Computational Modeling and Human Language

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LING 581 and 506 guest lecture. April 19th and 21st 2022.

Two Lectures

- Part 1: Background (*Tuesday*)
  - *some unfinished stuff*
- Part 2: Combinatorics (*Today*)

Theta theory

WS: R IA $\Rightarrow_{EM}$ {R, IA_θ}

WS: EA {v*, {R, IA_θ}} $\Rightarrow_{EM}$
{EA_θ, {v*, {R, IA_θ}}}

WS: {v*, {R, IA_θ}} $\Rightarrow_{IM}$
{IA_θ, {v*, {R, IA_θ}}}

- **Duality of Semantics**
  - strict separation of tasks between EM and IM
  - Theta positions populated by EM exclusively
  - IM cannot *move* something into a theta position
  - a **Language-specific Condition** (LSC) on Merge

Theta theory

WS: R IA $\Rightarrow_{EM}$ {R, IA_θ}

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WS: {v*, {R, IA_θ}} $\Rightarrow_{IM}$
{IA_θ, {v*, {R, IA_θ}}}

- **Duality of Semantics**
  - strict separation of tasks between EM and IM
  - a **Language-specific Condition** (LSC) on Merge
- Consequence
  - Theta theory must be built into Merge
  - *Theta positions must be detectable throughout the Merge derivation*
- Question
  - does this violate the Markovian assumption or the **NTC**?

Non-simplest Merges

SMT Condition

- **Minimal Yield** (MY):
  - no operation can increase the number of selectable items by more than the bare minimum, one.
- **Sideways Merge** variant (Nunes & Hornstein):
  - {X, Y}, Z, … ⇒ {X, Y}, {X, Z}, … (out: +2)
- **Parallel Merge** variant (Citko):
  - X, Y, Z ⇒ {X, Y}, {X, Z}, … (out: +2)
- **Merge + Deletion**:
  - {A, B}, C, D, … ⇒ {A, B}, {A, C}, … (still out: +1)

Non-simplest Merge

- **Simplest Binary Merge** imposes the least burden on computational resources.
  - Other variants are non-optimal.
- Actually, **Parallel Merge**
  - X, Y, Z ⇒ {X, Y}, {X, Z}, …

can be simulated using **Sideways Merge** (SiM):

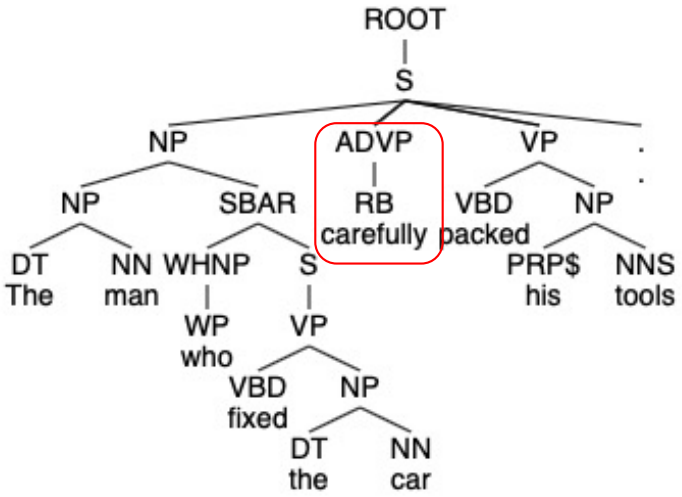
- WS: X, Y, Z, …
- EM: {X, Y}, Z, …
- SiM: {X, Y}, {X, Z}, …

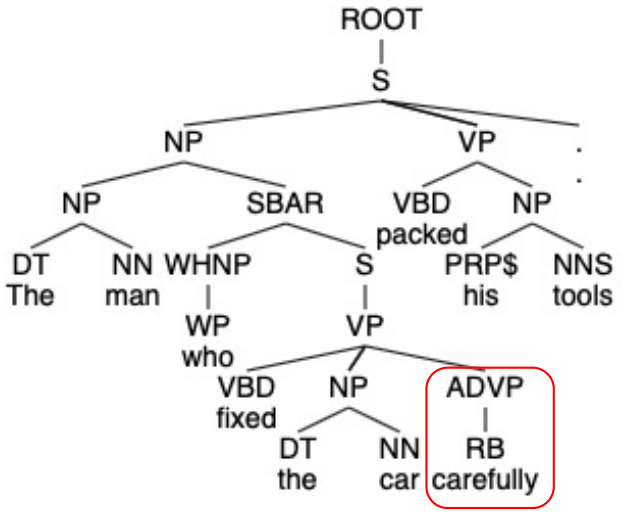
So, if we rule out SiM, we rule out Parallel Merge too.

WS Computation

- Example (*Chomsky refs*.):
  an adverb has to find a VP to modify
  - *the man who fixed the car carefully packed his tools*

Parses #3 and #1 from kbest standalone Stanford Parser (*used in* LING 581)





WS Computation

- Example (*Chomsky refs*.):
  - *the man who fixed the car carefully packed his tools*
- WS computation:
  - WS: {v*, {fix, the car}} {v*, {packed, his tools}} carefully
  - WS: {{v*, {fix, the car}}, carefully} WS:{{v*, {packed, his tools}}, carefully}
  - {carefully, {… {v*, {packed his tools}}, carefully}…}}

the man who carefully fixed the car …

the man who fixed the car carefully …

the man who fixed the car carefully packed …

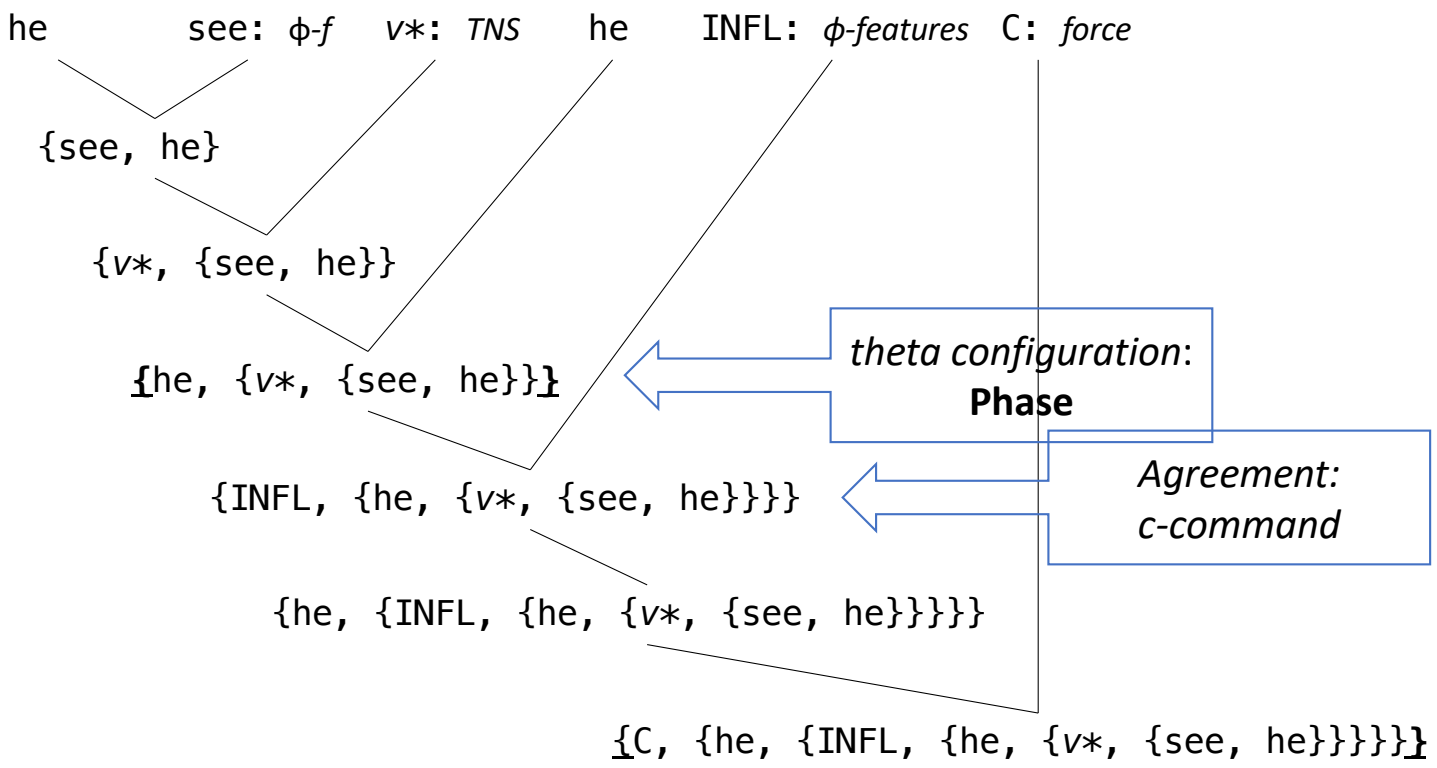
the man who fixed the car packed his tools carefully

Carefully, the man who fixed the car packed …

WS Computation

Example:

- *He saw him*
- WS: he, see, *v*∗, he, INFL, C

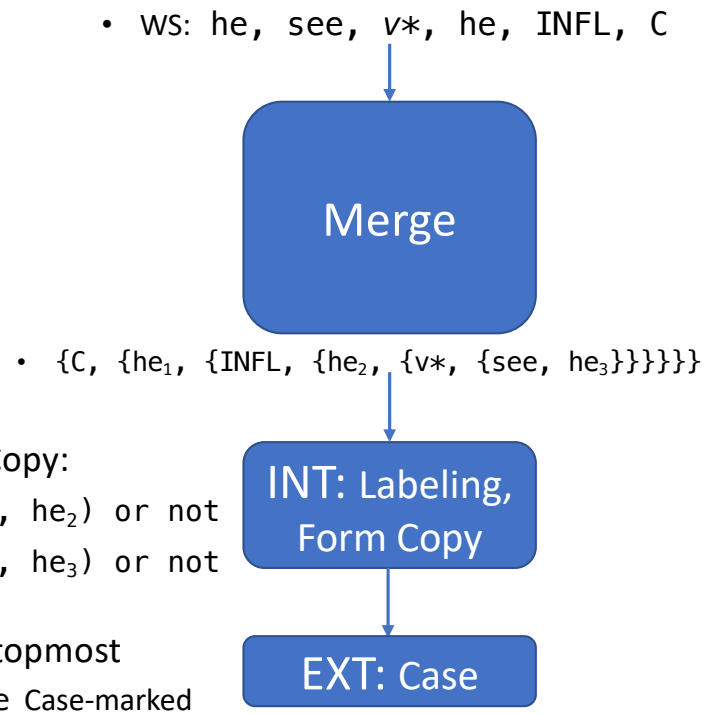


WS Computation

Example:

- *He saw him*
- WS: he, see, *v*∗, he, INFL, C

- Form Copy (FC) applies @ INT:
  - via c-command (Minimal Search)
  - Phases:
    - {he, {*v*∗, {see, he}}}
    - {C, {he, {INFL, {he, {*v*∗, {see, he}}}}}}
  - construct relations (he, he)
  - some cases ruled out by Theta Theory
- Form Copy (FC) *doesn't* apply:
  - no relation between the two *he*'s
  - pronounced as *he saw him*



Combinatorics of Free Merge

Suppose Merge is free

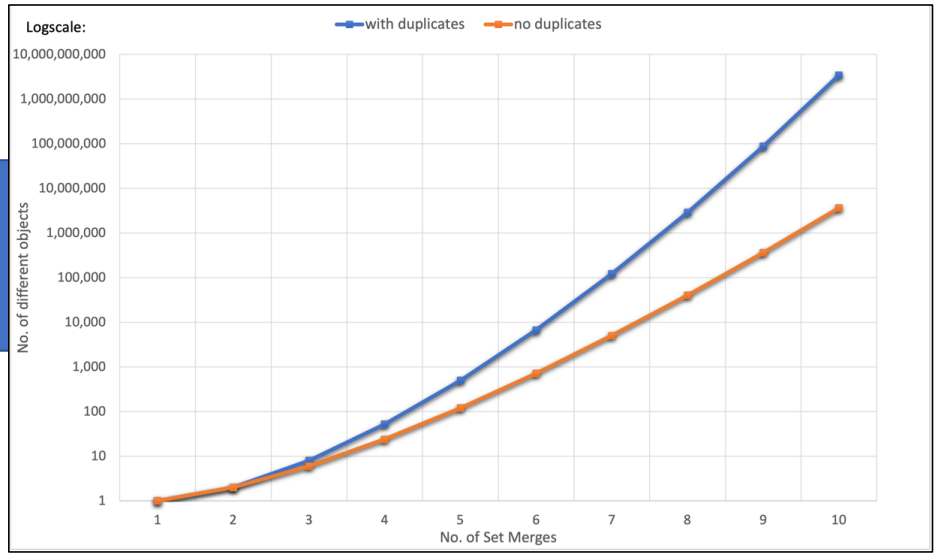
- We get *serious* combinatorial explosion
- **Example**:

  permit EM and IM

  - WS: a b

  1. {a, b}
  2. {a, {a, b}} {b, {a, b}}
  3. {{a, b}, {a, {a, b}}} {b, {a, {a, b}}} {a, {a, {a, b}}} {{a, b}, {b, {a, b}}} {b, {b, {a, b}}} {a, {b, {a, b}}}

Same structure derived in 2 ways:
{a_1, {a_2, b}}
a) {a_1, {a_1, {a_2, b}}}
b) {a_2, {a_1, {a_2, b}}}



should be listed twice!

Combinatorics of Free Merge

Duplicate detection violates SMT:

- *requires a memory device*

- Language requires "duplicates" (*repetitions*)
- **Example** (Chomsky, p.c.):
  - the man who saw many people didn't see many people
- WS: {*v**, {see, many people}} {who man} INFL C_{rel} the INFL Neg C

1. {who man, {INFL, {~~who man~~, {*v**, {see, many people}}}}} C_{rel} the INFL Neg C
2. {C_{rel}, {who man, {INFL, {~~who man~~, {*v**, {see, many people}}}}}} the INFL Neg C
3. {who man, {C_{rel}, {~~who man~~, {INFL, {~~who man~~, {*v**, {see, many people}}}}}}} the INFL Neg C
4. {the, {man, {who ~~man~~, {C_{rel}, {~~who man~~, {INFL, {~~who man~~, {*v**, {see, many people}}}}}}}}} INFL Neg C

- Now we're stuck!
  - would need to invent a new operation to deep fish out {*v**, …}
  - violates **Duality** anyway: need EM to introduce a theta role-bearing item

Combinatorics of Free Merge

Infinite loop without violating MS

- **Example**:
  - . {$\underline{a}_1$, {a_2, b}}
  - {a_1, {$\underline{a}_1$, {a_2, b}}}
  - {a_1, {$\underline{a}_1$, {a_1, {a_2, b}}}}
  - {a_1, {$\underline{a}_1$, {a_1, {a_1, {a_2, b}}}}}

  and so on …

Alternately select a or b

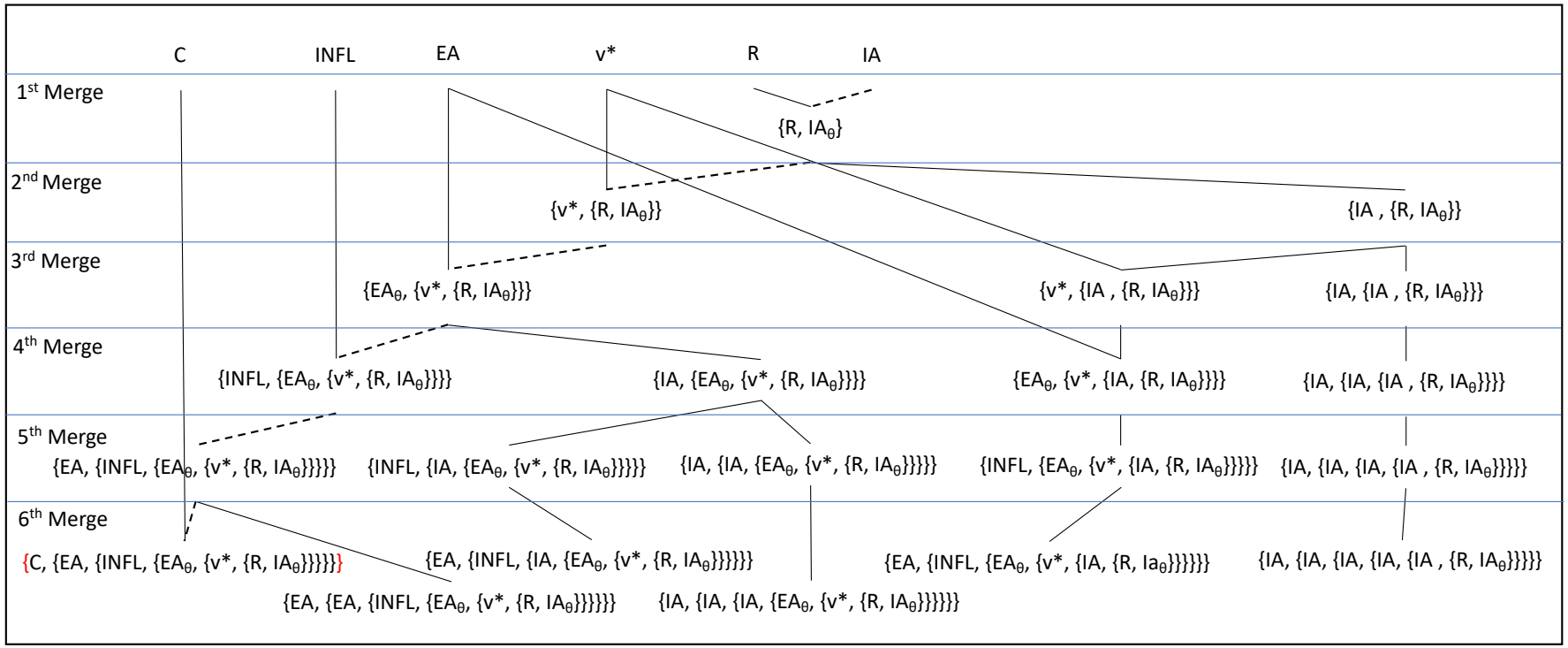
- **Example**:
  - {a, b}
  - {b, {a, b}}
  - {a, {b, {a, b}}}
  - {b, {a, {b, {a, b}}}}
  - {a, {b, {a, {b, {a, b}}}}}

  and so on …

Filter:
*ππ, where π = (IM O_1, … , IM O_n), $n \geq 1$

Problem: *it's another new device*

Combinatorics of Free Merge



Combinatorics of Free Merge

- Proposed filter
  - new device (*problem for* **Genuine Explanation**)
  - doesn't rule all cases anyway (*see below*)
  - requires access to history of Merge (*violates* **Markovian assumption**)
- Example:
  - a b
  - {a, b}
  - {b, {a, b}}
  - {{a, b}, {b, {a, b}}}
  - {{b, {a, b}}, {{a, b}, {b, {a, b}}}}
  - {{a, b}, {b, {a, b}}}, {{b, {a, b}}, {{a, b}, {b, {a, b}}}}

  and so on …

Note:
IM selects the WS item from previous round
cf. ordinals (*previous lecture*)
successor(x) = x ∪ {x}

C-Command Relations

Command relations underpin much of syntax: agreement, binding, etc.

Definition:

- X **c-commands** Y iff ∃ Z, W st. X ∈ Z and W ∈ Z, W ≠ X, (Y = W or W $\in^+$ Y)

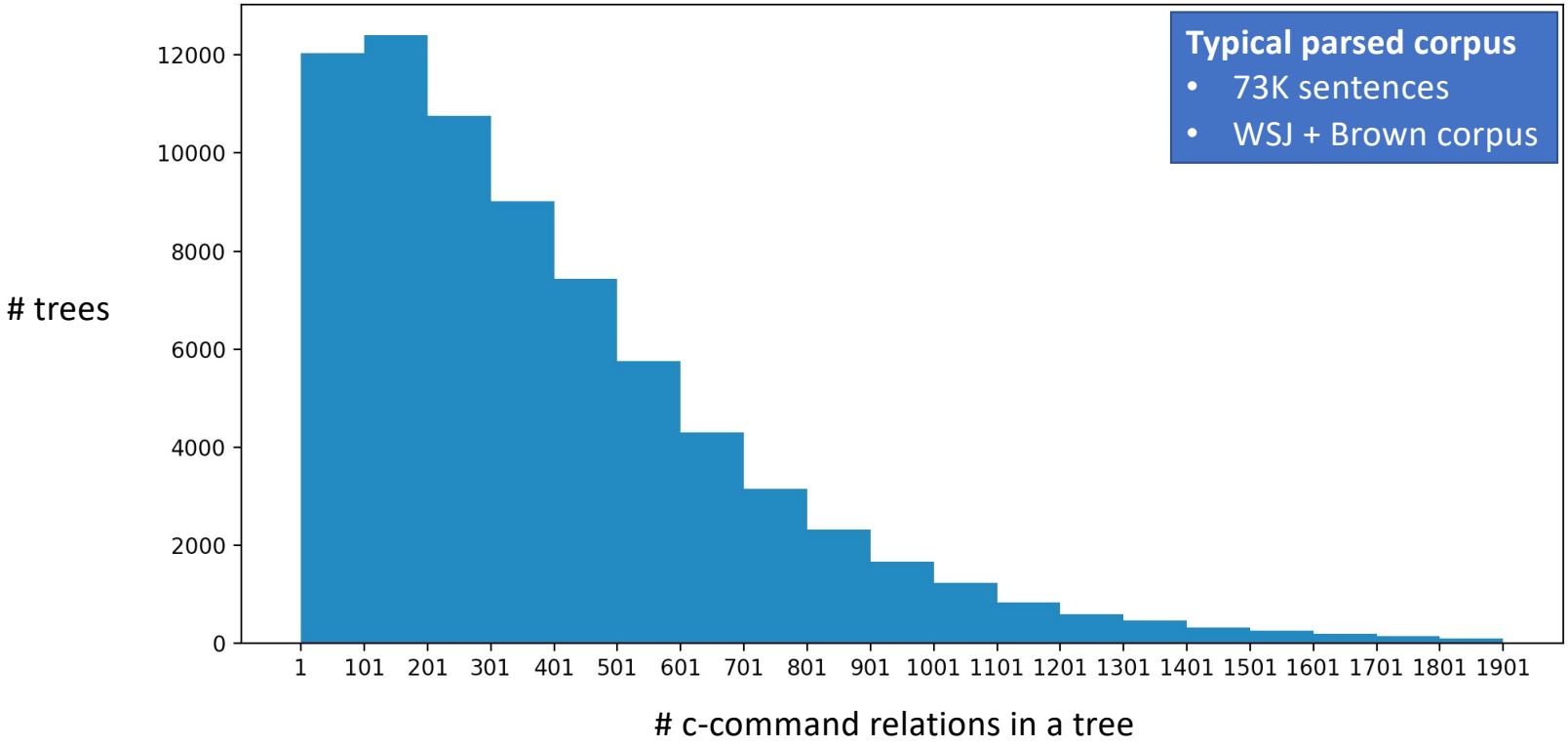
recall set theory:

- we use ∈, immediate dominance
- $\in^+$, dominates

However, we don't want to compute all possible c-command relations

- Example:
  - *he saw him*
  - `{C, {he, {INFL, {he, {v*, {R, he}}}}}}`
  - 34 c-command relations

C-Command Relations



C-Command Relations

Compute them only when needed

- limited by **Minimal Search** (MS) (when possible)

The direction of search matters

- Recall example (*Chomsky refs*.):
  - *the man who fixed the car carefully packed his tools*

  Construal: e.g. modification of a verb phrase by an adverb
  - *carefully* seeks a verb: can be computed as c-command with MS
- **Example**:
  - **Binding**: an anaphor seeks the closest possible antecedent
  - *he knew Mary liked those old pictures of herself*
  - *he knew Mary liked those old pictures of him*