Extremely Usage-based Approach to Syntax

with "Pattern Lattice" Model of Linguistic Knowledge and Performance

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"Blackship" Lectures at Tokyo University
2010/03/12

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- Why is people's speech **so stereotypical or formulaic**?
- Why is the distribution data **so sparse**?
- Why does **example-based machine translation work**?
- Why does **statistics matter** after all?

Burning Question

- These questions seem to boil down to a single question:
  - **How does human linguistic memory work?**
- The present work addresses a specific question (after Port 2007):
  - **What if human has all instances of linguistic expressions stored in vast (implicit) memory** (and virtually no expressions are generated in recognition process)?
- Caveat:
  - This work addresses only questions about comprehension, and will not discuss production.

Strategy

- I know this idea is **crazy**, and completely against the traditional wisdom of (theoretical) linguistics after Chomskian revolution.
- Yet **I take an extreme position** in my theorizing
  - with concerns of:
    - making it easier to draw nontrivial conclusions, and
    - making predictions easier to falsify.
  - and from awareness that **human memories are** (**still**) **far from well understood**.

Remark on Human Memory

- I assume the distinguish between two components/subsystems of human memory, i.e.:
  - **storage** of records and
  - **remembering/recall/retrieval** of stored records.
- There is a striking asymmetry between the two:
  - **Severe limitations on** (**explicit**) **remembering**,
    - especially constraints on working memories (Miller's (1956) magical number 7±2)
  - Virtually **no limits on storage**: this is a suggestion from recent findings in hyperthyemestic syndrome (Parker et al. 2006)

Outline

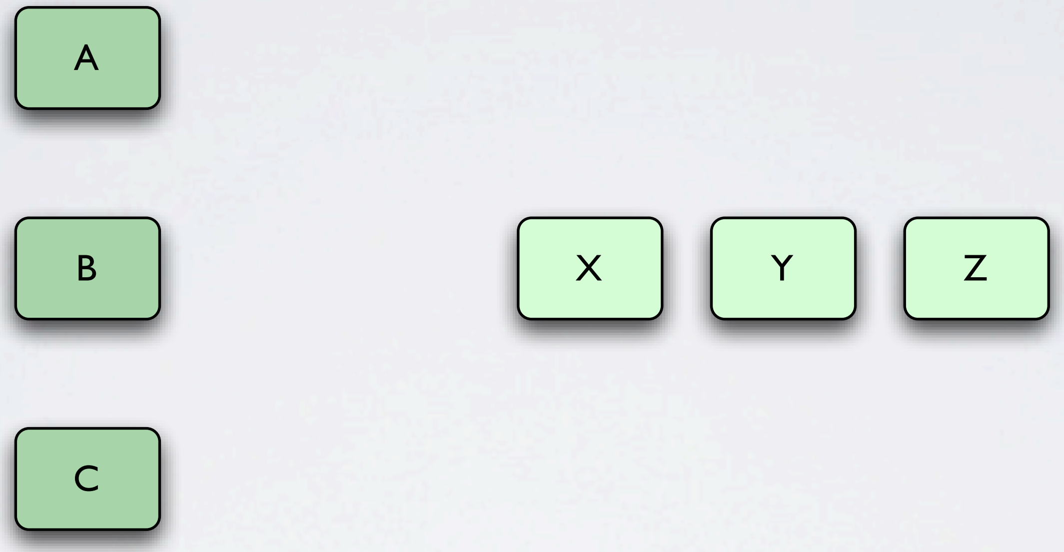
- **Superposition of patterns can implement composition**.
  - **Pattern Lattice** (PL) of a set of expressions defines a **hierarchy of superlxical patterns** used in superposition
- **Simulated Parallel Error-Correction** (SPEC) under pattern lattice provides a better account of "construction" effects (Goldberg 1995, 2006).
- Pattern lattice model (PLM) allows us to conceive of grammar of language as a **management system** rather than as a **generative system**.
- Conclusions

Why not Superposition?

Why Substitution?

- In virtually all linguistic theories, **composition is implemented by substitution**.
- Yet **there is no conceptual necessity for this**: **superposition can do it**, too.
- and it does so with several desirable features.
  - Remark: Conception of composition as substitution **has a long, strong tradition** (e.g. proof theory crucially relies on it (cf. production system (Post 1943)), but **this is a different matter**.

SUBSTITUTION



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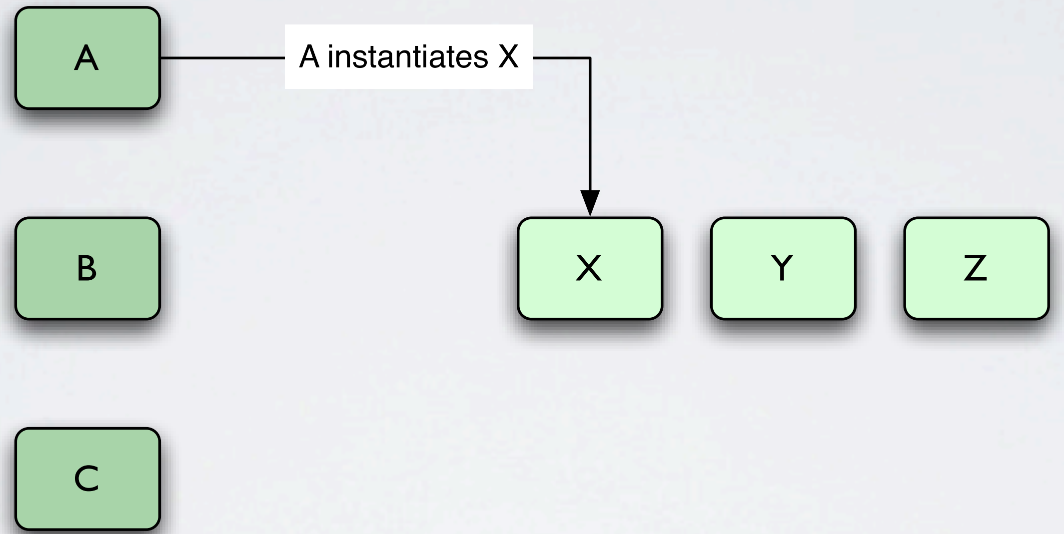

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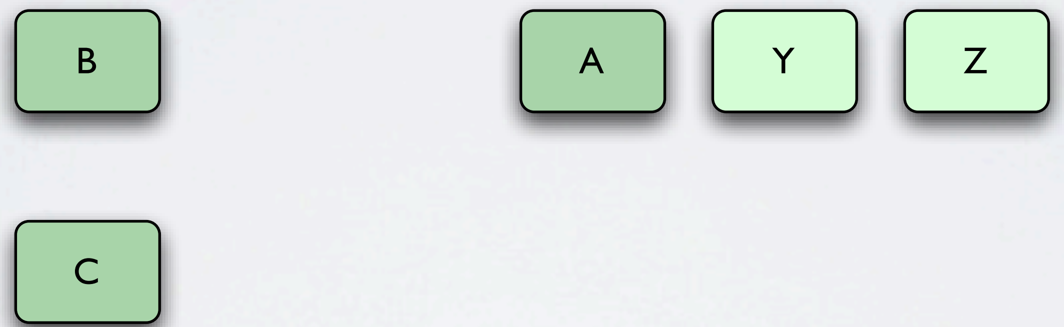

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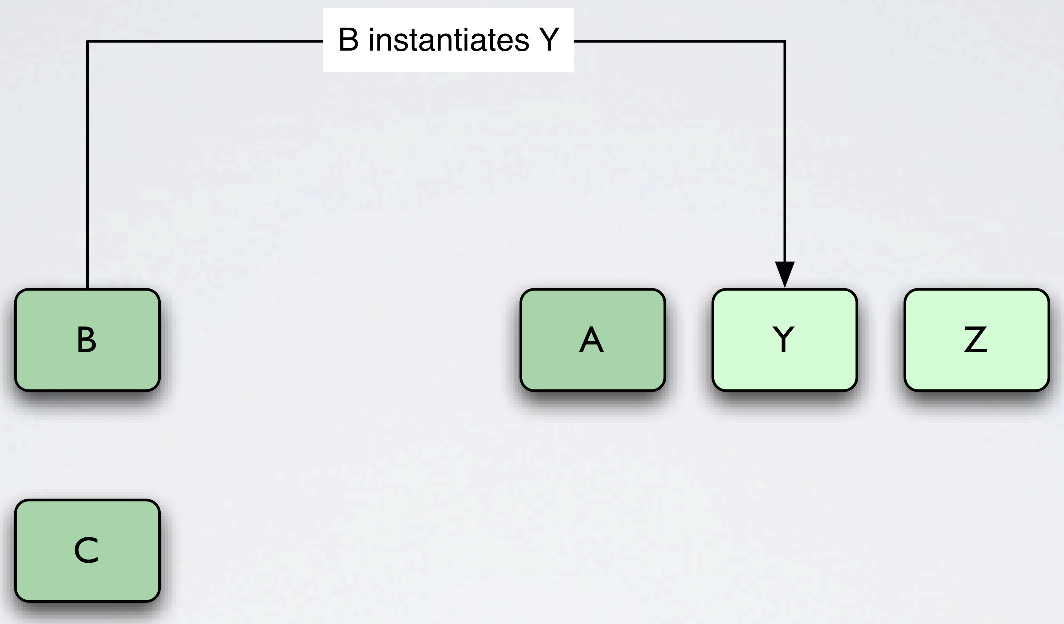

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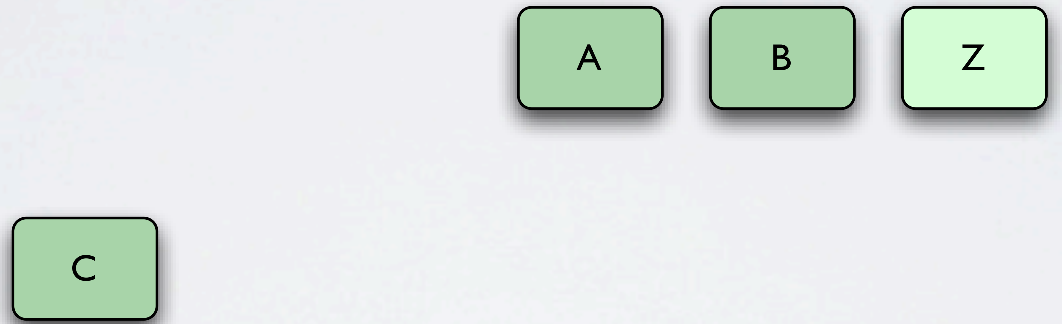

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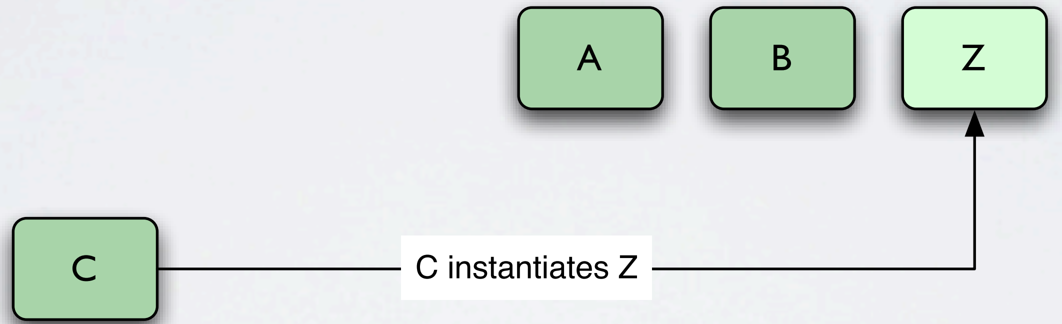
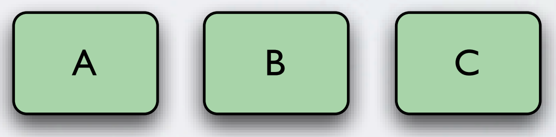


SUBSTITUTION (Result)



Desirable Properties

- Representation of items (to be inserted) can be **context-free** and therefore **redundancy-free**.
- Host structures can be defined **freely but systematically** if they are defined by something called "grammar."
  - This can answer the problem of human creativity.
- In essence, substitutional model **guarantees economy and generalization**
  - but only in terms of description load, and if computational time is counted as a resource, the conclusion should be different.

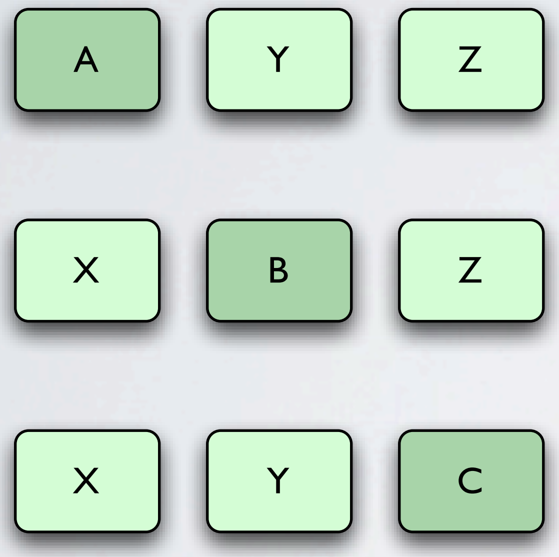
Superposition

- C is superposition of $A = a_1 \cdot a_2 \cdots a_m$ and $B = b_1 \cdot b_2 \cdots b_n$ iff:
  I. A and B have the same number of segments ($m = n$: equi-cardinality)
  II. either $\mathbf{a_i = b_i}$ or **instance-of(a_i, b_i)** or **instance-of(b_i, a_i)** holds for every i.
    - If II holds, it is **superposition without specification overrides**.
    - If II is violated, it is **superposition with specification overrides**.
  - Note: *a* is an instance of *b* iff *a* is an underspecification of *b*.
- It is trivial to implement superposition using feature structure.

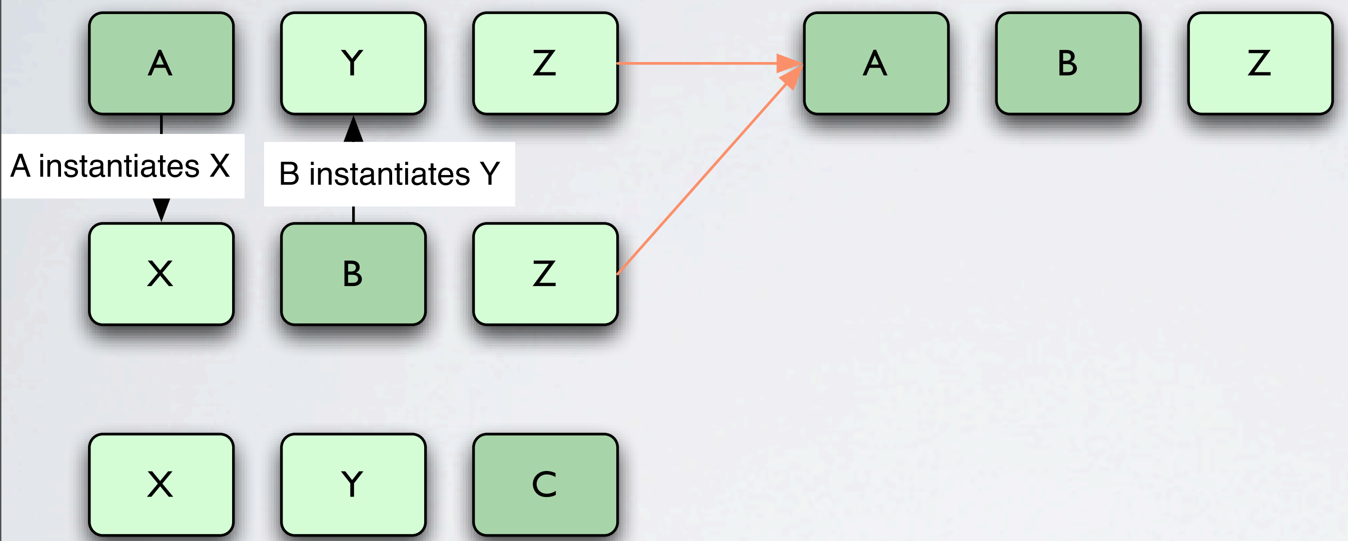
Relevant Terminology

- Superposition without overrides is (a special case of) **unification**.
- Superposition with overrides is (a special case of) **blending** in the sense of Fauconnier & Turner (1996, *et seq*.)
    - The latter case can **deal with inconsistencies** (e.g., conflicts in feature specification) between source structures, which is not allowed in the former.

SUPERPOSITION



SUPERPOSITION



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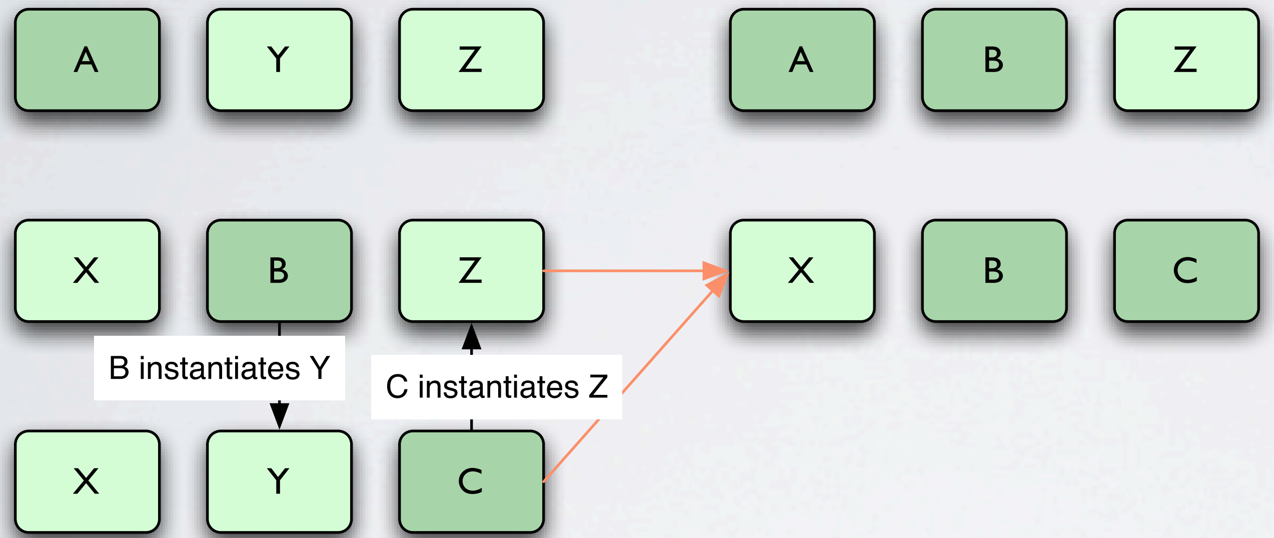

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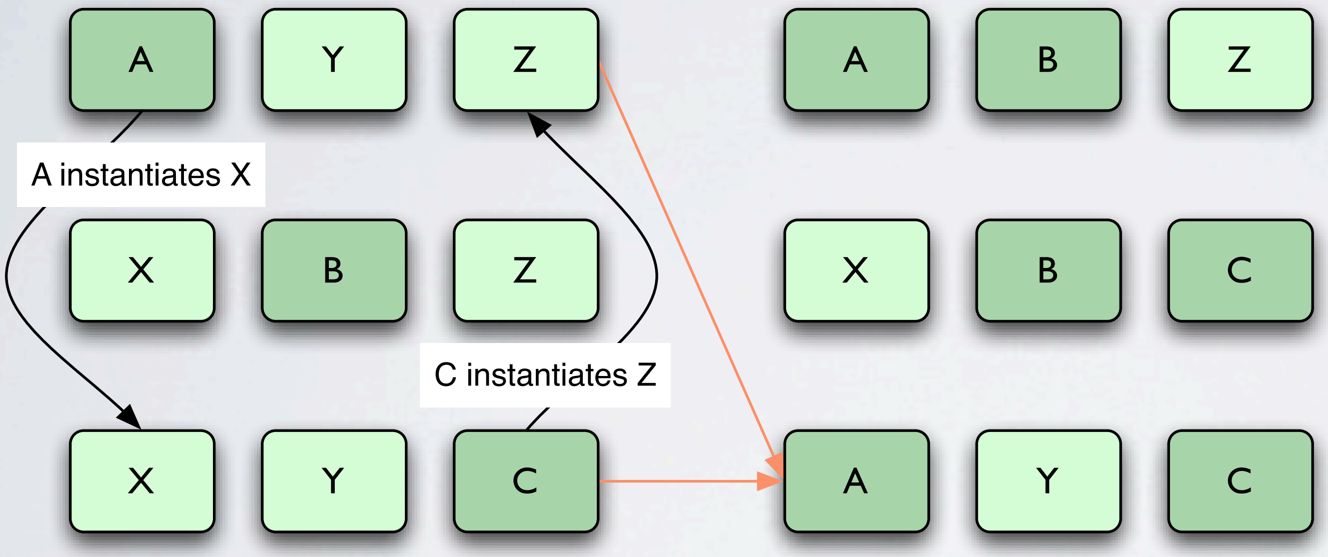
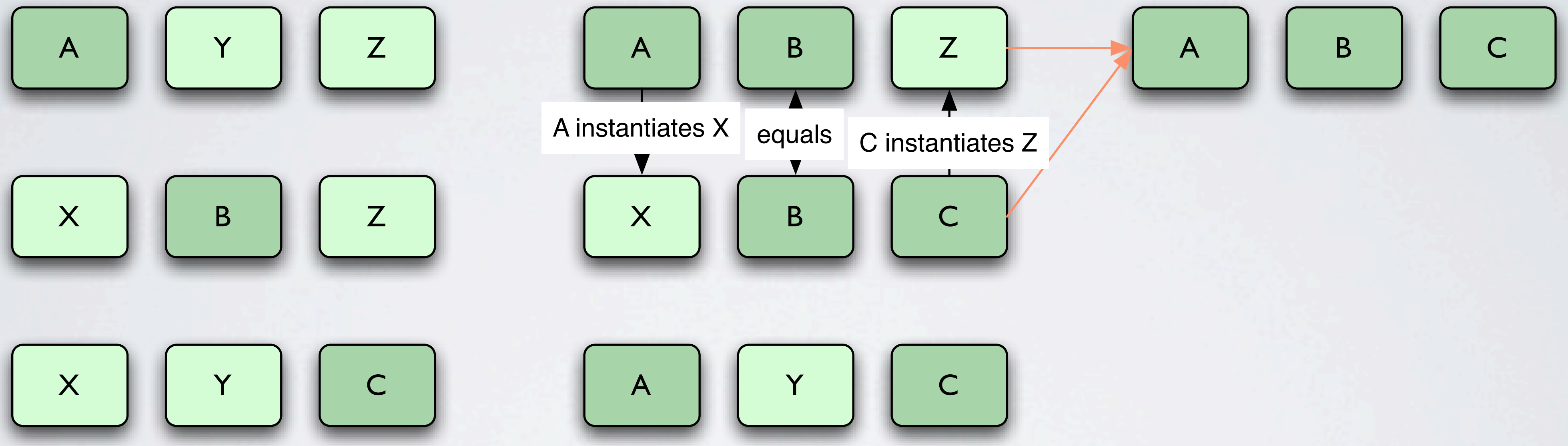
SUPERPOSITION



SUPERPOSITION (Result 1)



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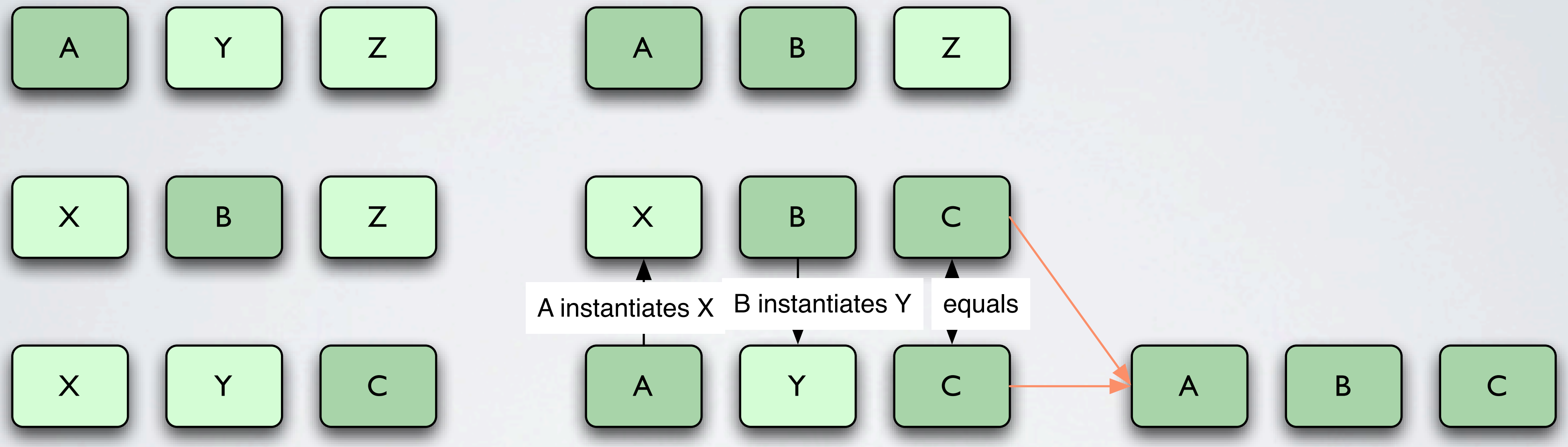
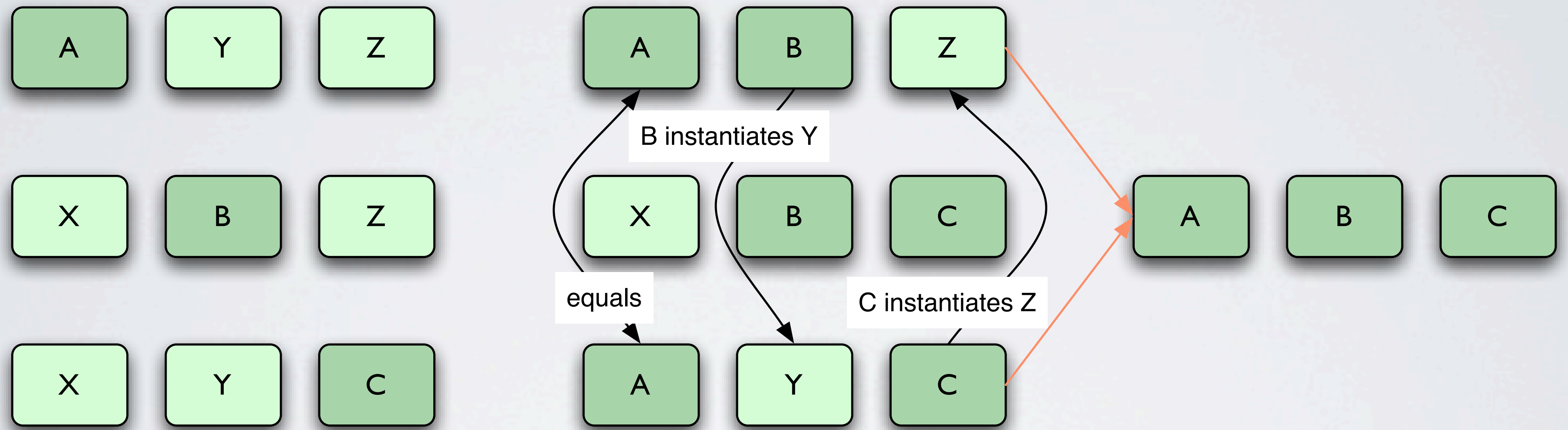
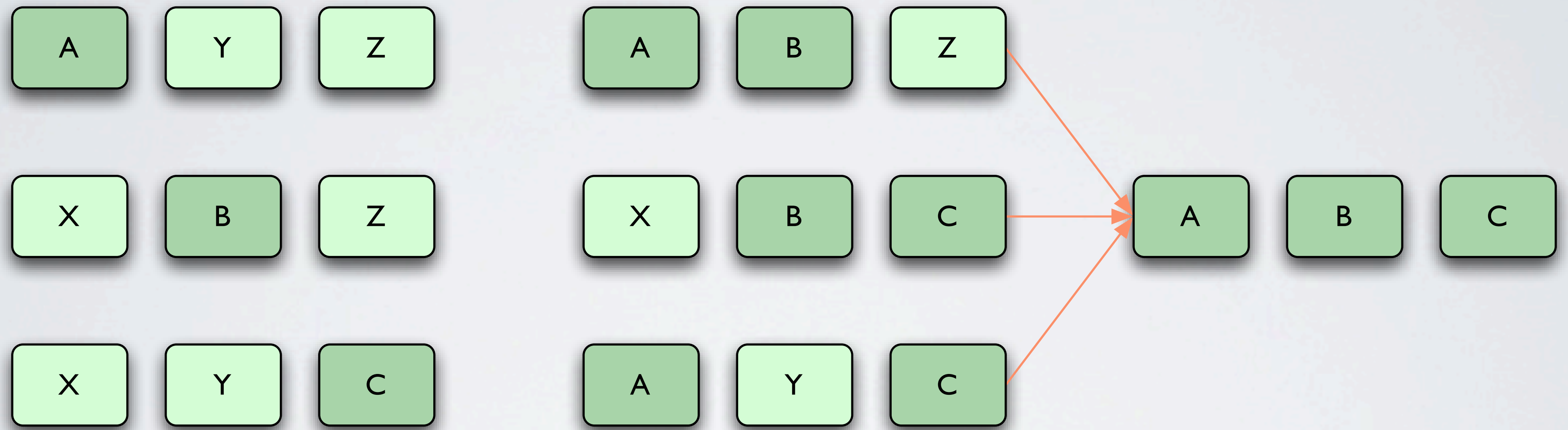
SUPERPOSITION (Result 2)



SUPERPOSITION (Result 3)



SUPERPOSITION (Results)



Note:

- Results 1, 2 and 3 are not mutually exclusive, and there is no reason to choose one of them.

- In other words, uniqueness of sources is not guaranteed in superposition.

Role of Redundancies

- **No superposition is possible if there are no redundancies in item representations.**
- Implications:
  - Phrase structure analysis under the **principle of proper analysis** is a roundabout to superposition.
  - Theoretically, superposition over a set of phrase structures is possible (e.g., Sadock's *Autolexical Syntax* (1991)), but it usually gets more complicated than superposition of (flat) patterns.

Desirable Properties

- Superposition **does not require proper analysis**,
  - and **phrase structure analysis**, either.
- Yet superposition
  - allows **composition without host structures**,
  - allows **composition under overlaps** over elements with redundancies,
  - and solves "bracketing paradox" (Spencer 1988) automatically

Examples of Overlap 1/2

- In morphology: ***generative grammarian*** (bracketing paradox Spencer 1988)
  - superposition of [$_{u1}$ **generative**][$_{u2}$ **grammar**] and [$_{u2}$ **grammar**][$_{u3}$ **-ian**]
- In syntax: ***an easy book to read*** (discontinuous constituent in McCawley 1988)
  - superposition of [u_1 **an**][u_2 **easy**][u_3 **book**] and [u_2 **easy**][u_3 ...][u_4 **to**] [u_5 **read**] with overlaps at u_2 and u_3.
- Remark:
  - **overlap is involved in most cases in which syntactic movement is necessary.**

Examples of Overlap 2/2

- 浮世絵師 (mundanity painter at Edo era) is superposition of [u_1 浮世][u_2 絵] (mundanity pictures at Edo era) and [u_2 絵][u_3 師] with overlap at u_2
- 投影像 (projective image) is superposition of [u_1 投][u_2 影] (projection) and [u_2 影][u_3 像] (image of shadow) with overlap at u_2.
- Remark:
  - **overlapping seems to be more frequent in head-final languages.**

Comparison

	Substitution	**Superposition**
item encoding and generativity	context-free	context-sensitive
memory load	minimum	maximum
size of lexicon	minimum	maximum
overlaps	can't handle	can handle
relation of semantics to syntax	extrinsic	intrinsic

Summary of Part I

- Superposition can implement composition properly.
  - Simply, composition **need not** be implemented by substitution.
  - Superpositional model of composition **can be computational** if superposition is properly defined as a formal operation.
- Superposition is desirable if we target overlapping phenomena.
  - Overlapping is far from well understood but is ubiquitous, and is likely to **have been overlooked due to linguist's (naïve) belief in proper analysis**.

Where do Patterns Come from?

Pattern Lattice Model in a nutshell

New Burning Question

- You may ask:
  - Alright, I understood that patterns have desirable properties, but **where do patterns come from** after all?
  - **Aren't they generated by grammar or something like that?**
- My answers:
  - Structure called "pattern lattice" (PL) over a set of expressions works as a generator of patterns.
  - This makes the challenge by the second question unsuccessful.

Definition of Pattern Lattice (PL)

- A pattern lattice is a complete lattice over a sequence of units with a fixed number n (i.e., patterns of length n) under the instance-of relation.
- An expression (including pattern) $E = e_1 \cdot e_2 \cdots e_m$ (e_i denotes the ith segment of E) is an instance of pattern $P = p_1 \cdot p_2 \cdots p_n$ (p_i denotes the ith segment of P) if and only if:

A. E and P **have the same number of segments** (i.e., $m=n$).

B. either **$e_i = p_i$** or **instance-of(e_i, p_i)** holds for every i.

Example 1

- Take (1) for example:

(1) **Ann sent Bill a letter.**

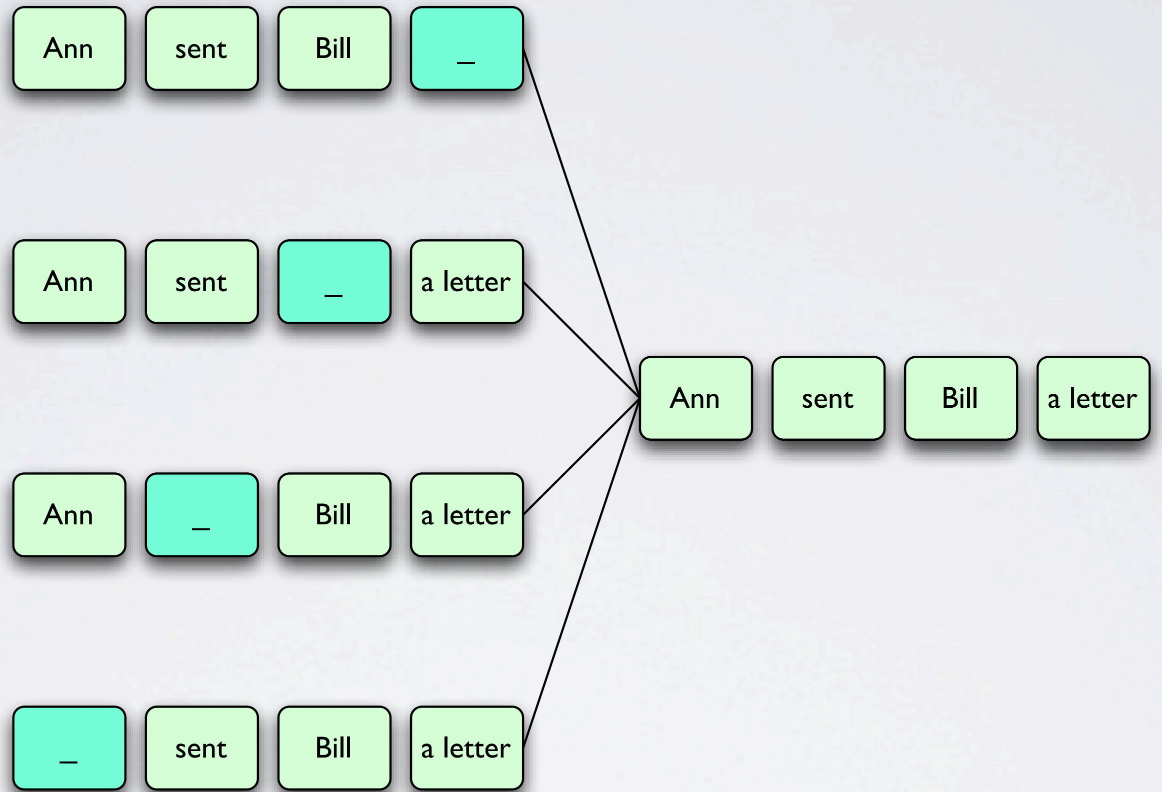
Example 1

- Suppose (1) has 4 segments.
  - [**Ann**, **sent**, **Bill**, **a letter**]
- Remark:
  - I just assume that this segmentation with four segments is (nearly) optimal.
  - Its optimality is not justified intrinsically in the PLM. It needs to be justified extrinsically either by relying on unsupervised classification/learning methods or more radically stochastic methods like Monte Carlo simulation.

At the Bottom

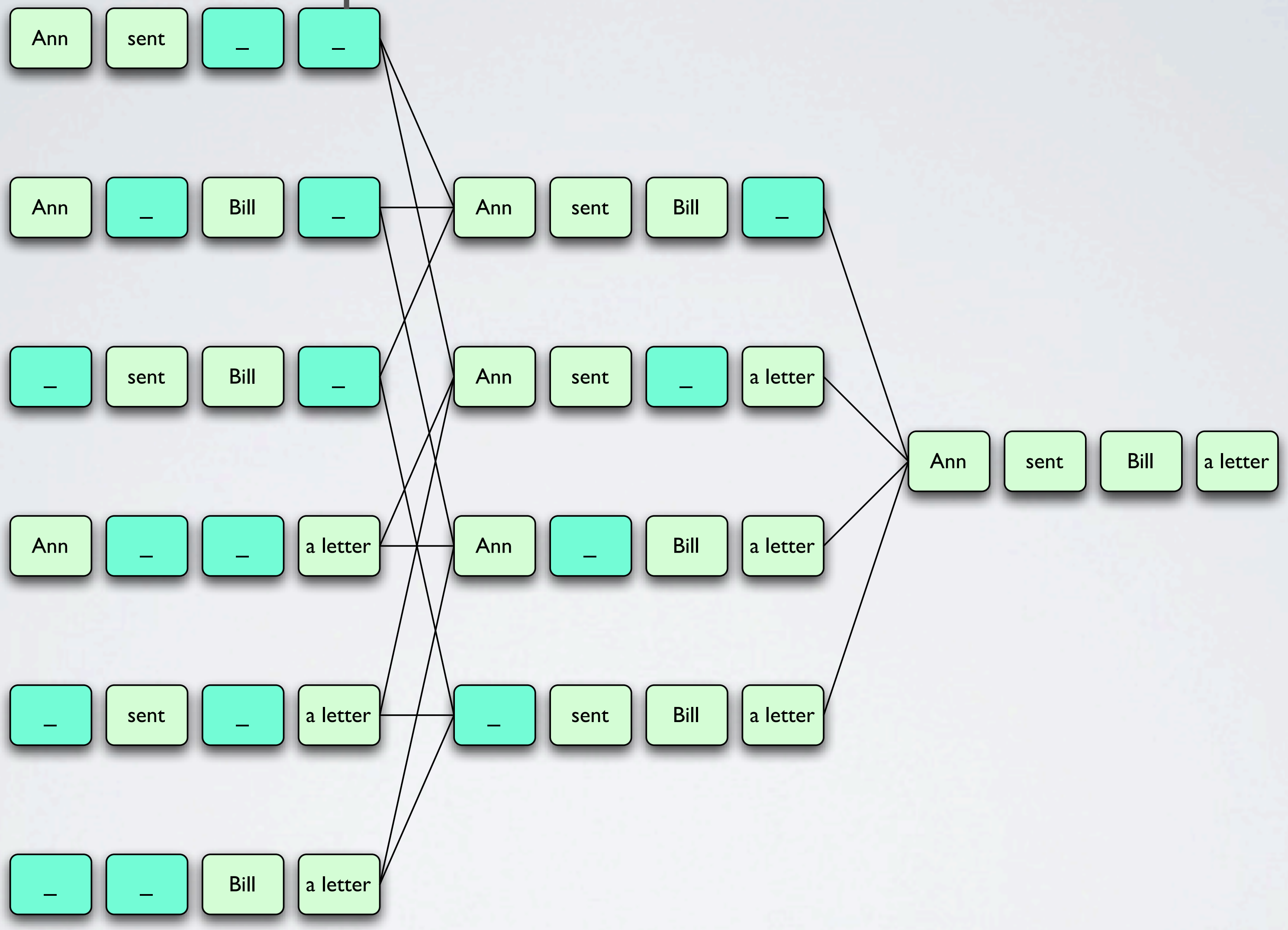
Ann | sent | Bill | a letter

Decomposition into Patterns



- Decomposition introduces variables denoted by "_". In general, expression *E* of size *n* has *m* **immediate components** when it has *m* constants in it ($m \leq n$).
- [Ann, sent, Bill, _], [Ann, sent, _, a letter], [Ann, _ Bill, a letter], and [_, sent, Bill, a letter] are immediate components of [Ann, sent, Bill, a letter] = (1).

Decomposition into Patterns



[Ann, sent, _, _], [Ann, _, Bill, __], and [_, sent, Bill, _] are **immediate components** of [Ann, sent, Bill, _], and so on.

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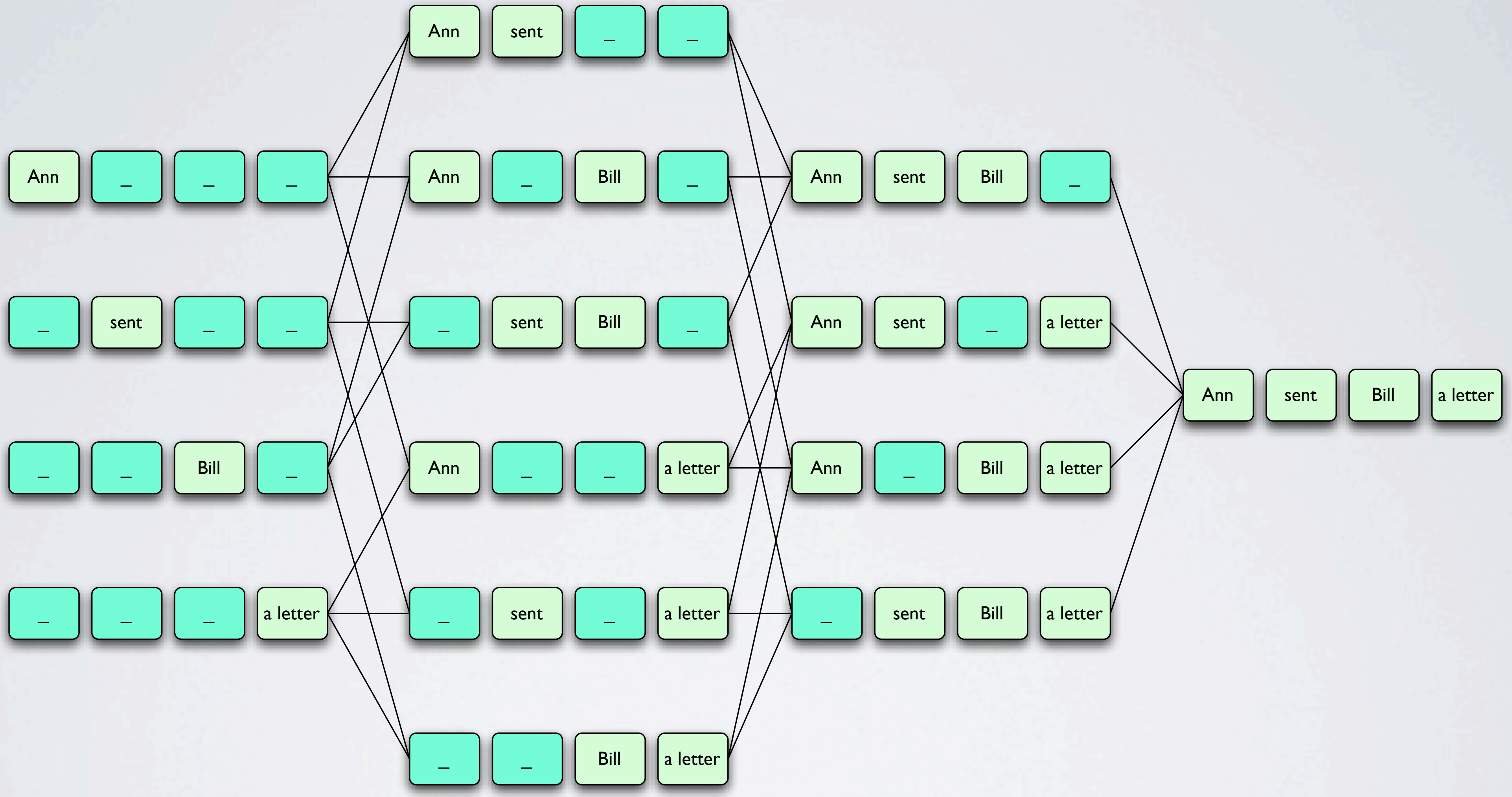
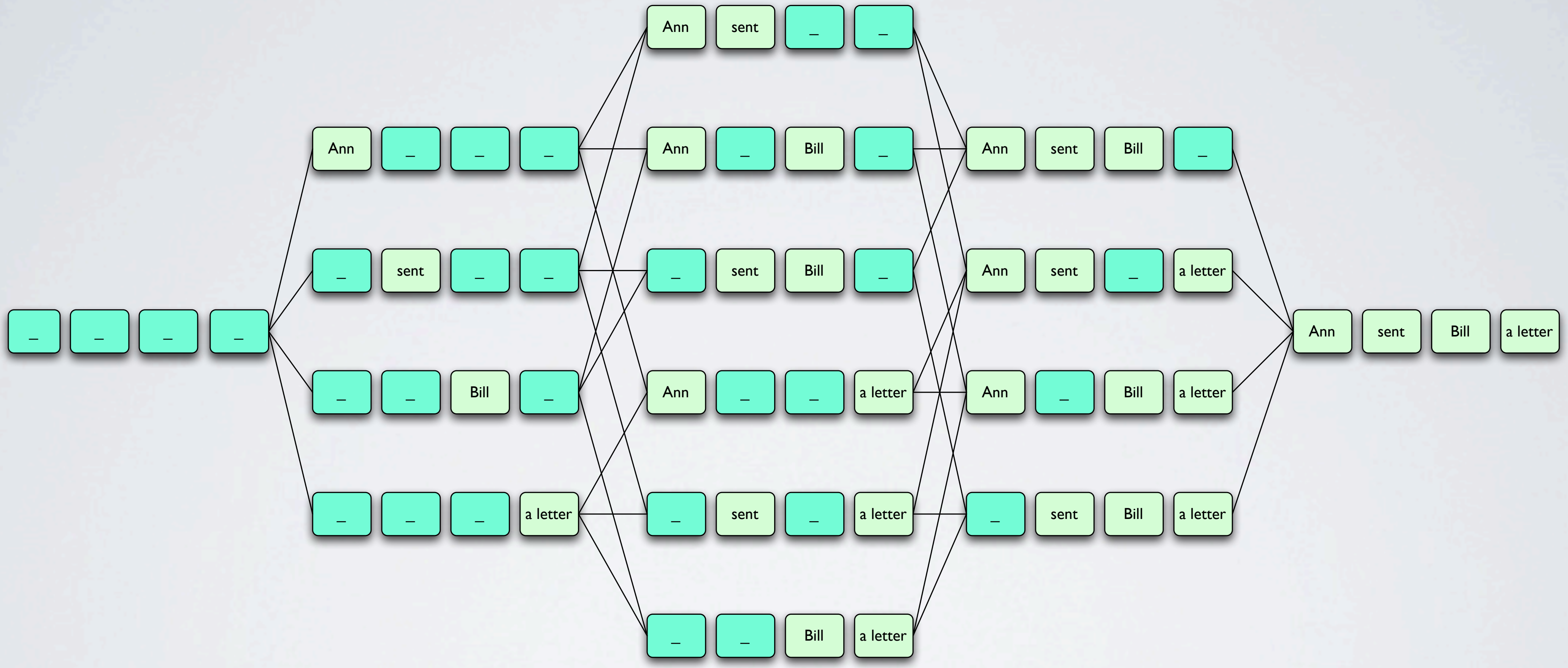


[Ann, _, _, _] and [_, sent, _, _] are **immediate components** of [Ann, sent, _, _], and so on.

Pattern Lattice Built for (1)



[_, _, _, _] is **the only immediate component** of [Ann, _, _, _], [_, sent, _, _], [_, _, Bill, _], and [_, _, _, a letter].

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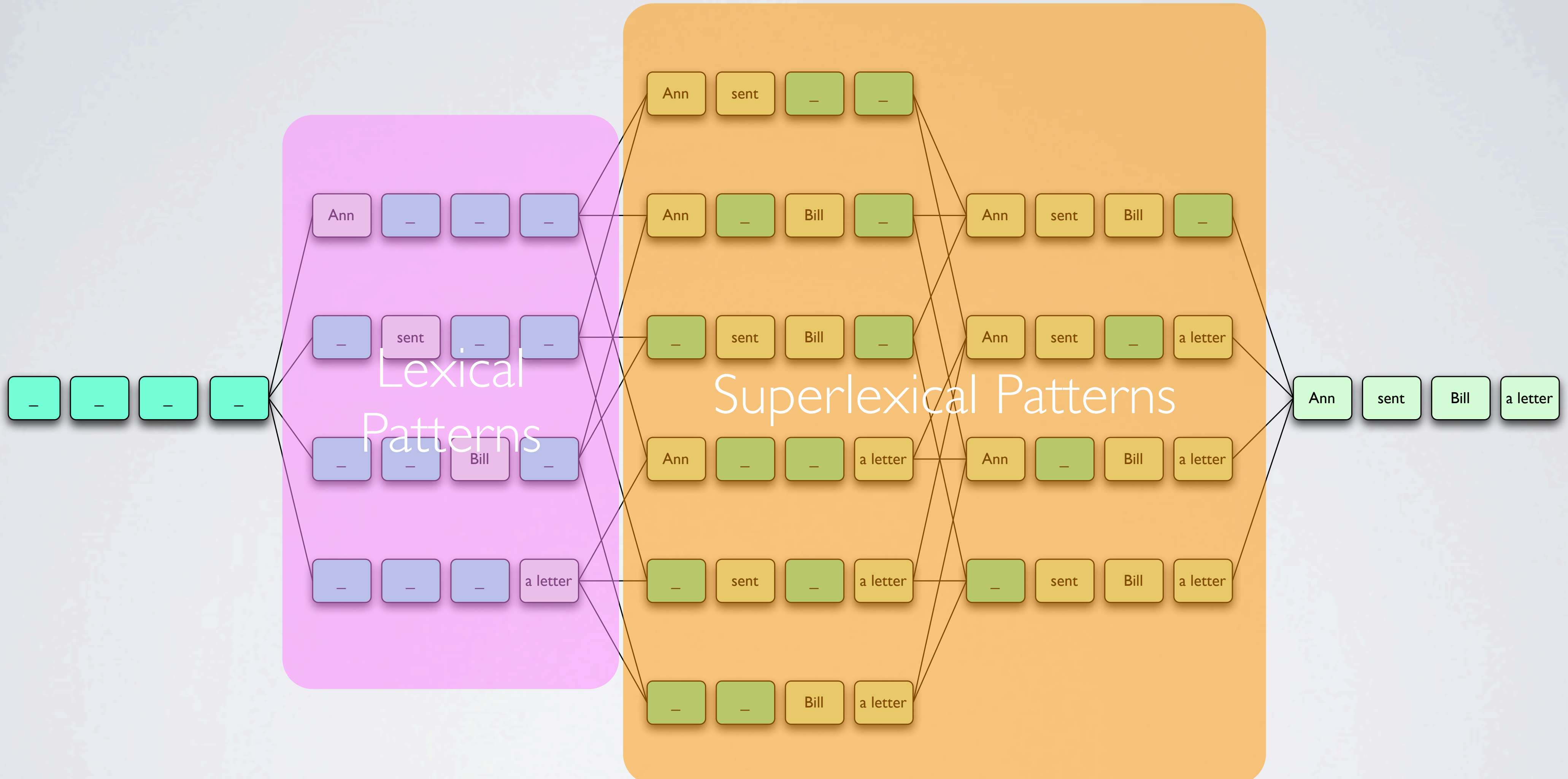

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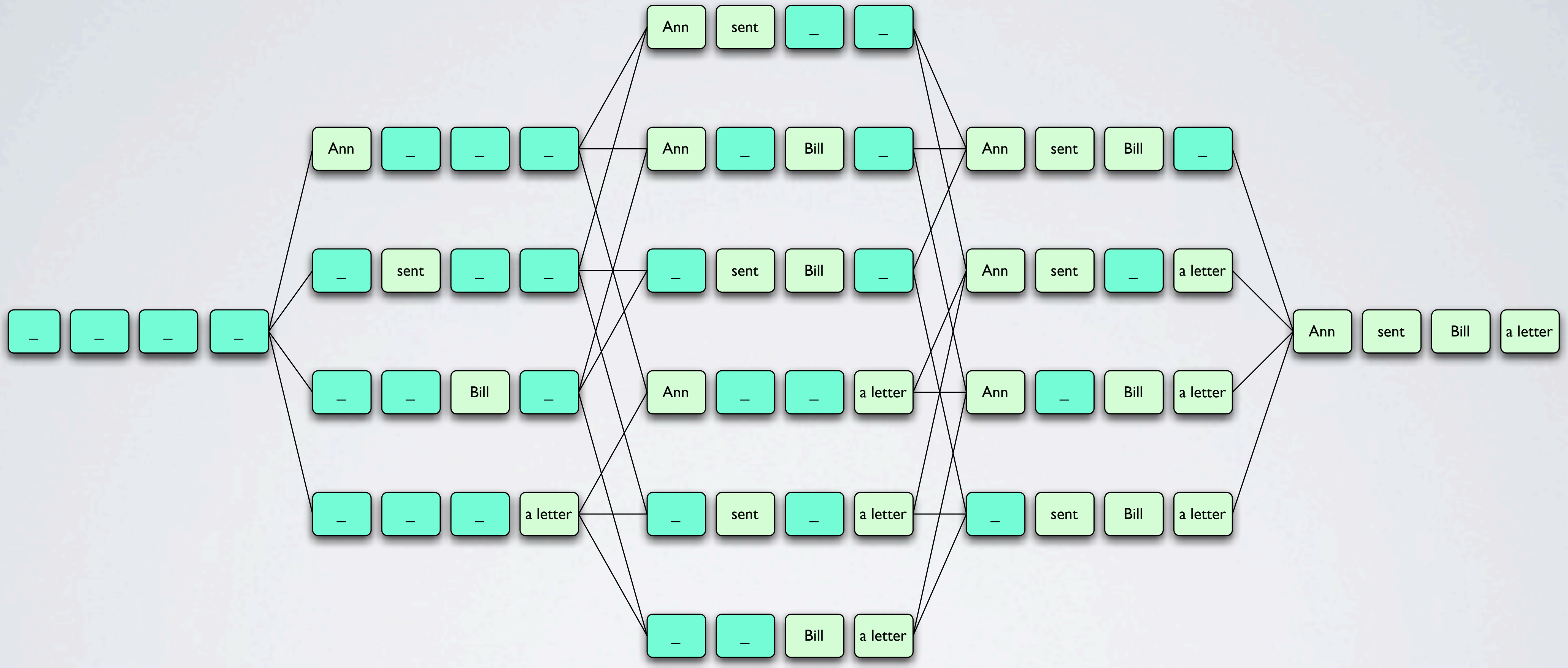
Constituency



Equivalents of constituents **are implicitly specified**: they are simply **patterns that contain only continuous constants**.

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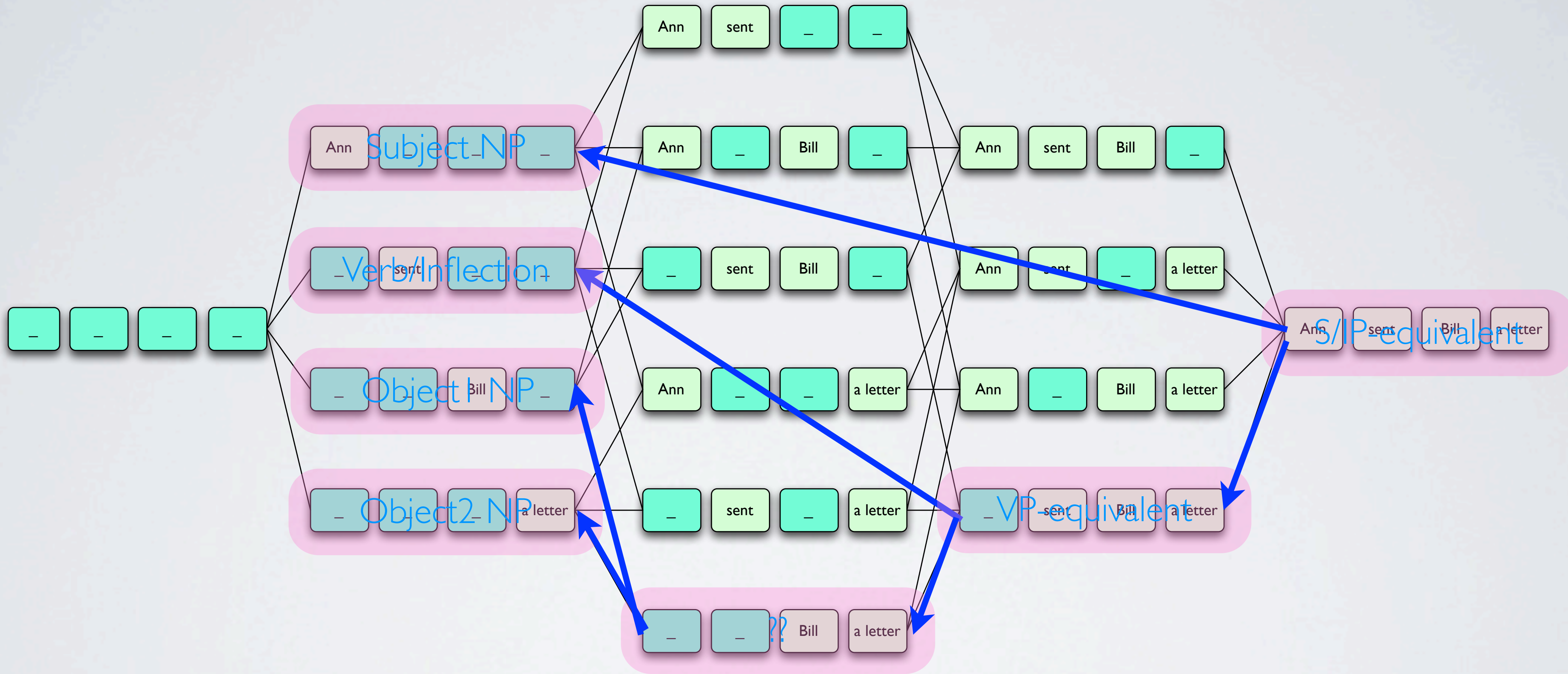

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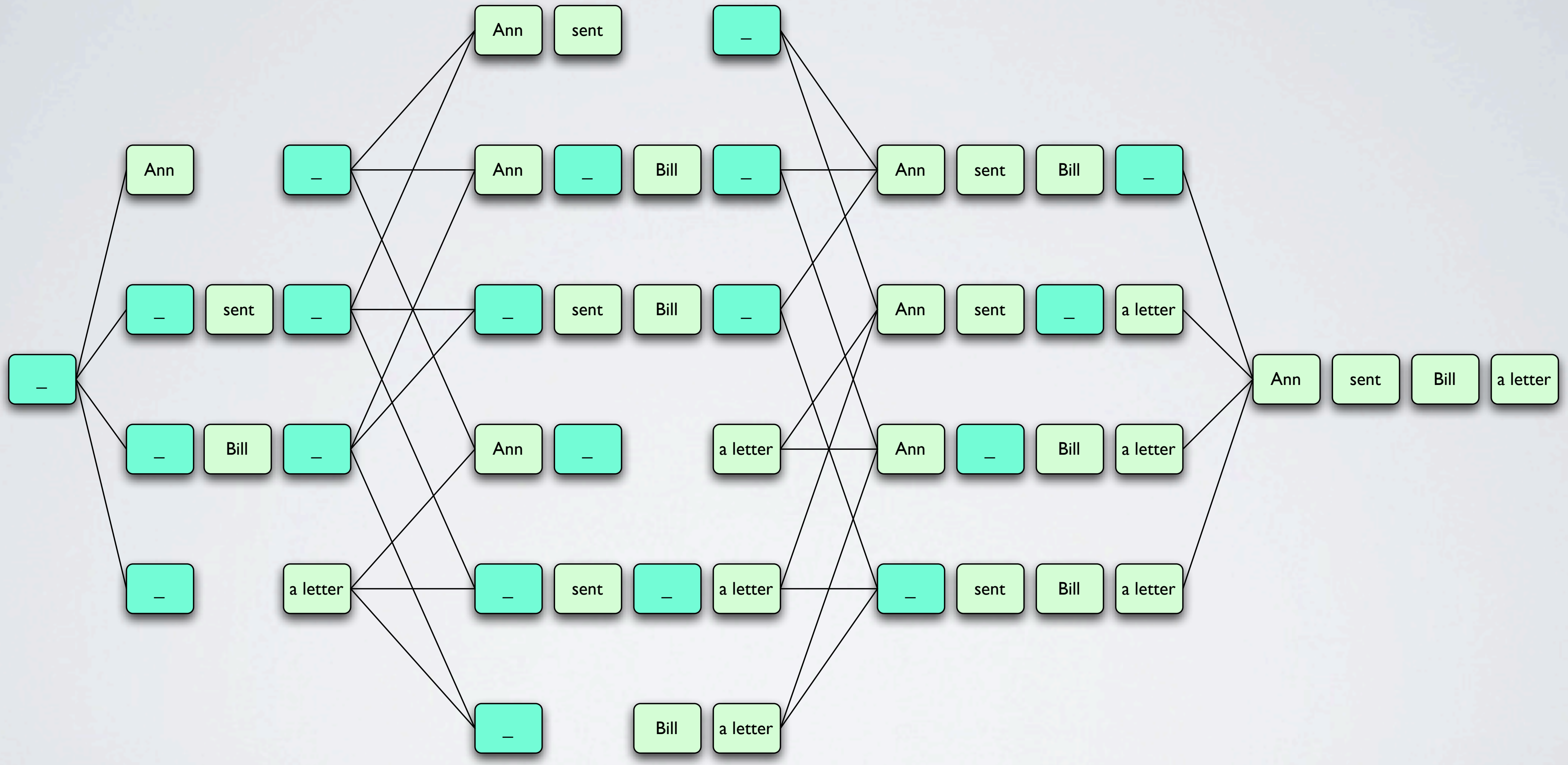
In Simplified form



variable sequences are simplified.

Semantics under a Patter Lattice

with “Simulated Parallel Error Correction” Model of Meaning Construction

Yet Another Burning Question

- You may further ask
  - Alright, but **how does semantics works under Pattern Lattice Model?**
  - More specifically, what guarantees the compositional nature of semantic interpretation?
- My answers:
  - We have an algorithm called **Simulated Parallel Error Correction** (SPEC) that gives the "right" interpretation of a given input.
  - SPEC is an extremely exemplar-based algorithm that can handle both the compositional and noncompositional aspects of interpretation.

SPEC in a Nutshell

- SPEC (see my paper for details) is a mechanism for semantic interpretation of a given expression *E* that **works in the same way as example-based machine translation works** (EBMT: 佐藤 1997; Sato & Nagao 1993).
- Basic correspondences:
  - Input expressions in SPEC correspond to expressions of source language in EBMT.
  - Superlexical (usually, sentential) semantics in SPEC correspond to expressions of target language (i.e., translations) in EMBT.
- In a sense, EBMT is a version of SPEC in that it equates semantic representations with expressions observed at surface.

Example 2

- Suppose we have other two examples (2) and (3) with 4 segments:

  (1) [Ann, sent, Bill, a letter]

  (2) [Ann, faxed, Bill, a letter]

  (3) [Carol, sent, Bill, a letter]

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- Suppose we have other two examples (2) and (3) with 4 segments:

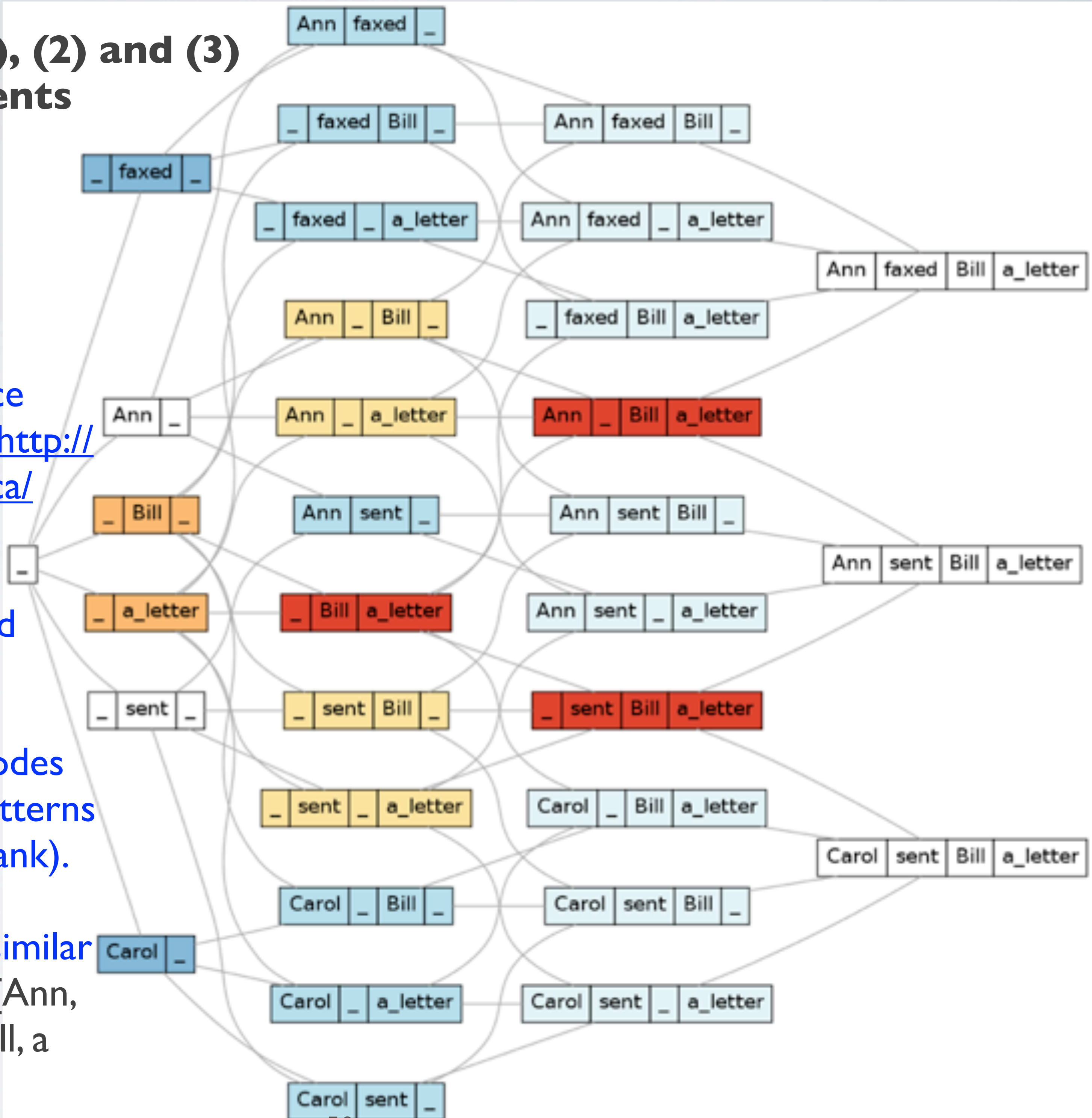
  (1) [Ann, sent, Bill, a letter]

  (2) [Ann, faxed, Bill, a letter]

  (3) [Carol, sent, Bill, a letter]

- Note:
  - Goldberg (1995) treated (2) as an example of Ditransitive Construction.

Pattern lattice for (1), (2) and (3) with 4 segments



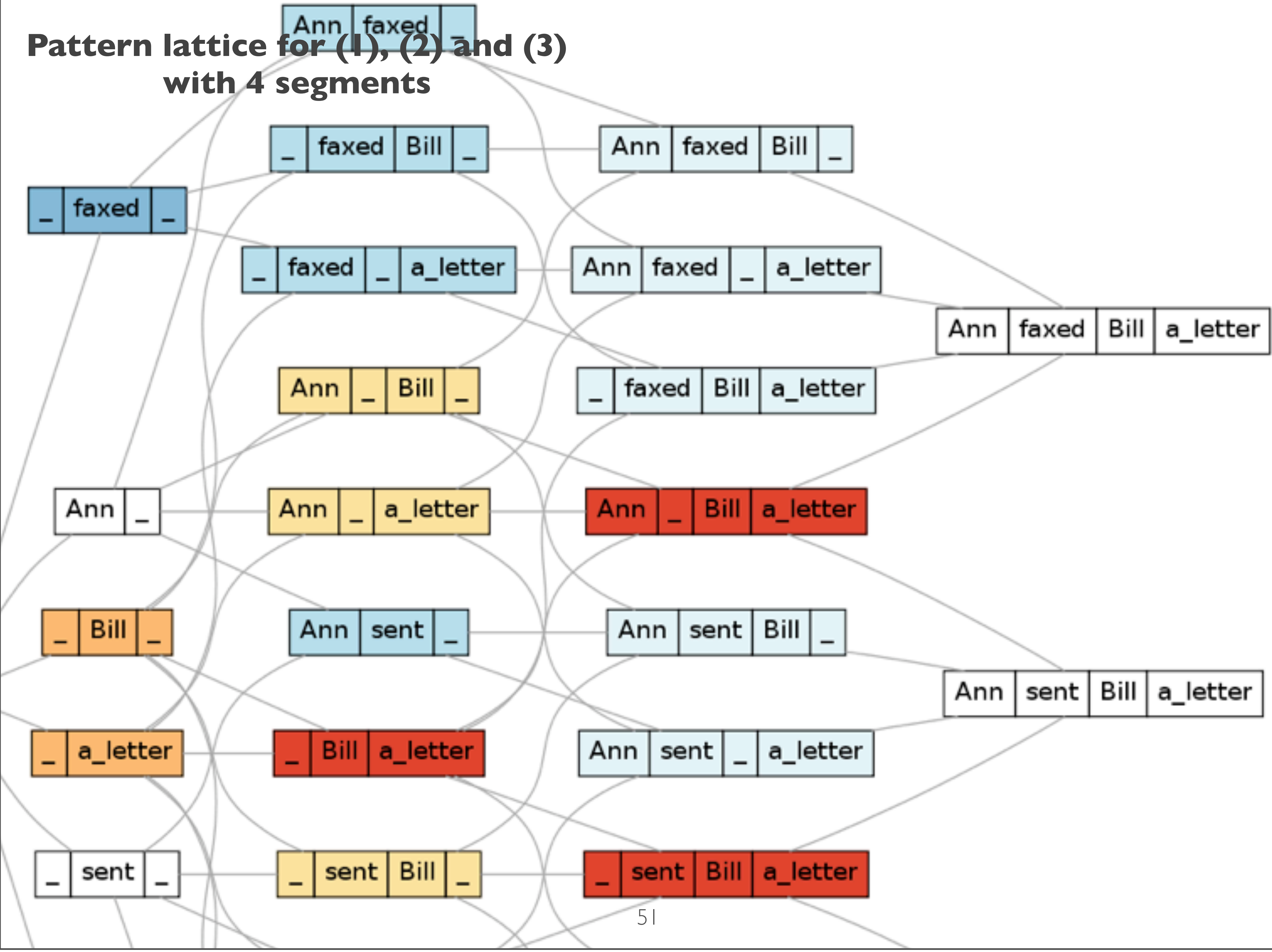
- Built using Pattern Lattice Builder (PLB) available at http://www.kotonoba.net/rubyfca/pattern

- Represented in simplified form.

- Color temperature encodes relative productivity of patterns (in terms of z-score for rank).

- (1) is one of (2)'s most similar instances due to pattern [Ann, _, Bill, a letter] or [_, _, Bill, a letter].

Pattern lattice for (1), (2) and (3) with 4 segments



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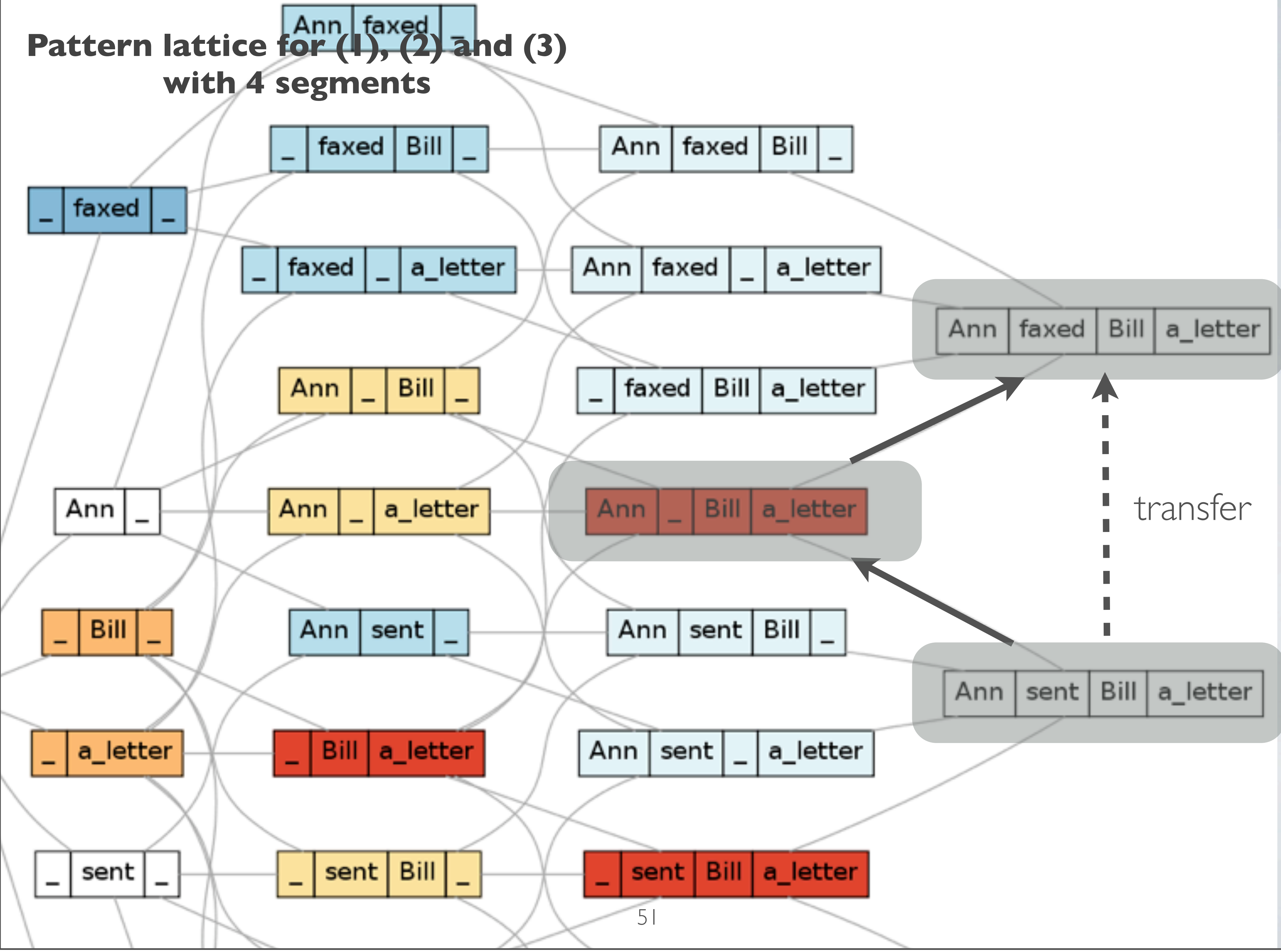

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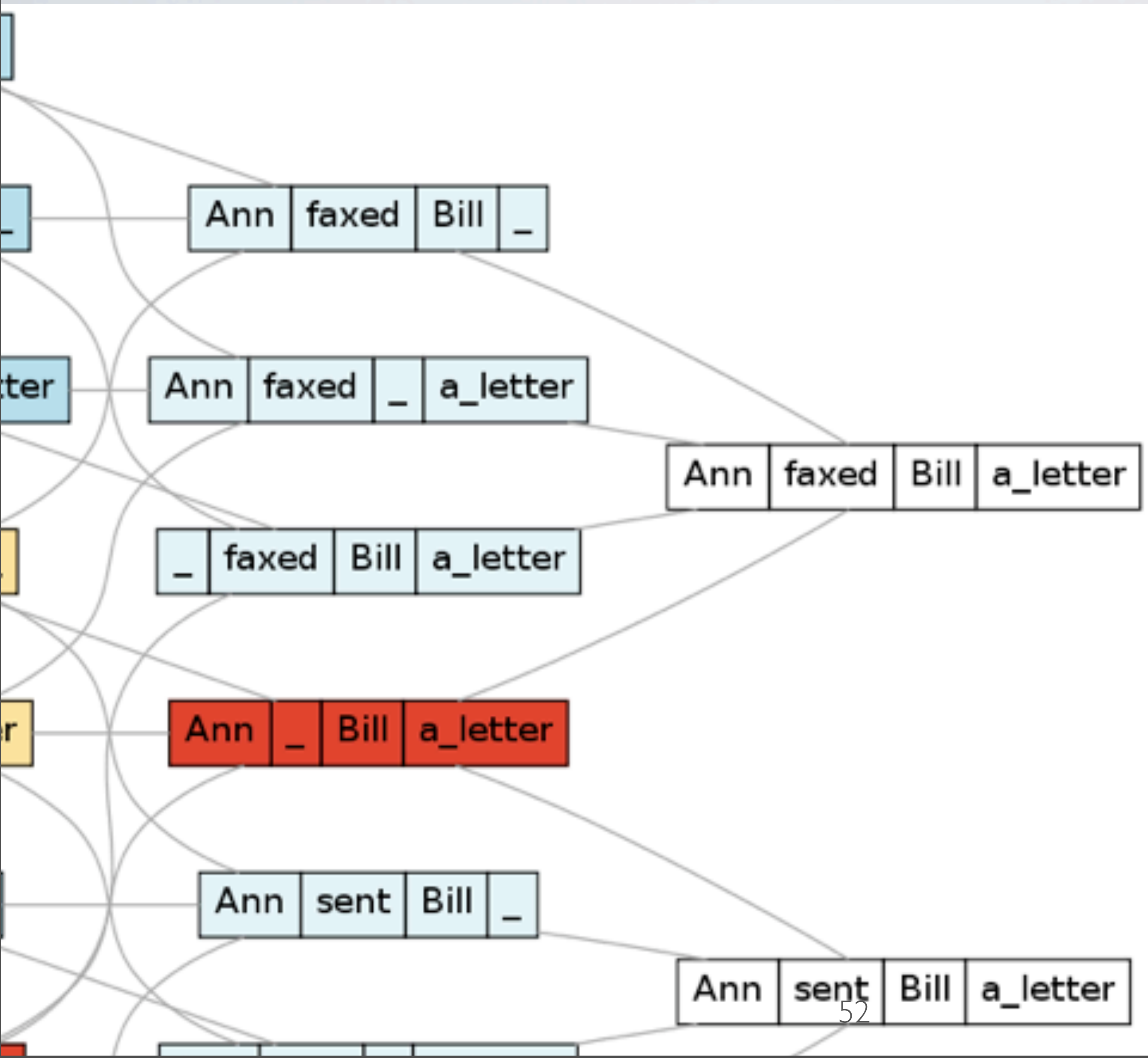
How SPEC Works



- Introduced variables are regarded as simulated errors that need correction.
- Each simulated error is corrected by equating it with the most likely constant based on the distributions, identified due to pattern completion.
- Different superlexical patterns have different instantiation distributions! This is why some patterns have strong bias for particular variable, and others do not.

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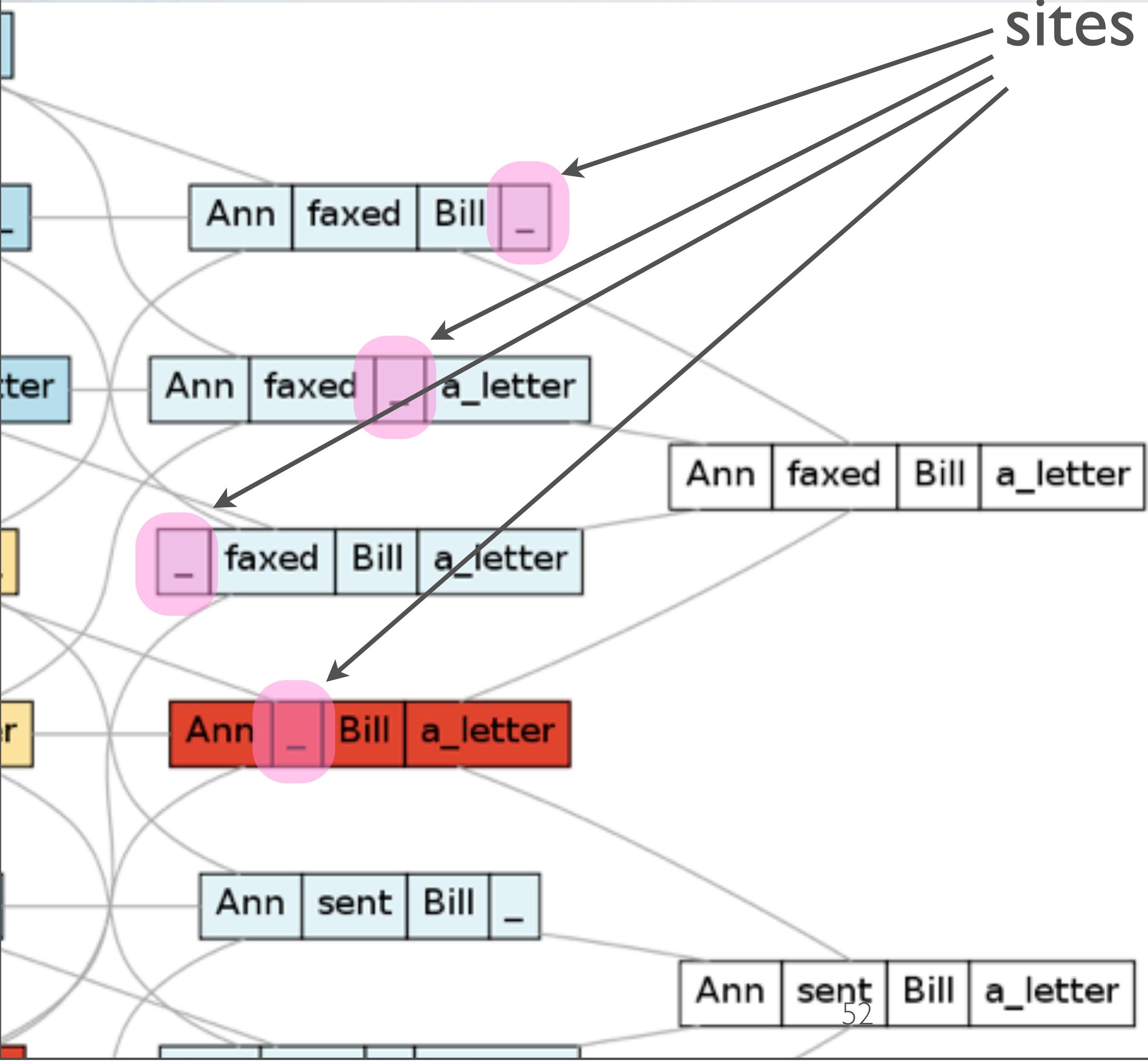

sites of simulated errors

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- Different superlexical patterns have different instantiation distributions! This is why some patterns have strong bias for particular variable, and others do not.

Noncompositionality

- Under SPEC under PL, **superlexical semantics**, i.e., (expected) semantics of superlexical patterns, **is always preferred over lexical semantics**, i.e., semantics of lexical patterns.
    - Reason: Semantics of lexical patterns is accessed only when superlexical semantics at lower ranks turned out to be informative enough.
    - Roughly, SPEC equates the semantics of an expression *E* as an **expected semantics** over a set of instances similar enough to *E*.
- Claim: this gives the most straightforward account of why **collocations and constructions with noncompositional semantics are more important** in semantic interpretation.

Summary of Part II

- **No grammar is necessary for construction of a pattern lattice**.
    - All we need is a mechanism for segmentation and variable-introduction.
    - Note, however, that segmentation can be realized stochastically (using Monte Carlo method) or through unsupervised learning (using Hierarchical Bayes (Mochihashi et al. 2009)).
- SPEC under PL provides a straightforward account for effects of "constructions" without stipulating constructions *per se*.
    - **Basic tenets of Construction Grammar** (Fillmore 1988; Goldberg 1995) **are theoretical consequences of SPEC under PL**: they need not be stipulated as a doctrine.

DISCUSSION

What Can We Expect?

- A radically memory-based model of language is expected to
  - explain the importance of **collocations** (Sinclair 1991) or **multiword units/ expressions** (Sag et al. 2002), and
  - better explain the effects of **constructions** (Fillmore 1988; Goldberg 1995, 2006) with no stipulation for constructions *per se*.
- and it is also expected to
  - explain the **formulaicity** of language (Wray 2002), and
  - explain the mysterious **survival of lower-frequency items** (my personal point of view)

What is Grammar after all?

- PLM implements **a radically memory-based model** (RMBM) in which **virtually no instances are generated**.
    - A "new" expression *E* is recognized as superposition of patterns, p_1, p_2, ..., p_n that usually have only partial matches on *E*.
- In a RMBM, grammar is best understood as a **management system** rather than a **generative system**.
    - In a vast memory system, **all instances need to be indexed for effective retrieval**: PL does this.
    - Trade-off between rapid and flexible enough responses and redundancies.

Good News and Bad News

- Good news
  - Radically memory-based models explain better (at least in terms of descriptive adequacy), and will provide implementations that perform better (at least in terms of precision).
  - Lay foundations for **usage-based model** (Bybee 2001, Langacker 1988, Tomasello 2003) and **example-based machine translation** (佐藤 1997; Sato & Nagao 1990).
- Bad news
  - Language is not guaranteed to be as **systematic** as linguists want it to be.
  - Memory-based models are **computationally expensive**, and **harder to implement** (at least for realistic performance).

Conclusions

- This talk
  - presented an alternative to traditional, **substitutional** model of linguistic syntax and semantics.
  - proposed superposition-based model called **pattern lattice model** (PLM) which is **both compositional and computational** and argues for a **radically memory-based view** of language in which grammar of language is conceived of as **memory-management system** rather than a generative system.
  - showed that PLM under SPEC provides a natural account for "constructional meanings" without postulating constructions *per se*.

Acknowledgements

- The following people helped me in preparing this talk:
  - Yoichiro HASEBE (Doshisha University)
    - for implementation of Pattern Lattice Builder available at **http://www.kotonoba.net/rubyfca/pattern/**
  - Yasunari HARADA (Waseda University) and Masaya IDEGUTI
    - for insightful comments and suggestions
- This work was partly supported in part by Grant-in-Aid for Scientific Research (B) (19330156) (PI: Masanori Nakagawa, Tokyo Institute of Technology) from the Japan Society for the Promotion of Science

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