP

AUX → MODAL | HAVE | BE

- Use features to capture necessary agreements.

Voice 1

- **Voice:** System of assigning thematic roles to syntactic positions.

- English has **active** and **passive** voices.

- Passive expressed with *be*+past participle.
Other auxiliaries may also apply, including progressive *be*.

- *Nadia was kissed.* *Nadia was being kissed.*
Nadia had been kissed. *Nadia had been being kissed.*
Nadia could be kissed. *Nadia could have been being kissed.*

- Structure:
[MODAL] [HAVE] [BE₁] [BE₂] MAIN-VERB

Voice 2

The goalie kicked the ball.

ACTIVE

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Event: *kicked*

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Role: Agent
(doer)

Role: Theme
(thing affected)

Thing: *the goalie* Thing: *the ball*

kick (agent=goalie, theme=ball)

Voice 3

The ball was kicked.

PASSIVE

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Event: *kicked*

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Role: Theme
(thing affected)

Thing: *the ball*

kick (agent=?, theme=ball)

Voice 4

The ball was kicked by the goalie. **PASSIVE**

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Event: *kicked*
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Role: Theme
(thing affected)

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Role: Agent
(doer)

Thing: *the ball* Thing: *the goalie*

kick (agent=goalie, theme=ball)

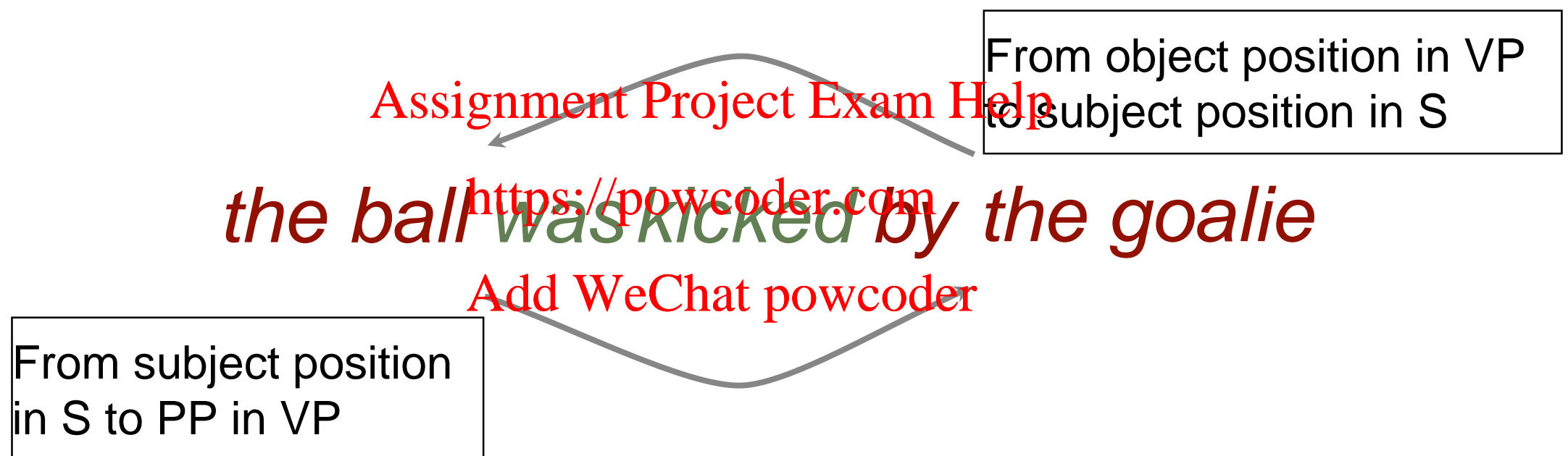
Passive as *Diathetic alternation*

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the goalie <https://powcoder.com> *kicked* *the ball*

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Passive as *Diathetic alternation*



But the semantic representation doesn't change

Some useful features

- **VForm**: The tense/aspect form of a verb:
passive, pastprt, ...
- **CompForm**: The tense/aspect form of the
complement of an auxiliary.

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Augmenting rules for passive voice

- For all rules of the form:

$VP \rightarrow V \ NP \ X$

$(V \text{ Subcat}) = _y$

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$VP \rightarrow V \ X$

$(V \text{ Subcat}) = _y$

$(V \text{ VForm}) = \text{passive}$

$(VP \text{ VForm}) = \text{passive}$

Metarule to ease grammar coding

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- Augment Aux+VP rules:

$VP \rightarrow AUX \ VP$

$(AUX \text{ Root}) = \text{Be2}$

$(AUX \text{ CompForm}) = (VP_2 \text{ VForm})$

$(VP_2 \text{ VForm}) = \text{passive}$

The GAP feature for passive voice

S → NP VP

- ¹ (NP **Agr**) = (VP **Agr**)
- ² (VP **VForm**) = passive
- ³ (VP **Gap Cat**) = NP
- ⁴ (VP **Gap Agr**) = (NP **Agr**)
- ⁵ (VP **Gap Sem**) = (NP **Sem**)

VP → AUX VP

- ¹ (VP₁ **Agr**) = (AUX **Agr**)
- ² (VP₁ **VForm**) = (VP₂ **VForm**)
- ³ (VP₁ **Gap**) = (VP₂ **Gap**)
- ⁴ (AUX **Lex**) = be2
- ⁵ (VP₂ **VForm**) = passive

V → *kicked*

- ¹ (V **VForm**) = {pastprt, passive}
- ² (V **Subcat**) = _np
- ³ (V **Lex**) = *kick*
- ⁴ (V **Sem**) = kick

VP → V NP

- ¹ (VP **VForm**) = (V **VForm**)
- ² (VP **Gap**) = (NP **Gap**)
- ³ (V **Subcat**) = _np

NP → ε

- ¹ (NP **Gap Cat**) = NP
- ² (NP **Gap Agr**) = (NP **Agr**)
- ³ (NP **Gap Sem**) = (NP **Sem**)

NP → *cans*

- ¹ (NP **Agr**) = 3p
- ² (NP **Lex**) = *can*
- ³ (NP **Sem**) = cans

AUX → *were*

- ¹ (AUX **Agr**) = 3p
- ² (AUX **Lex**) = be2

Assignment Project Exam Help

Empty string

<https://powcoder.com>

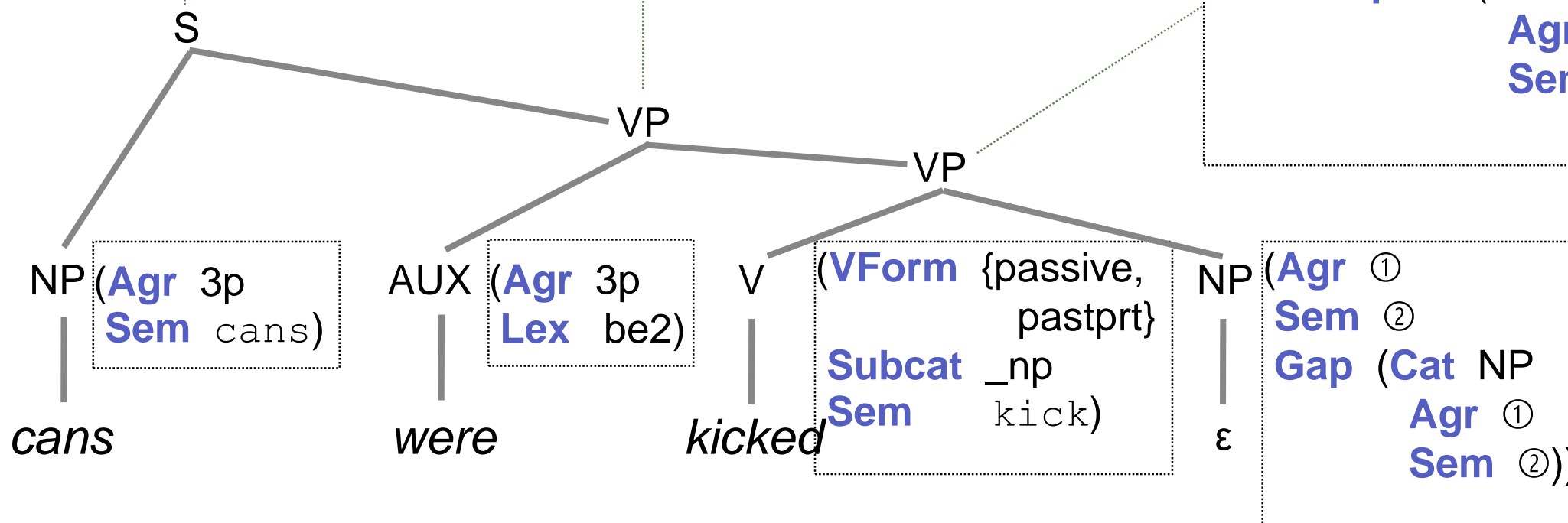
Add WeChat powcoder

(NP (Agr ① 3p
Sem ② cans)
VP (Agr ①
VForm ③
Gap ④
AUX (Agr ① 3p
Lex be2)
VP (VForm ③
Gap ④
V (VForm ③ passive
Subcat _np
Sem kick)
NP (Agr ①
Sem ②
Gap ④ (Cat NP
Agr ①
Sem ②))))

(Agr ⑤
VForm ③
Gap ④
AUX (Agr ⑤ 3p
Lex be2)
VP (VForm ③
Gap ④
V (VForm ③ passive
Subcat _np
Sem kick)
NP (Agr ①
Sem ②
Gap ④ (Cat NP
Agr ①
Sem ②))))

Note: The green ①'s of the S were ⑤'s until the 4th constraint of the rule $S \rightarrow NP VP$. The 5th constraint fills in the Sem of the Gap ②.

(VForm ③
Gap ④
V (VForm ③ {passive,
pastprt}
Subcat _np
Sem kick)
NP (Agr ①
Sem ②
Gap ④ (Cat NP
Agr ①
Sem ②))))



Other cases of *gap percolation*

- Other constructions involve NPs in syntactic configurations where they would not get the right thematic roles using linear order alone.

Nadia seems to like Ross.

Nadia seems to be liked.

Nadia is easy to like.

Who did Nadia like?

I fed the dog that Nadia likes to walk.

- Can use grammar rules with gap features to ensure correct structure/interpretation of these as well.

Summary

- Features help capture syntactic constructions in a general and elegant grammar.
- Features can encode the compositional semantics of a sentence as you parse it.
- Features can accomplish mapping functions between syntax and semantics that simplify the interpretation process.