Reference-Set Computation = Minimalism + Transformational Rules?

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Reference-Set Constraints

Reference-set constraint ≈ transderivational constraint ≈ global economy condition ≈ interface strategy

An Informal Definition

Given some input tree t, a reference-set constraint computes a set of possible output trees for t — called the reference set of t — and picks from said set the optimal output tree according to some economy metric.

Some examples from the literature:

- Rule I (Reinhart 2006)
- Scope Economy (Fox 2000)
- Fewest Steps (Chomsky 1995)
- Merge-over-Move (Chomsky 2000)
- Focus Economy (Reinhart 2006)

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Example: Focus Economy

(1) a. [$_{\text{TP}}$ John [$_{\text{VP}}$ bought [$_{\text{DP}}$ a red **car**]]].
Focus set: {TP, VP, DP, red car, car}

b. [$_{\text{TP}}$ John [$_{\text{VP}}$ bought [$_{\text{DP}}$ a **red** car]]].
Focus set: {red}

Focus Projection

Any constituent containing the carrier of sentential main stress may be focused.

Focus Economy Rule

If the main stress has been shifted, a constituent containing its carrier may be focused iff it cannot be focused in the tree with unshifted stress.

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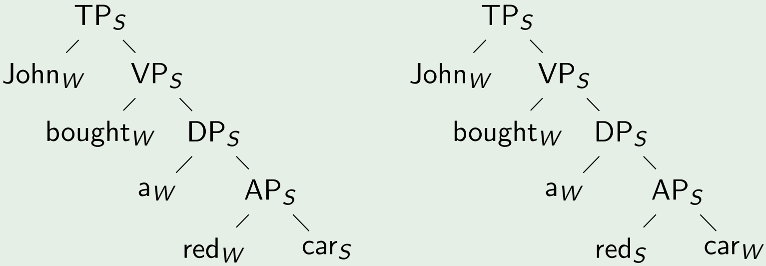
Computing the Focus Sets

a) Neutral Stress **b) Shifted Stress**



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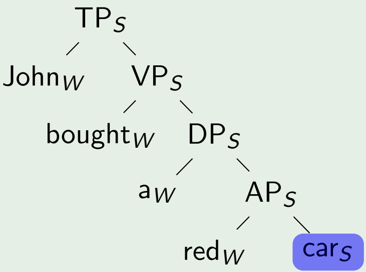

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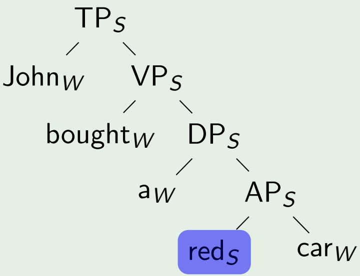

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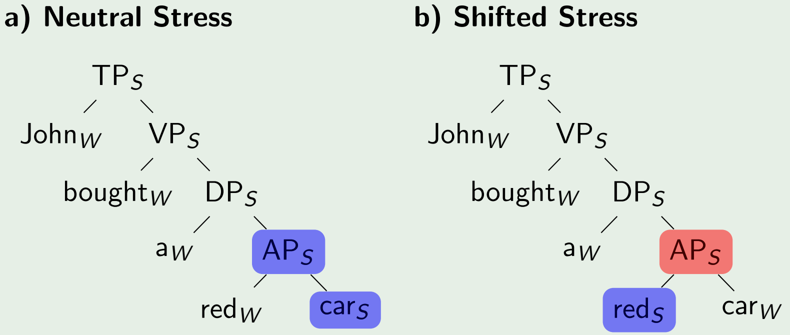

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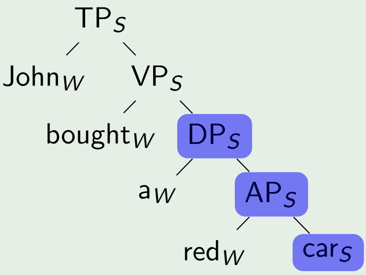

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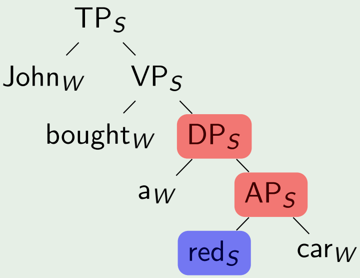

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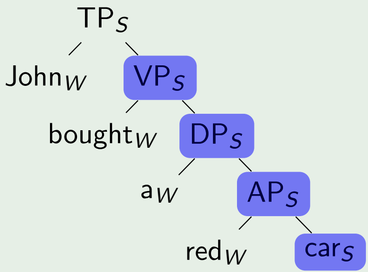

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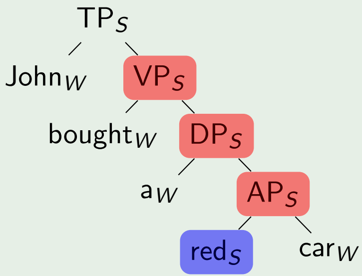

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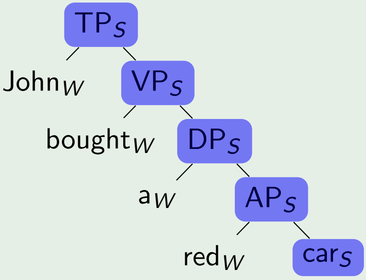

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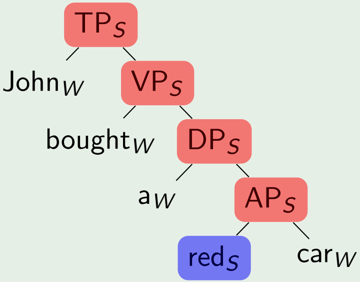


So What's the Deal?

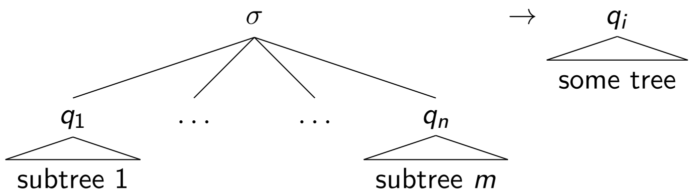
- Reference-set constraints are argued to be
  - too computationally demanding for narrow syntax (Collins 1996; Johnson and Lappin 1999)
  - unwieldy for empirical work (Sternefeld 1996)
- But if we use linear tree transducers as a model, it turns out that the concerns are unwarranted. Rather, reference-set constraints are...
  - **Unity 1 (theory-internal)** a different way of specifying standard well-formedness constraints.
  - **Unity 2 (across theories)** connected to OT and Synchronous TAG.
  - **Unity 3 (connection of formal and empirical work)** ideally suited to account for cross-linguistic variation (which they are hardly ever used for).

Linear Tree Transducers in Pictures

A linear finite-state bottom-up tree transducer

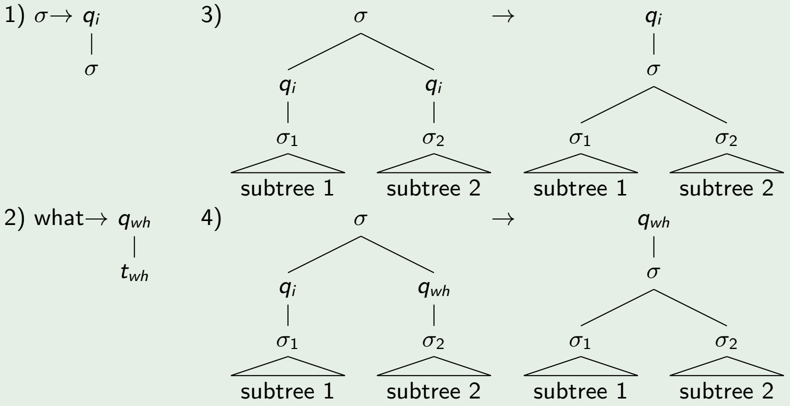
- traverses an input-tree from the leaves towards the root,
- labels it with states q_i, and
- transforms it into an output-tree.

It does so using rules of the following kind:



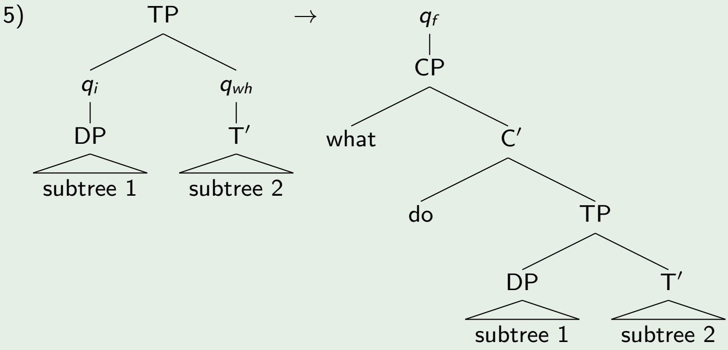
A Simple Example (Part 1)

A Transduction for wh-Movement, Rules 1–4



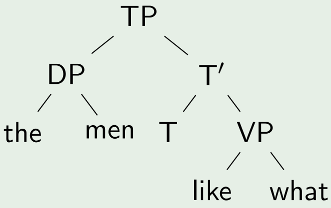
A Simple Example (Part 2)

A Transduction for wh-Movement, Rule 5



A Simple Example (Part 3)

A Transduction for wh-Movement, Application



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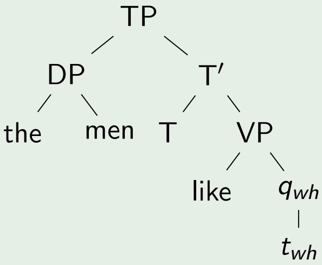

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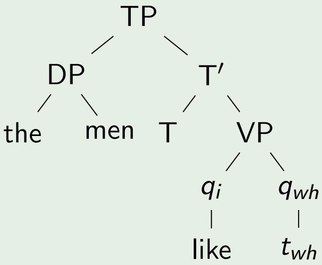

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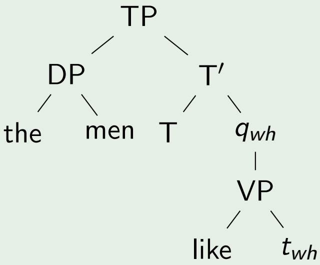

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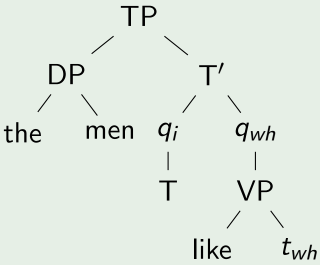

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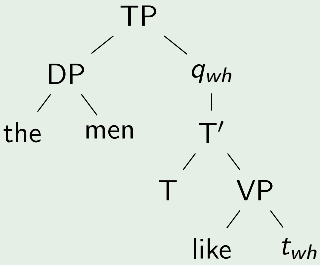

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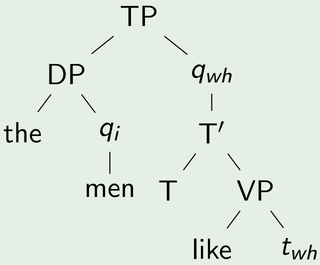

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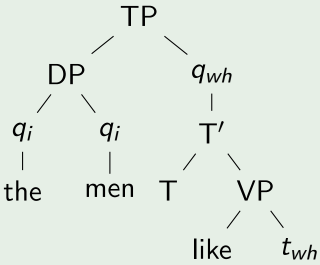

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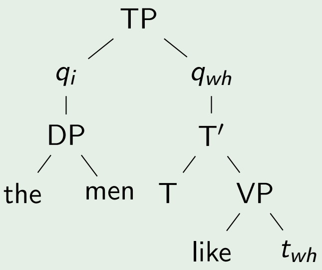

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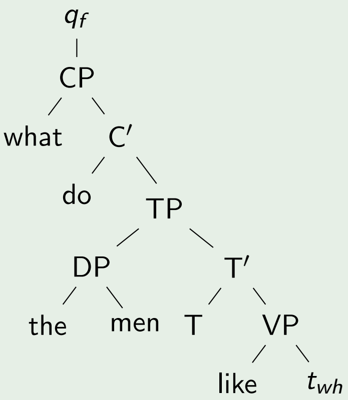

Some Important Facts

What is Possible?

- Relabeling nodes
- Deleting subtrees
- Inserting subtrees of bounded size
- Enforcing constraints that define regular tree languages

What is Impossible?

- Copying of arbitrary subtrees
- Switching positions of non-siblings (e.g. specifier and complement)
- Counting past some threshold

Mathematical Properties

- A transducer can be decomposed into a sequence of smaller transducers, *et vice versa*.
- If the input tree language of a transducer is regular, then so is its output language. Regular tree languages are sufficiently powerful for Minimalism (Kobele et al. 2007).

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Strategy

For a given reference-set constraint C, exhibit

- a Minimalist grammar that generates the input language, and
- a sequence of transducers that computes the same mapping from inputs to optimal outputs.

- Due to the mathematical properties of transducers, the output language is no more complex than the input language
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But why should this work for arbitrary reference-set constraints?

OT: A Bird's Eye Perspective

It seems natural to model reference-set constraints via OT.

Reference-Set Constraints as OT Grammars

- Use GEN to compute the reference-sets.
- Use a sequence of constraints to filter out the suboptimal candidates.

A Major Complaint

Without further restrictions, OT grammars can generate any kind of (tree) language
$\Rightarrow$ they don't tell us anything about reference-set constraints.

Fortunately, there is a weaker alternative. . .

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Optimality Systems: A Restricted Version of OT

Optimality Systems (OSs; Frank and Satta 1998)

A variant of OT that keeps just the bare skeleton.

- All constraints only consider the output, never the input.
- No correspondence theory
- No output-output correspondence
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There are mathematical conditions that ensure that an OS can be implemented by a tree transducer.

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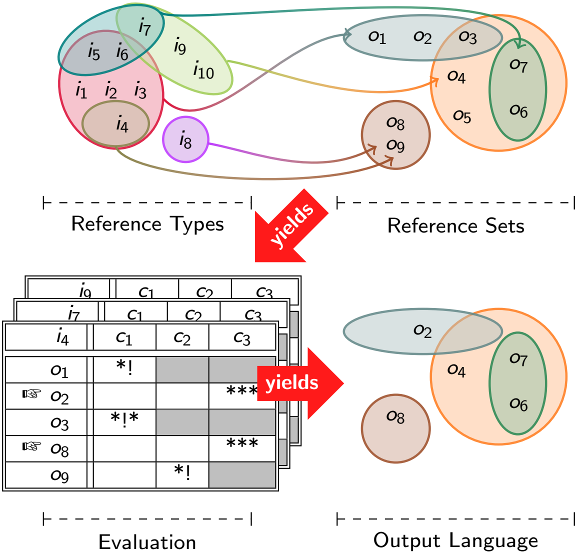
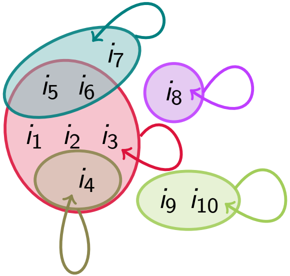
Depiction of a Controlled OS

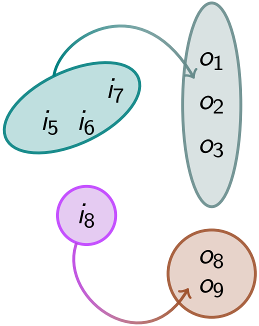


i_4	c_1	c_2	c_3
o_1	*!		
☞ o_2			***
o_3	*!*		
☞ o_8			***
o_9		*!	

Reference-set Constraints as Controlled OSs

- Almost all constraints in the literature exhibit one of the two configurations below.
- What do the two have in common?





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If two reference sets overlap, then so do the reference types that are mapped to them.

Theorem (Frank and Satta 1998; Wartena 2000; Jäger 2002)

A controlled OS can be implemented as a transducer if

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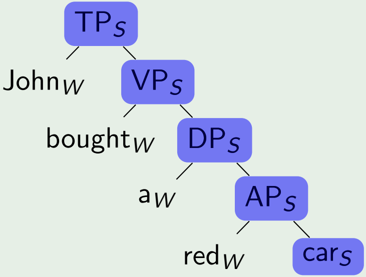

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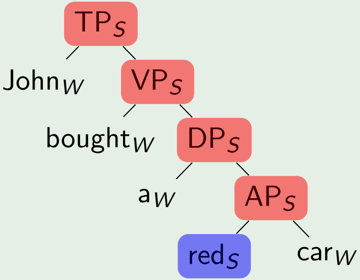
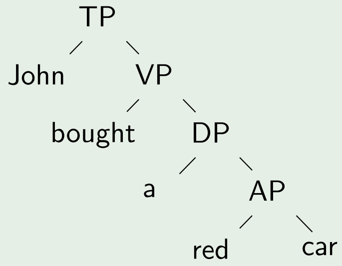


Transducer Model: Gen

Step 1 & 2: Gen

- Non-deterministically relabel input with S/W-subscripts.
- Non-deterministically focus some node along the "stress path".

Transducing an Input into a Stress-Annotated Output with Focus



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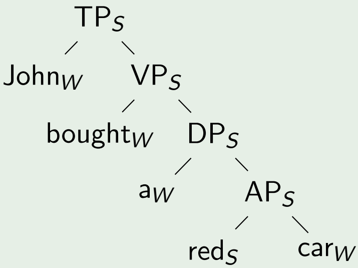

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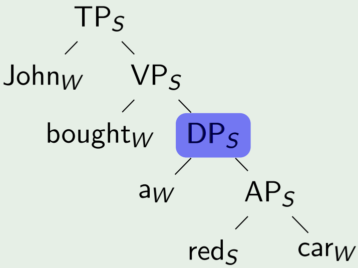


Transducer Model: The Constraint

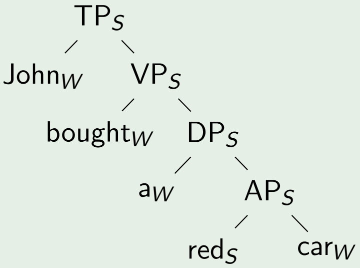
Focus Economy requires reference to the neutral stress pattern. We allow this by implicitly representing the neutral stress within the same tree!

Strategy

- Define two paths StressPath and NeutralPath.
- StressPath represents the path of the current stress.
- NeutralPath represents the path of the neutral stress.
- Add a constraint that requires focus to be in the stress path, but unless StressPath and NeutralPath pick out the same nodes, focus may not be in NeutralPath.

Example of ϕ

StressPath and NeutralPath



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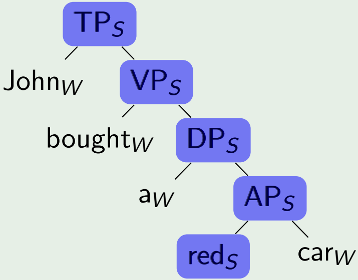

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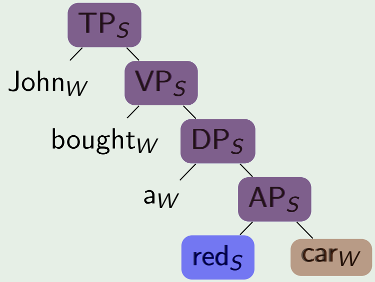

Merge-over-Move (MOM)

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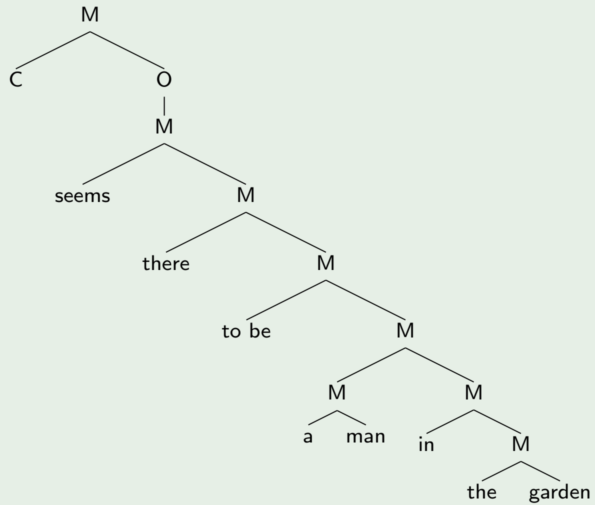
If two convergent derivations d and d' are built from the same lexical items and identical up to step n, at which point d continues with Merge and d' with Move, filter out d'.

(3)
a. There seems t_{there} to be a man in the garden.
b. * There seems a man to be $t_{\text{a man}}$ in the garden.
c. A man seems $t_{\text{a man}}$ to be $t_{\text{a man}}$ in the garden.

Derivation Trees of (3a) and (3b)

Example



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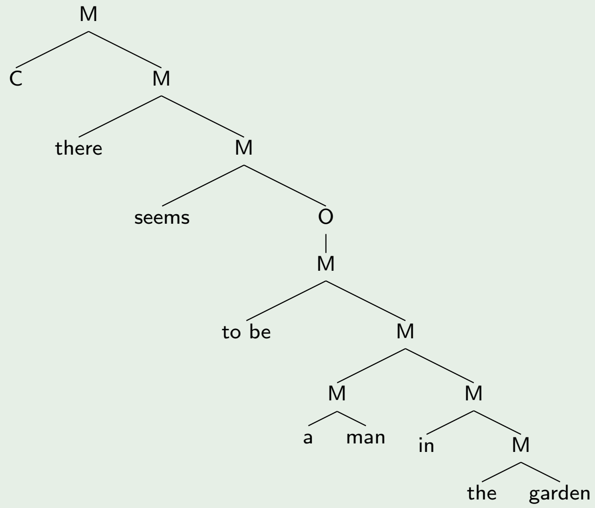
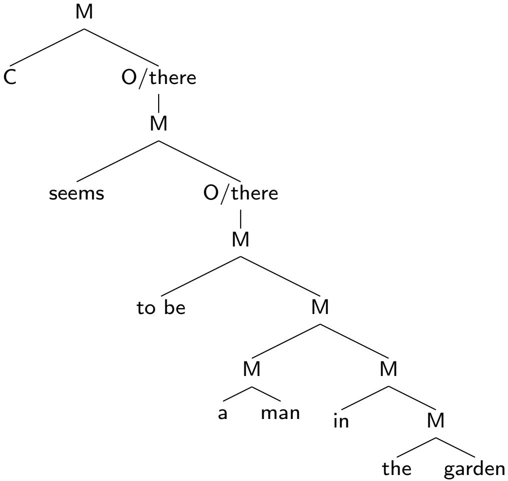


Transducer Model: Gen (Step 1)

- Fuse the two derivations into one underspecified derivation.
  - Remove all features but the category feature.
  - Inside TP: Replace O or Merger of *there* by new label O/there.

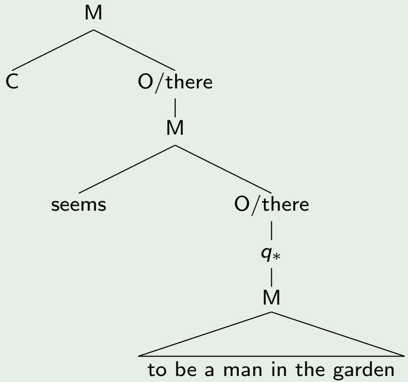


Transducer Model: Gen (Step 2)

- Turn O/there back into O or Merge of *there*.
  - Use a transducer with states q_*, q_O and q_C.
  - In state q_*, the transducer non-deterministically rewrites O/there as O or Merge of *there*.
  - If the transducer rewrites O/there as O, it switches into state q_0.
  - In state q_0, every occurence of O/there is rewritten just as O.
  - The transducer switches out of q_0 only if it encounters a CP (indicated by state q_C; cf. structured numerations).
- Reinstantiate the features.

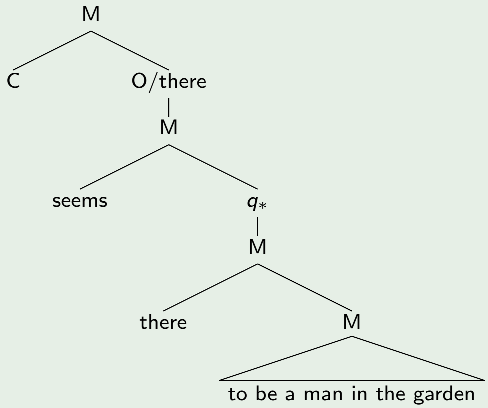
Transducer Model: Examples of Step 2

Example 1



Transducer Model: Examples of Step 2

Example 1



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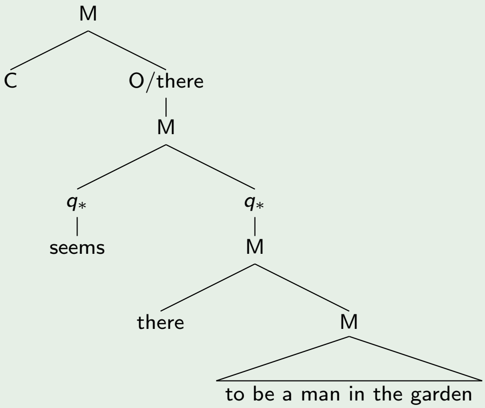

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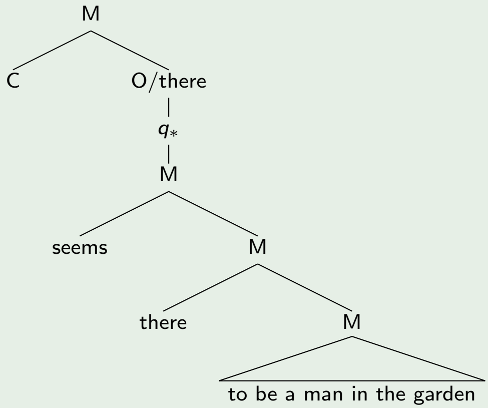

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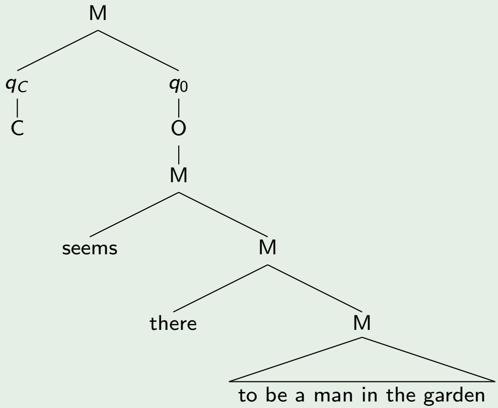

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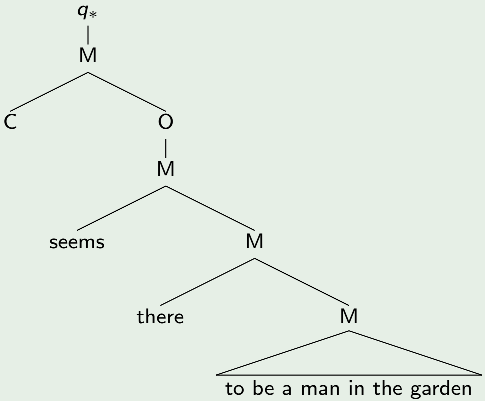
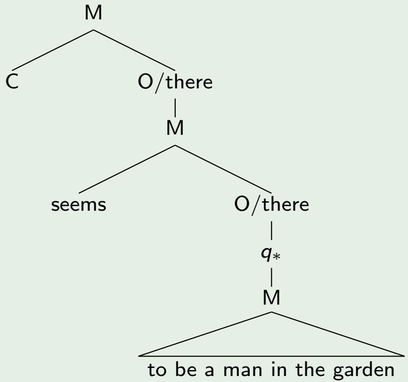


Transducer Model: Examples of Step 2

Example 2



Transducer Model: Examples of Step 2

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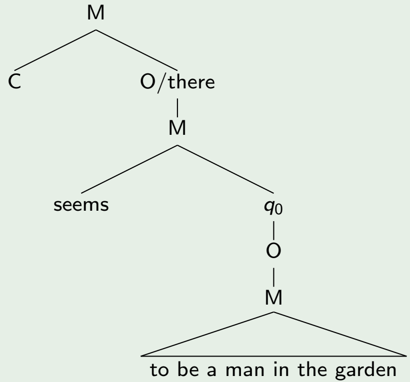

Transducer Model: Examples of Step 2

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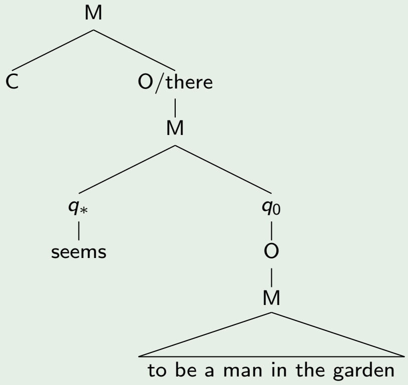

Transducer Model: Examples of Step 2

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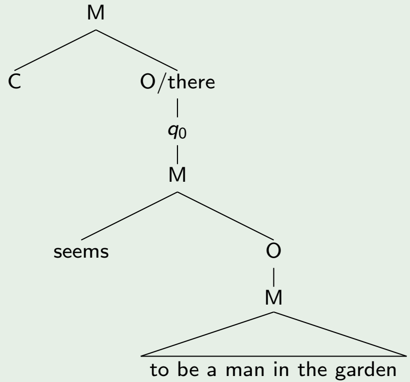

Transducer Model: Examples of Step 2

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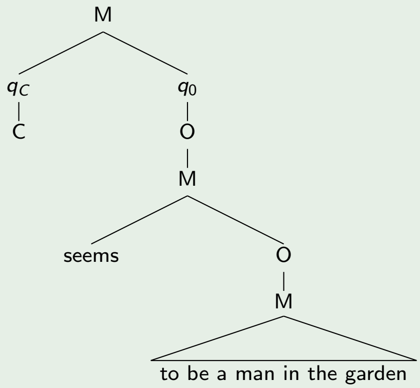

Transducer Model: Examples of Step 2

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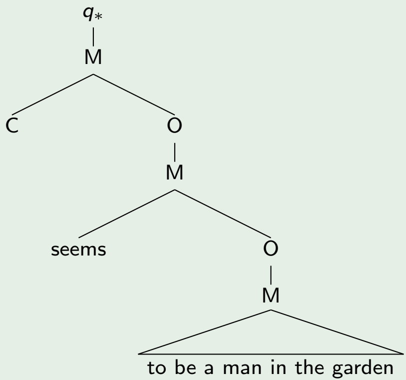


Transducer Model: The Induced Mapping

The output candidates for both (4a) and (4b) are now (5a)–(5b).

(4) a. There seems t_{there} to be a man in the garden.

b. * There seems a man to be $t_{\text{a man}}$ in the garden.

(5) a. * There seems there to be a man in the garden.

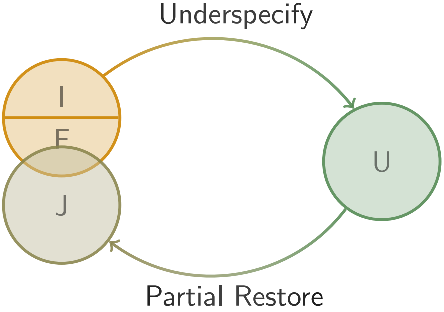
b. There seems t_{there} to be a man in the garden.

c. A man seems $t_{\text{a man}}$ to be $t_{\text{a man}}$ in the garden.

- We may extend the mapping such that (5c) is also assigned this reference set.
- (5a) still has to be ruled out.

Transducer Model: The Constraint

The only constraint is the input language itself!
By turning it into a transducer and composing it with GEN,
we remove all instances of overgeneration and filter out the illicit MOM violators.



Shortest Derivation Principle (SDP)

SDP

Given convergent derivations $d_1, \ldots, d_n$ over the same lexical items, pick the one(s) with the fewest instances of Move.

Why is the following sentence ungrammatical?

(6) * Who$_i$ was [$_{\text{DP}_j}$ a picture of t_i] taken t_j by John?

Derivations for (6)

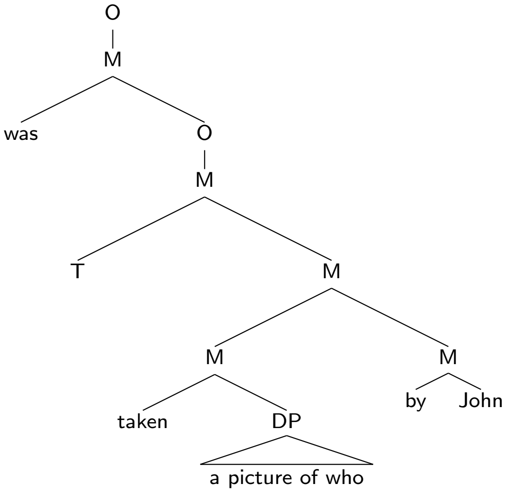
Two derivations are possible for (6).
CED violation in (7c)

(7) a. [$_{VP}$ taken [$_{DP_j}$ a picture of who$_i$] by John]
b. [$_{TP}$ [$_{DP_j}$ a picture of who$_i$] T [$_{VP}$ taken t_j by John]]
c. [$_{CP}$ who$_i$ was [$_{TP}$ [$_{DP_j}$ a picture of t_i] T [$_{VP}$ taken t_j by John]]]

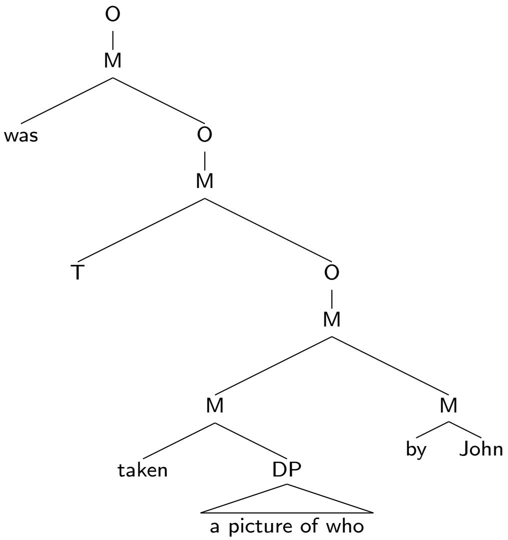
Derivation (8) is longer than (7)!

(8) a. [$_{VP}$ taken [$_{DP_j}$ a picture of who$_i$] by John]
b. [$_{VP}$ who$_i$ taken [$_{DP_j}$ a picture of t_i] by John]
c. [$_{TP}$ [$_{DP_j}$ a picture of t_i] T [$_{VP}$ who$_i$ taken t_j by John]]
d. [$_{CP}$ who$_i$ was [$_{TP}$ [$_{DP_j}$ a picture of t_i] T [$_{VP}$ taken t_j by John]]]

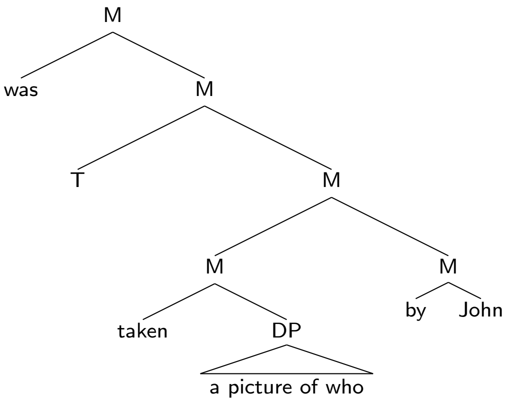
Derivation Tree of (7)



Derivation Tree of (8)



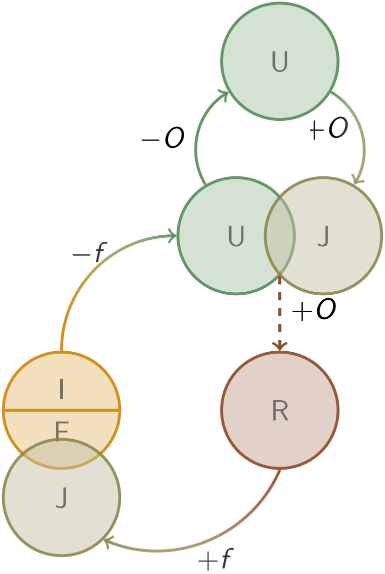
Underspecified Derivation Tree of (7) and (8)



Strategy

- Compute reference-set by
  1. mapping to underspecified derivation (i.e. remove Move-nodes)
  2. arbitrarily adding Move-nodes to underspecified derivation
  3. discarding all derivation trees that aren't in the input language (i.e. the junk)
- Filter out the suboptimal derivation trees (those that can be obtained from others by adding Move-nodes)
  1. Let R be the transduction that maps a derivation tree to the trees in its reference-set and $+O$ the transduction defined by adding Move-nodes
  2. The range of the composition of R with $+O$ is the set of derivation trees that can be obtained from some tree in the range of R by adding Move-nodes, i.e. the suboptimal outputs.
  3. Thus, the relative complement of the range of R and the range of the composition of R with $+O$ is the set S of optimal outputs. Composing R with the diagonal over S maps every tree to its optimal outputs.

Architecture of SDP



Underspecification-and-Filtration

A Rule of Thumb

A reference-set constraint is likely to be computable by a transducer if

- one can find a structure that encodes the commonalities of all the competitors, and
- neither the underspecification step nor the recovery step require insertion of material of unbounded size, and
- the economy metric can be implemented as
  - a well-formedness constraint on underspecified structures, or
  - a specific restriction on the recovery step, or
  - a transducer that turns optimal candidates into suboptimal ones.

Why Keep Them?

- **Modularity**
  Constraint only depends on input language,
  not on mechanisms that generate it
- **Succinctness**
  Non-reference-set correspondent may fail to make the restriction explicit or be much more complicated; reference-set constraint may subsume very different constraints
- **More Tweakable Parameters**
  Reference-set constraint gives us at least four parametrizable components: reference types, reference sets, the map between the two, and the economy metric.
- **Reaching out**
  Connections to OT, sTAG and others may allow us to incorporate results from these frameworks

Conclusion (Part 1)

- Tree transducers were proposed as a model for reference-set constraints.
- OSs offer a bird's eye view on them (**Unity 2**).
- Most requirements for an OS to be efficiently computable are fulfilled by reference-set constraints; in particular, their corresponding OSs are output joint preserving.
- The only problematic areas are GEN and the OS constraints.
- The underspecification-and-filtration strategy offers a general solution.

Conclusion (Part 2)

- **Concern 1: Computability**
  - If a reference-set constraint can be modeled as a tree transducer, it is efficiently computable.
  - In fact, it is equivalent to some standard well-formedness condition (**Unity 1**).
- **Concern 2: Empirical applicability**
  - Now that we have a natural class of licit reference-set algorithms and economy metrics (those definable by tree transducers), we can see if more nuanced revisions of them are more suitable.
  - We can use computational tools to test our predictions.
  - The additional parameters may make available new cross-linguistic generalizations (**Unity 3**).

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