PARSING in a BROAD SENSE

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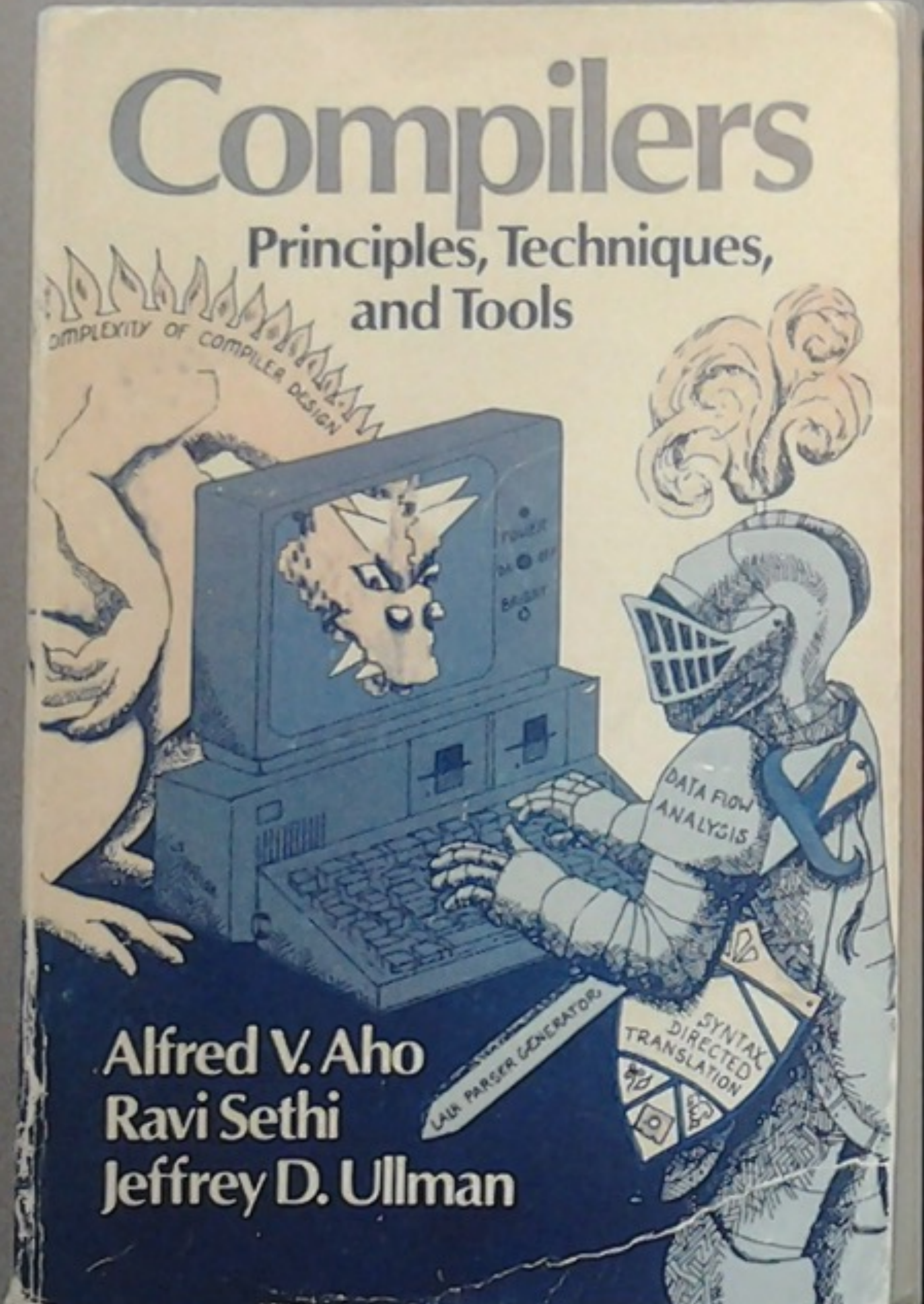


Compilers

Principles, Techniques, and Tools

Alfred V. Aho
Ravi Sethi
Jeffrey D. Ullman

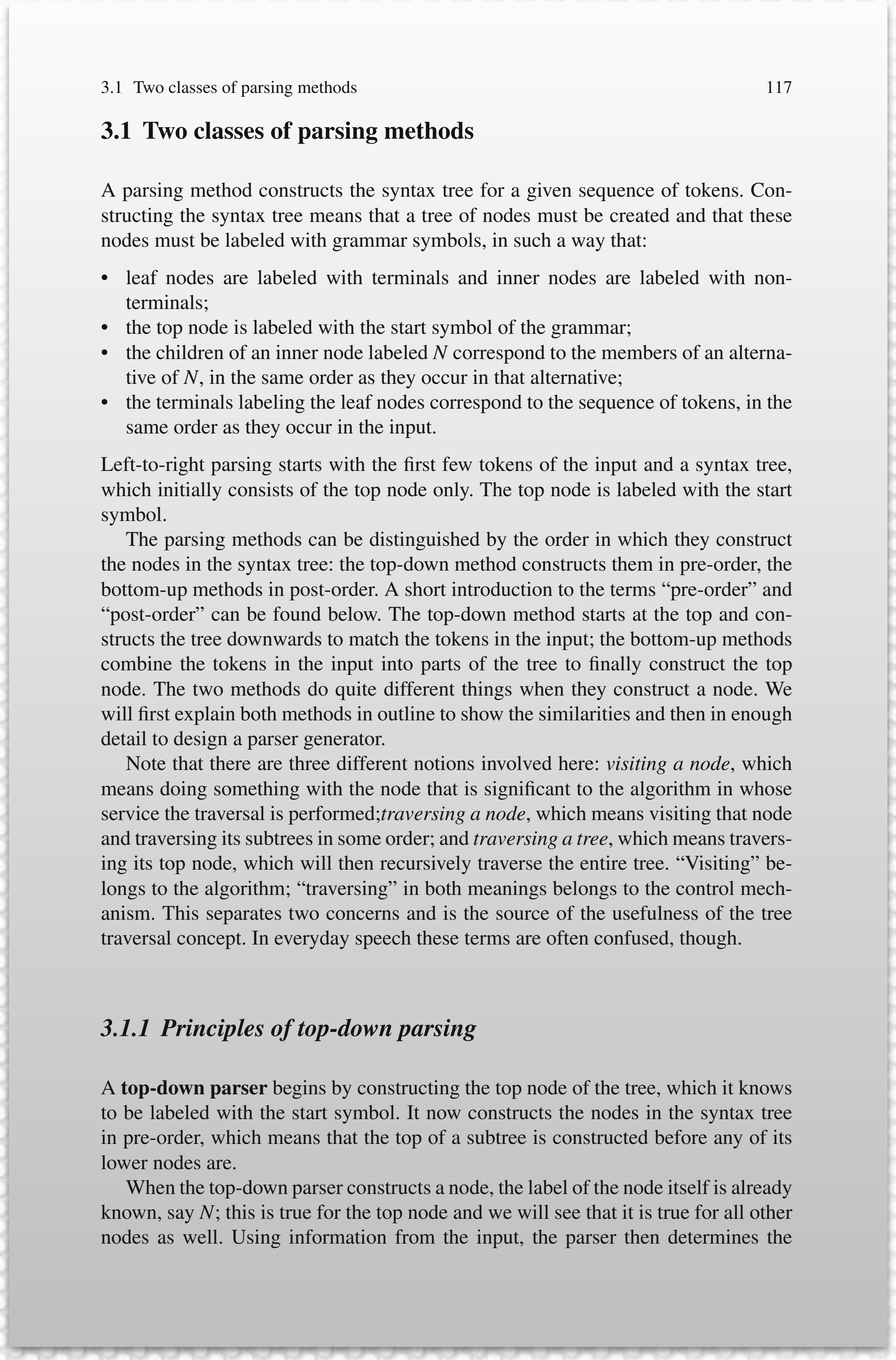
Компиляторы

Принципы, технологии, инструменты

СЛОЖНОСТЬ РАЗРАБОТКИ КОМПИЛЯТОРА
СЕТЬ
ЯРКОСТЬ
АНАЛИЗ ПОТОКА ДАННЫХ
ГЕНЕРАТОР LALR АНАЛИЗАТОРОВ
СИНТАКСИЧЕСКИ УПРАВЛЯЕМАЯ ТРАНСЛЯЦИЯ

Альфред Ахо
Рави Сети
Джеффри Ульман

ADDISON WESLEY



3.1 Two classes of parsing methods

A parsing method constructs the syntax tree for a given sequence of tokens. Constructing the syntax tree means that a tree of nodes must be created and that these nodes must be labeled with grammar symbols, in such a way that:

- leaf nodes are labeled with terminals and inner nodes are labeled with non-terminals;
- the top node is labeled with the start symbol of the grammar;
- the children of an inner node labeled *N* correspond to the members of an alternative of *N*, in the same order as they occur in that alternative;
- the terminals labeling the leaf nodes correspond to the sequence of tokens, in the same order as they occur in the input.

Left-to-right parsing starts with the first few tokens of the input and a syntax tree, which initially consists of the top node only. The top node is labeled with the start symbol.

The parsing methods can be distinguished by the order in which they construct the nodes in the syntax tree: the top-down method constructs them in pre-order, the bottom-up methods in post-order. A short introduction to the terms “pre-order” and “post-order” can be found below. The top-down method starts at the top and constructs the tree downwards to match the tokens in the input; the bottom-up methods combine the tokens in the input into parts of the tree to finally construct the top node. The two methods do quite different things when they construct a node. We will first explain both methods in outline to show the similarities and then in enough detail to design a parser generator.

Note that there are three different notions involved here: *visiting a node*, which means doing something with the node that is significant to the algorithm in whose service the traversal is performed;*traversing a node*, which means visiting that node and traversing its subtrees in some order; and *traversing a tree*, which means traversing its top node, which will then recursively traverse the entire tree. “Visiting” belongs to the algorithm; “traversing” in both meanings belongs to the control mechanism. This separates two concerns and is the source of the usefulness of the tree traversal concept. In everyday speech these terms are often confused, though.

3.1.1 Principles of top-down parsing

A **top-down parser** begins by constructing the top node of the tree, which it knows to be labeled with the start symbol. It now constructs the nodes in the syntax tree in pre-order, which means that the top of a subtree is constructed before any of its lower nodes are.

When the top-down parser constructs a node, the label of the node itself is already known, say *N*; this is true for the top node and we will see that it is true for all other nodes as well. Using information from the input, the parser then determines the

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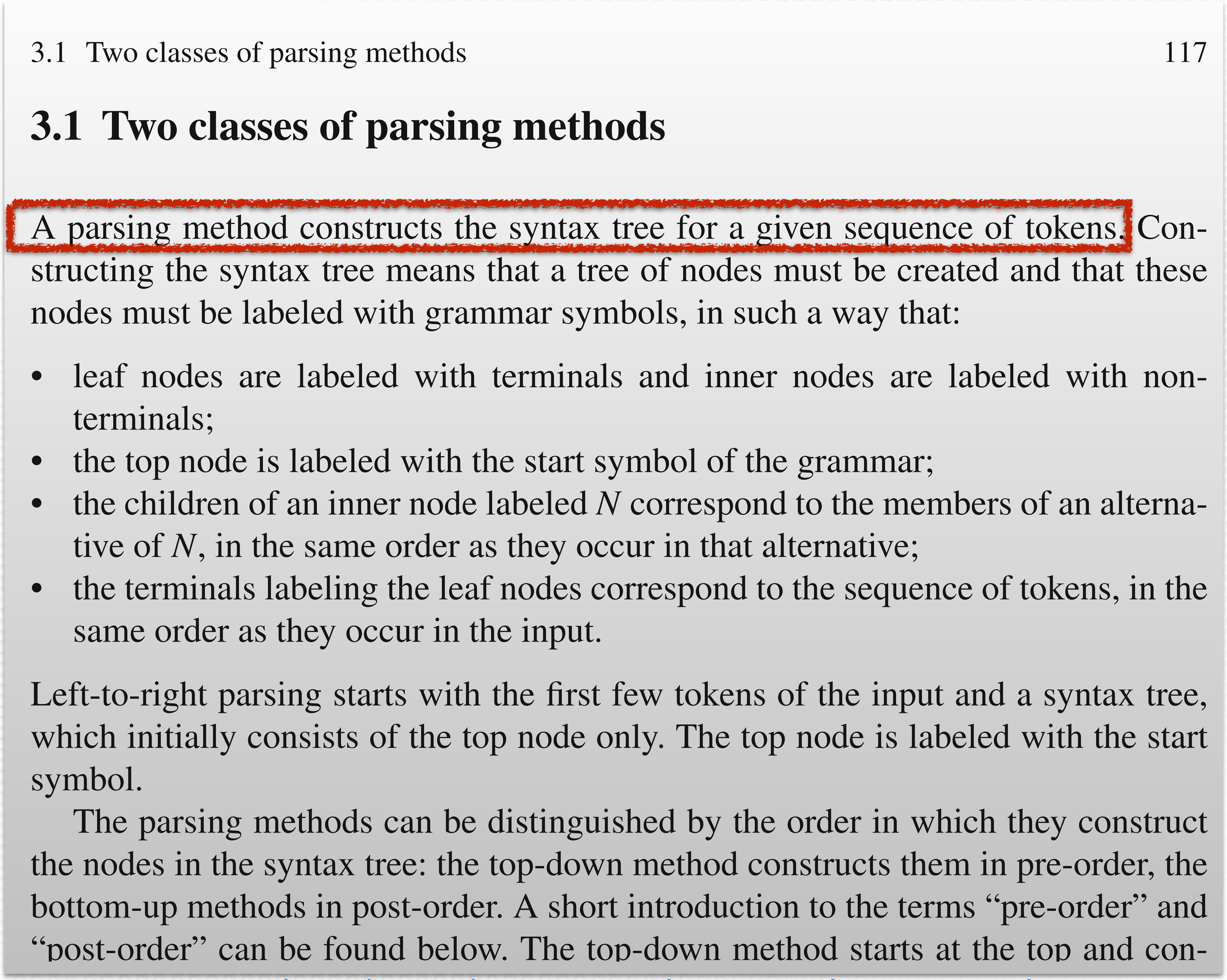

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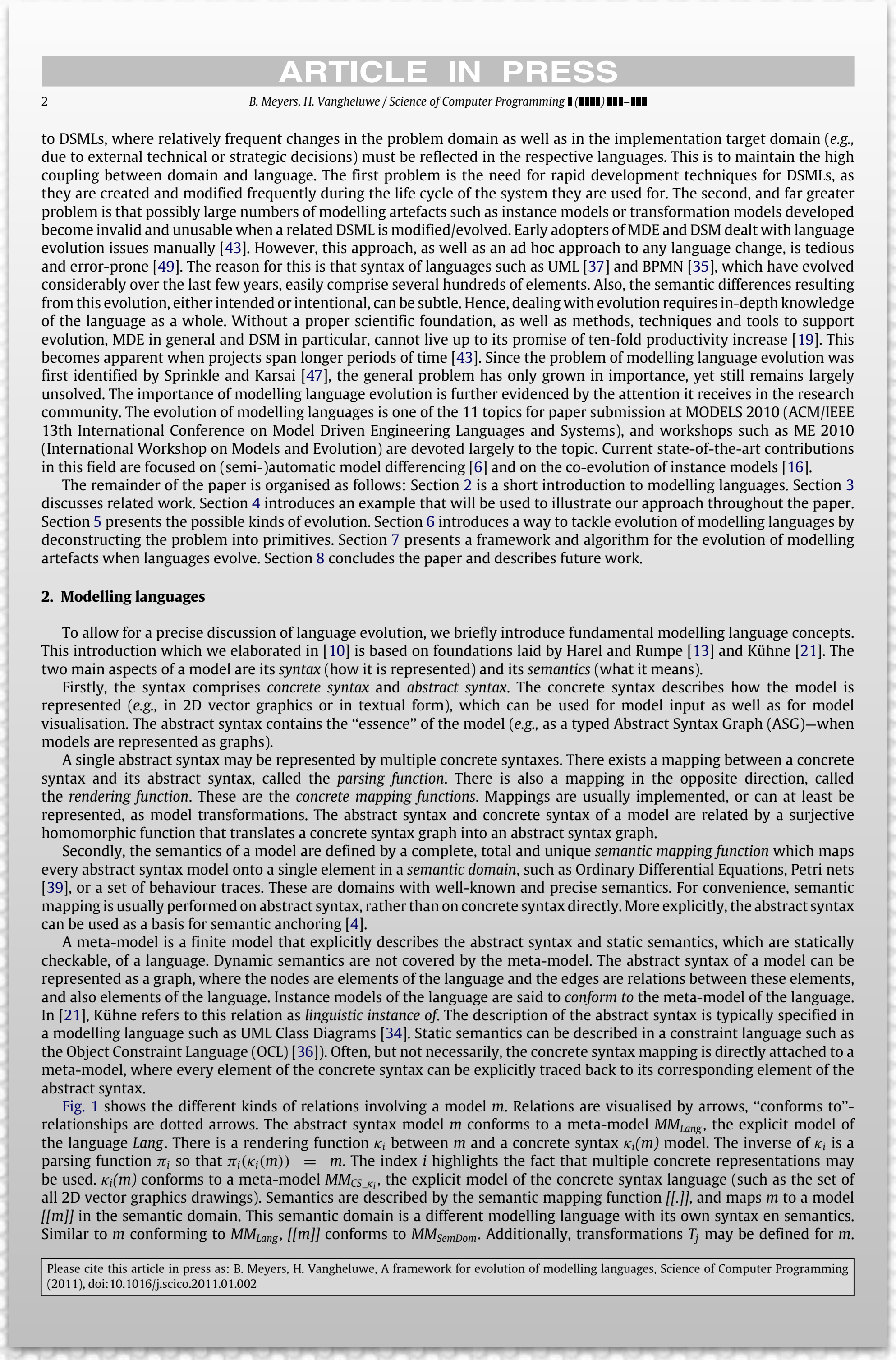

to DSMLs, where relatively frequent changes in the problem domain as well as in the implementation target domain (*e.g.*, due to external technical or strategic decisions) must be reflected in the respective languages. This is to maintain the high coupling between domain and language. The first problem is the need for rapid development techniques for DSMLs, as they are created and modified frequently during the life cycle of the system they are used for. The second, and far greater problem is that possibly large numbers of modelling artefacts such as instance models or transformation models developed become invalid and unusable when a related DSML is modified/evolved. Early adopters of MDE and DSM dealt with language evolution issues manually [43]. However, this approach, as well as an ad hoc approach to any language change, is tedious and error-prone [49]. The reason for this is that syntax of languages such as UML [37] and BPMN [35], which have evolved considerably over the last few years, easily comprise several hundreds of elements. Also, the semantic differences resulting from this evolution, either intended or intentional, can be subtle. Hence, dealing with evolution requires in-depth knowledge of the language as a whole. Without a proper scientific foundation, as well as methods, techniques and tools to support evolution, MDE in general and DSM in particular, cannot live up to its promise of ten-fold productivity increase [19]. This becomes apparent when projects span longer periods of time [43]. Since the problem of modelling language evolution was first identified by Sprinkle and Karsai [47], the general problem has only grown in importance, yet still remains largely unsolved. The importance of modelling language evolution is further evidenced by the attention it receives in the research community. The evolution of modelling languages is one of the 11 topics for paper submission at MODELS 2010 (ACM/IEEE 13th International Conference on Model Driven Engineering Languages and Systems), and workshops such as ME 2010 (International Workshop on Models and Evolution) are devoted largely to the topic. Current state-of-the-art contributions in this field are focused on (semi-)automatic model differencing [6] and on the co-evolution of instance models [16].

The remainder of the paper is organised as follows: Section 2 is a short introduction to modelling languages. Section 3 discusses related work. Section 4 introduces an example that will be used to illustrate our approach throughout the paper. Section 5 presents the possible kinds of evolution. Section 6 introduces a way to tackle evolution of modelling languages by deconstructing the problem into primitives. Section 7 presents a framework and algorithm for the evolution of modelling artefacts when languages evolve. Section 8 concludes the paper and describes future work.

2. Modelling languages

To allow for a precise discussion of language evolution, we briefly introduce fundamental modelling language concepts. This introduction which we elaborated in [10] is based on foundations laid by Harel and Rumpe [13] and Kühne [21]. The two main aspects of a model are its *syntax* (how it is represented) and its *semantics* (what it means).

Firstly, the syntax comprises *concrete syntax* and *abstract syntax*. The concrete syntax describes how the model is represented (*e.g.*, in 2D vector graphics or in textual form), which can be used for model input as well as for model visualisation. The abstract syntax contains the "essence" of the model (*e.g.*, as a typed Abstract Syntax Graph (ASG)—when models are represented as graphs).

A single abstract syntax may be represented by multiple concrete syntaxes. There exists a mapping between a concrete syntax and its abstract syntax, called the *parsing function*. There is also a mapping in the opposite direction, called the *rendering function*. These are the *concrete mapping functions*. Mappings are usually implemented, or can at least be represented, as model transformations. The abstract syntax and concrete syntax of a model are related by a surjective homomorphic function that translates a concrete syntax graph into an abstract syntax graph.

Secondly, the semantics of a model are defined by a complete, total and unique *semantic mapping function* which maps every abstract syntax model onto a single element in a *semantic domain*, such as Ordinary Differential Equations, Petri nets [39], or a set of behaviour traces. These are domains with well-known and precise semantics. For convenience, semantic mapping is usually performed on abstract syntax, rather than on concrete syntax directly. More explicitly, the abstract syntax can be used as a basis for semantic anchoring [4].

A meta-model is a finite model that explicitly describes the abstract syntax and static semantics, which are statically checkable, of a language. Dynamic semantics are not covered by the meta-model. The abstract syntax of a model can be represented as a graph, where the nodes are elements of the language and the edges are relations between these elements, and also elements of the language. Instance models of the language are said to *conform to* the meta-model of the language. In [21], Kühne refers to this relation as *linguistic instance of*. The description of the abstract syntax is typically specified in a modelling language such as UML Class Diagrams [34]. Static semantics can be described in a constraint language such as the Object Constraint Language (OCL) [36]). Often, but not necessarily, the concrete syntax mapping is directly attached to a meta-model, where every element of the concrete syntax can be explicitly traced back to its corresponding element of the abstract syntax.

Fig. 1 shows the different kinds of relations involving a model m. Relations are visualised by arrows, "conforms to"-relationships are dotted arrows. The abstract syntax model m conforms to a meta-model MM_{Lang}, the explicit model of the language *Lang*. There is a rendering function κ_i between m and a concrete syntax $\kappa_i(m)$ model. The inverse of κ_i is a parsing function π_i so that $\pi_i(\kappa_i(m)) = m$. The index i highlights the fact that multiple concrete representations may be used. $\kappa_i(m)$ conforms to a meta-model $MM_{CS\_\kappa_i}$, the explicit model of the concrete syntax language (such as the set of all 2D vector graphics drawings). Semantics are described by the semantic mapping function $[[.]]$, and maps m to a model $[[m]]$ in the semantic domain. This semantic domain is a different modelling language with its own syntax en semantics. Similar to m conforming to MM_{Lang}, $[[m]]$ conforms to MM_{SemDom}. Additionally, transformations T_j may be defined for m.

Meyers, Vangheluwe, A framework for evolution of modelling languages, SCP.

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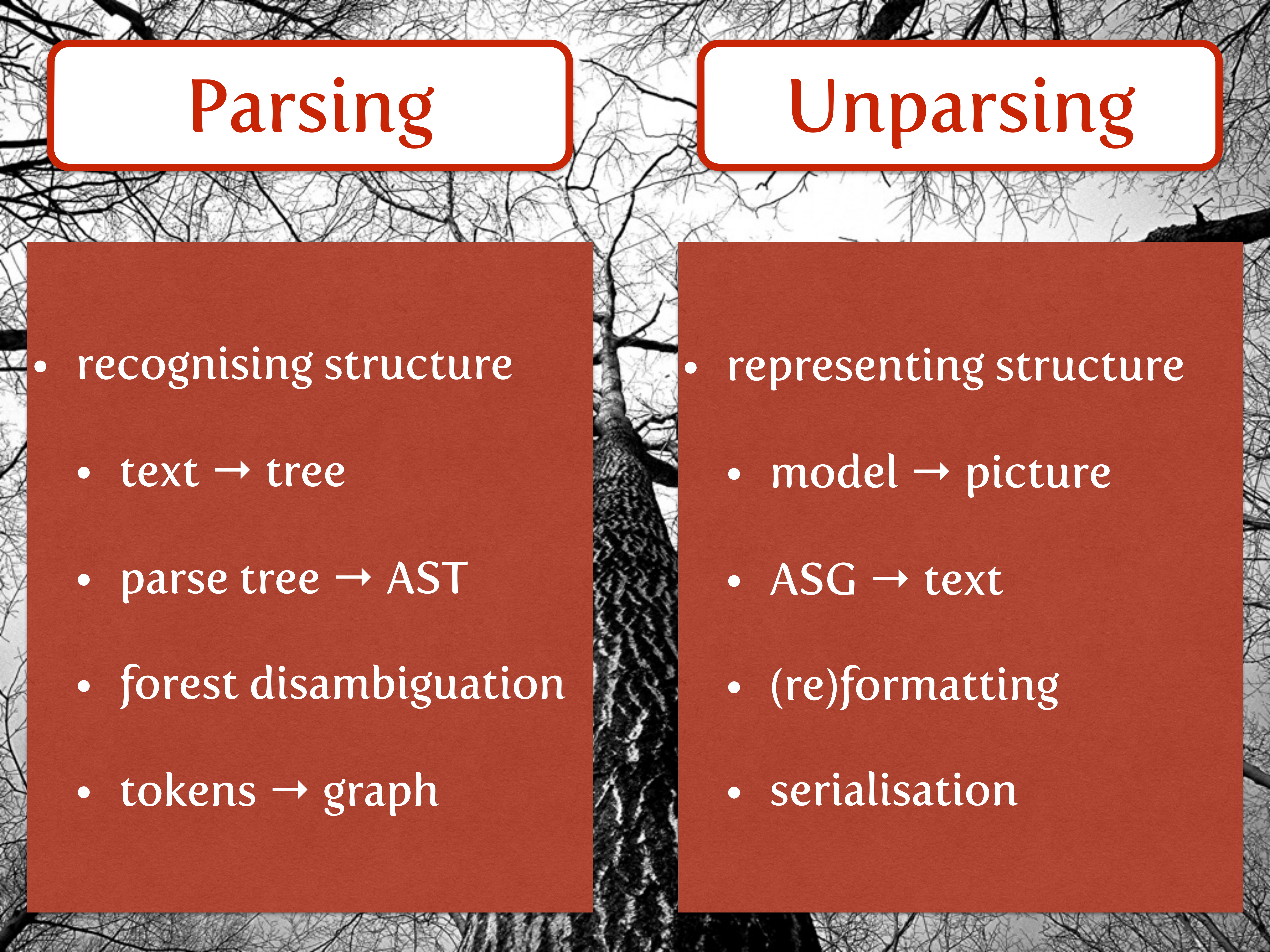
PARSING
in a
BROAD
SENSE

Technological Space Megamodel

Bidirectional Transformations

...in the paper



Parsing

- recognising structure
  - text → tree
  - parse tree → AST
  - forest disambiguation
  - tokens → graph

Unparsing

- representing structure
  - model → picture
  - ASG → text
  - (re)formatting
  - serialisation

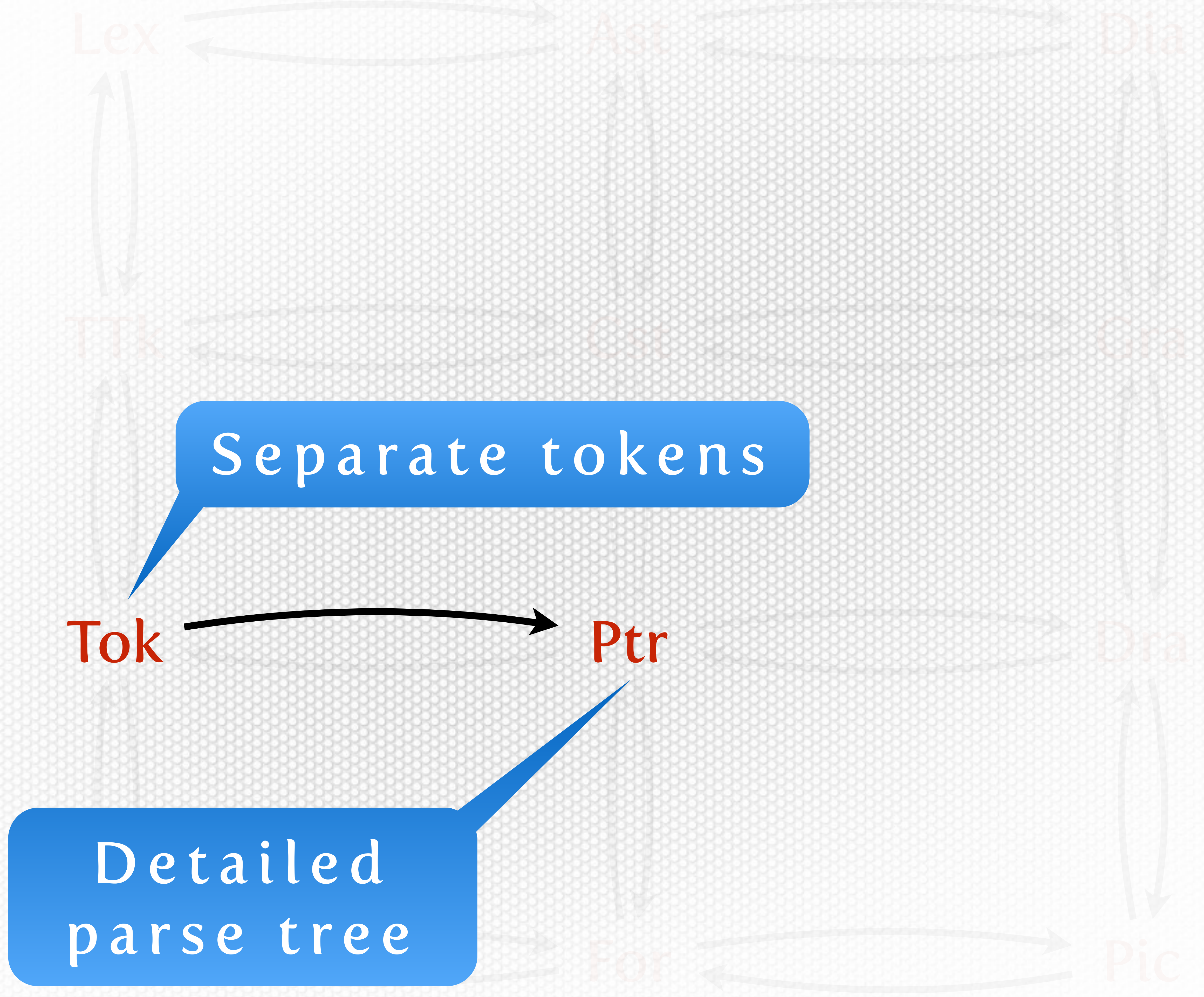
$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left] \arrow[d, bend left] & \text{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\text{TTk} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Str} \arrow[u, bend left] \arrow[r, bend left] & \text{For} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & \text{Pic} \arrow[u, bend left] \arrow[l, bend left]
\end{tikzcd}$$

Separate tokens

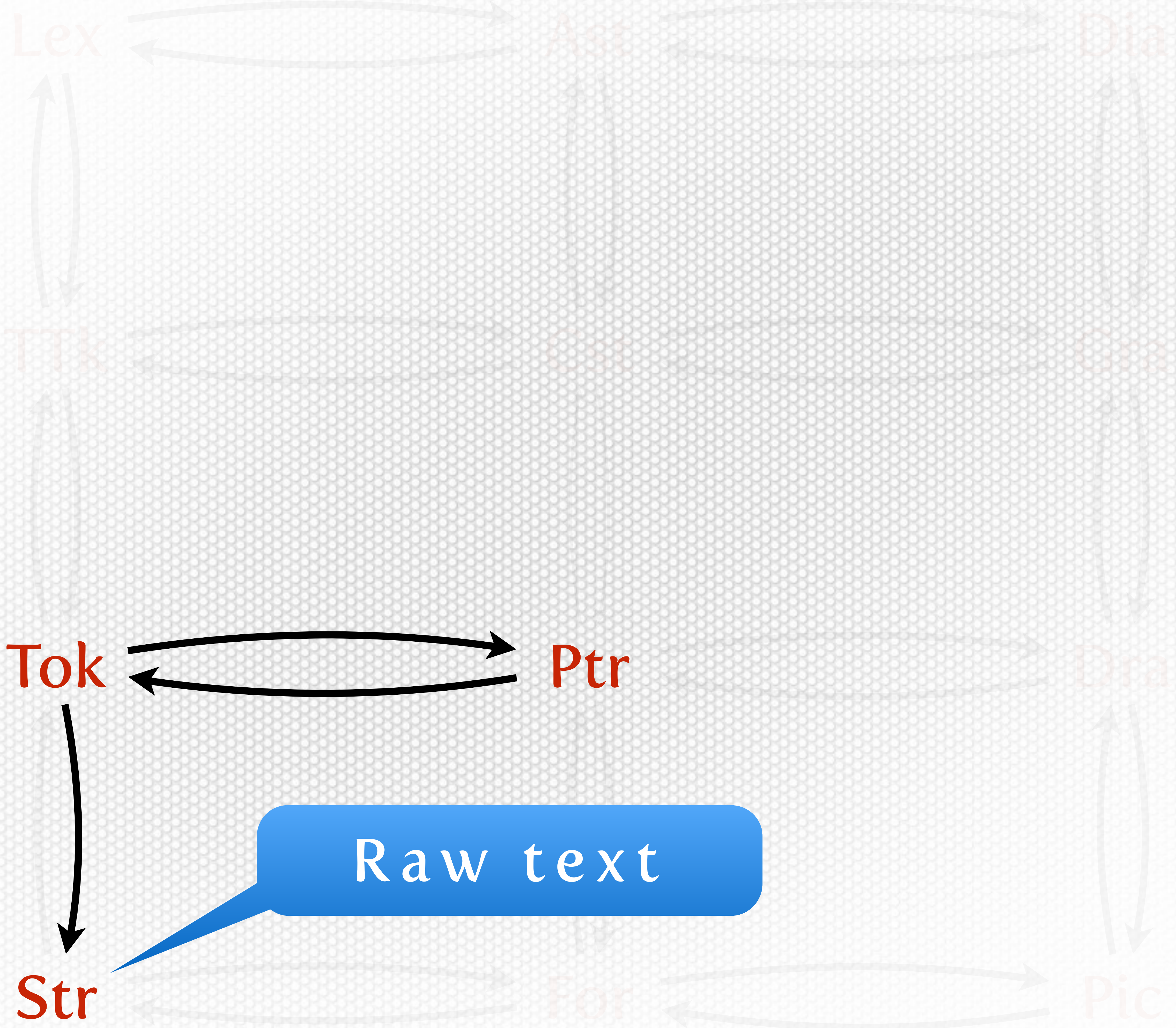
$$\begin{tikzcd}
Lex \arrow[r, bend left] \arrow[d, bend left] & Ast \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & Dia \arrow[l, bend left] \arrow[d, bend left] \\
TTk \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & Cst \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & Gra \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
Tok \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & Ptr \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & Dra \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
{} \arrow[u, bend left] \arrow[r, bend left] & For \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & Pic \arrow[u, bend left] \arrow[l, bend left]
\end{tikzcd}$$

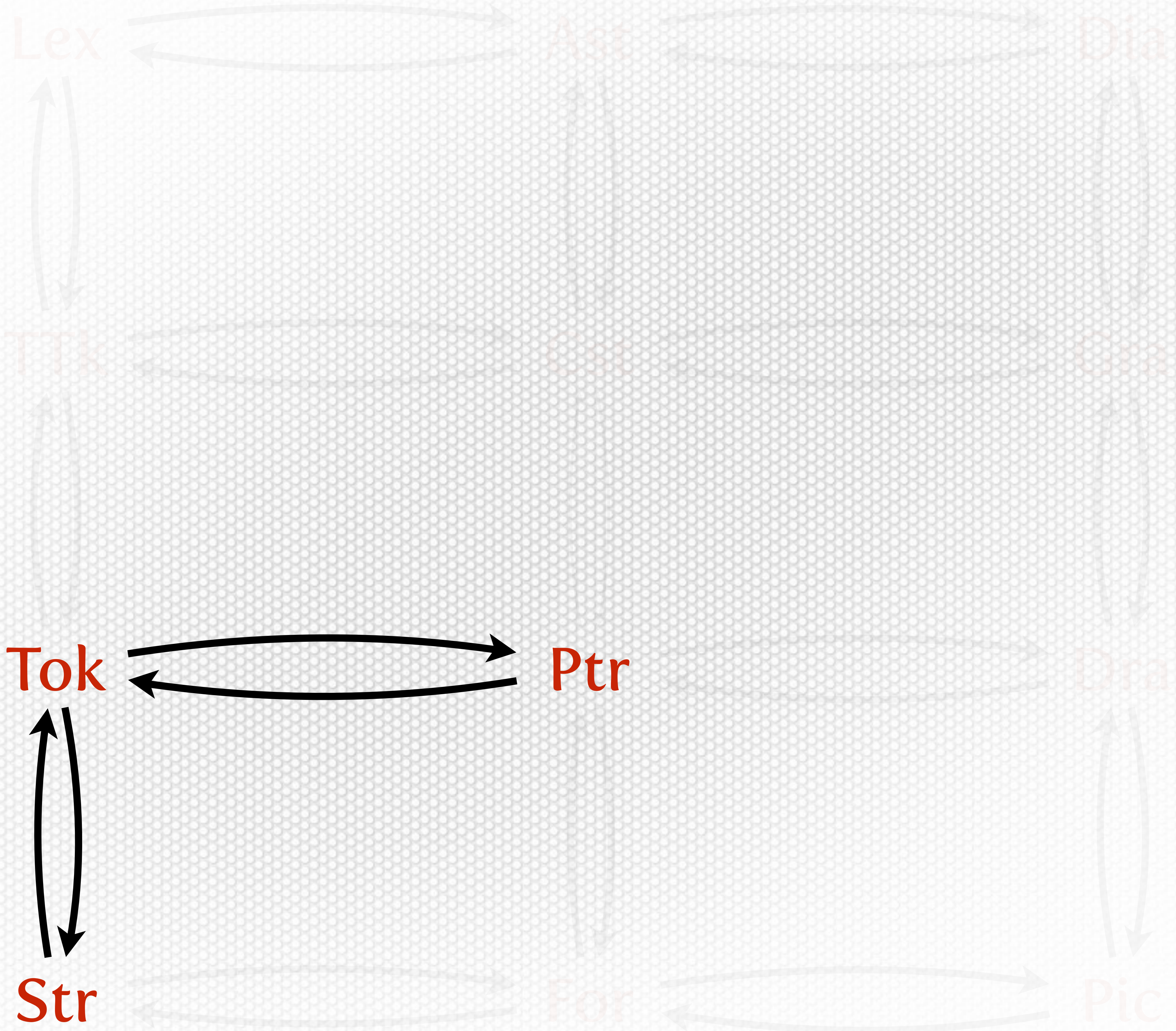
Separate tokens

Detailed parse tree

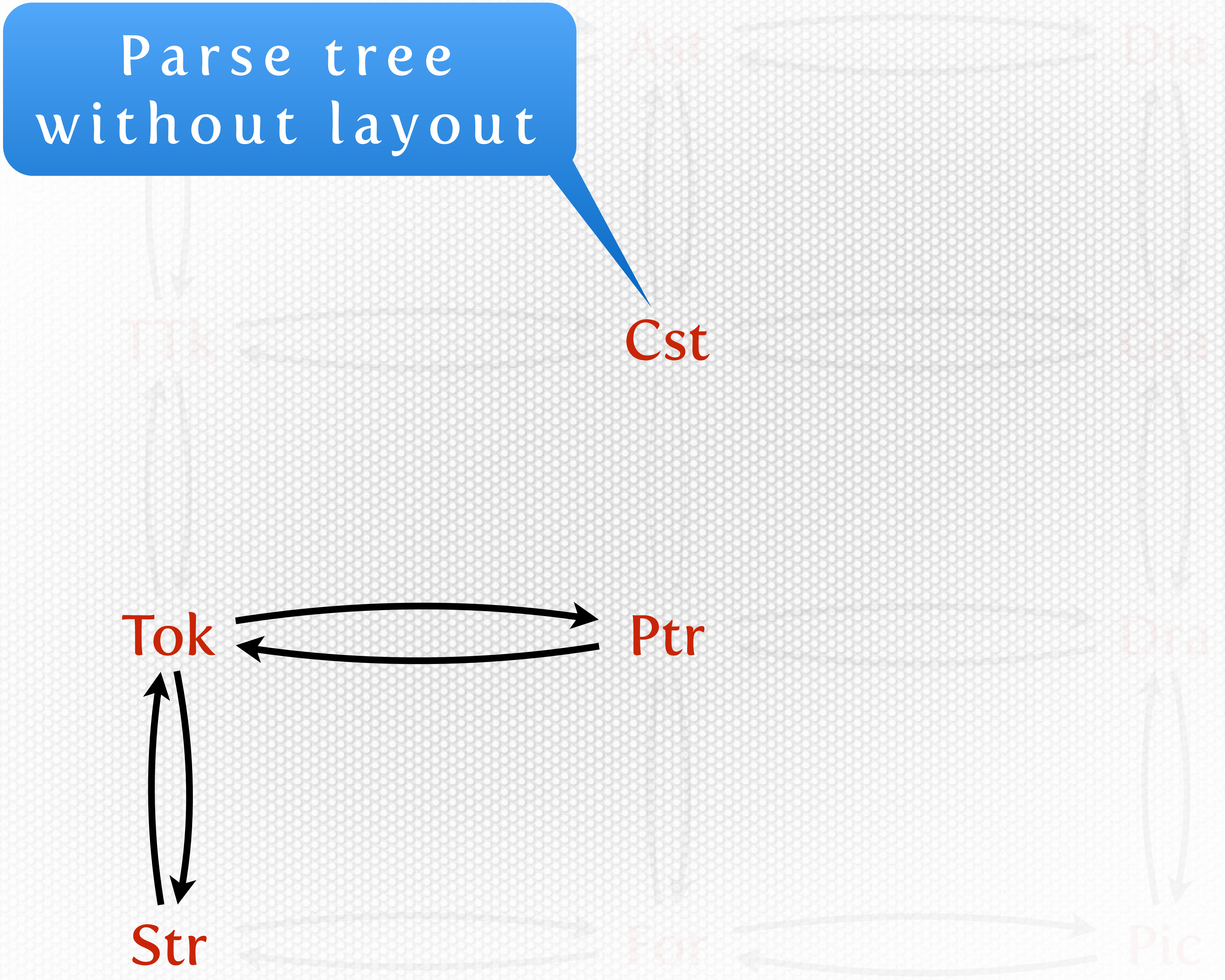

Separate tokens
Tok
Ptr
Detailed parse tree

$$\begin{tikzcd}
\text{Tok} \arrow[r, bend left] & \text{Ptr} \arrow[l, bend left]
\end{tikzcd}$$


Tok
Ptr
Str
Raw text



$$\begin{tikzcd}
\text{Tok} \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \\
\text{Str} \arrow[u, bend left] &
\end{tikzcd}$$


Parse tree without layout
Cst
Tok
Ptr
Str

Parse tree without layout

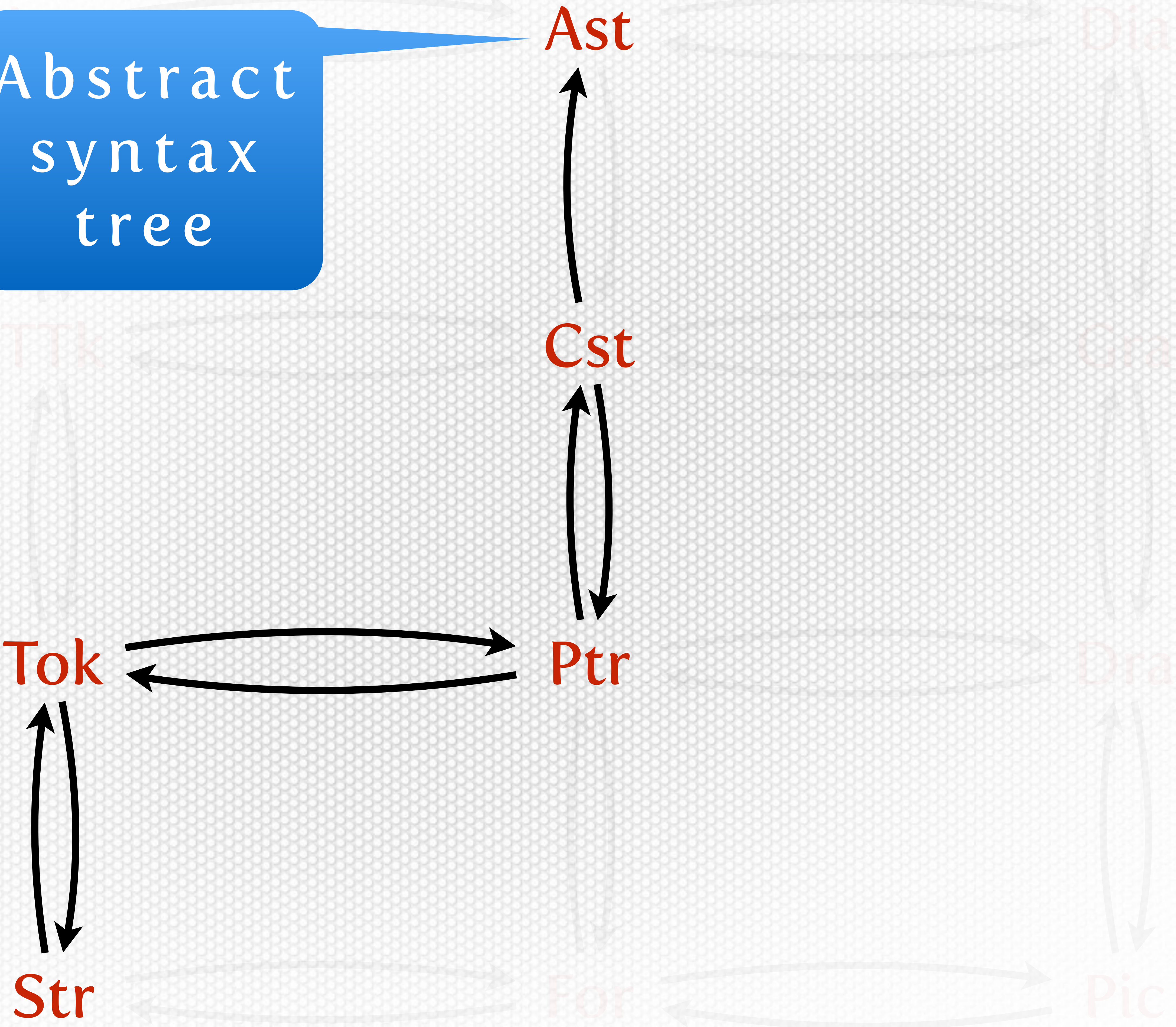
$$\begin{tikzcd}
 & \mathrm{Cst} \\
\mathrm{Tok} \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Ptr} \arrow[l, bend left] \arrow[u] \\
\mathrm{Str} \arrow[u, bend left] &
\end{tikzcd}$$

$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left] \arrow[d, bend left] & \text{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\text{TTk} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Str} \arrow[u, bend left] \arrow[r, bend left] & \text{For} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & \text{Pic} \arrow[u, bend left] \arrow[l, bend left]
\end{tikzcd}$$

Abstract syntax tree

$$\begin{tikzcd}
 & \text{Ast} \\
 & \text{Cst} \arrow[d, bend left] \\
\text{Tok} \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \arrow[u, bend left] \\
\text{Str} \arrow[u, bend left] &
\end{tikzcd}$$

Abstract syntax tree



$$\begin{tikzcd}
 & Ast \\
 & Cst \arrow[u] \arrow[d, bend left] \\
Tok \arrow[r, bend left] \arrow[d, bend left] & Ptr \arrow[l, bend left] \arrow[u, bend left] \\
Str \arrow[u, bend left] &
\end{tikzcd}$$

Abstract syntax

graph

$$\begin{tikzcd}
 & \text{Ast} \\
 & \text{Cst} \arrow[u] \arrow[d, bend left] \\
\text{Tok} \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \arrow[u, bend left] \\
\text{Str} \arrow[u, bend left] &
\end{tikzcd}$$

$$\begin{tikzcd}
\text{Lex} & \text{Ast} \arrow[r, bend left] & \text{Dia} \arrow[l, bend left] \\
\text{TTk} & \text{Cst} \arrow[u] \arrow[d, bend left] & \text{Dia} \\
\text{Tok} \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \arrow[u, bend left] & \text{Dra} \\
\text{Str} \arrow[u, bend left] & \text{For} & \text{Pic}
\end{tikzcd}$$

Visual model

$$\begin{tikzcd}
\text{Lex} & \text{Ast} \arrow[r, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d] \\
\text{TTs} & \text{Cst} \arrow[u] \arrow[d, bend right] & \text{Gra} \\
\text{Tok} \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \arrow[u, bend right] & \text{Dra} \\
\text{Str} \arrow[u, bend left] & \text{For} & \text{Pic}
\end{tikzcd}$$

Boxes & arrows

$$\begin{tikzcd}
\text{Lex} & \text{Ast} \arrow[r, shift left] & \text{Dia} \arrow[l, shift left] \arrow[d] \\
\text{TTs} & \text{Cst} \arrow[u] \arrow[d, shift left] & \text{Gra} \arrow[d] \\
\text{Tok} \arrow[r, shift left] \arrow[d, shift left] & \text{Ptr} \arrow[l, shift left] \arrow[u, shift left] & \text{Dra} \\
\text{Str} \arrow[u, shift left] & \text{For} & \text{Pic}
\end{tikzcd}$$

coordinates

$$\begin{tikzcd}
\text{Lex} & \text{Ast} \arrow[r, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d] \\
\text{Tts} & \text{Cst} \arrow[u] \arrow[d, bend left] & \text{Gra} \arrow[d] \\
\text{Tok} \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \arrow[u, bend left] & \text{Dra} \arrow[d] \\
\text{Str} \arrow[u, bend left] & \text{For} & \text{Pic}
\end{tikzcd}$$

pixels

$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left] \arrow[d, bend left] & \text{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\text{TTs} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Str} \arrow[u, bend left] \arrow[r, bend left] & \text{For} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & \text{Pic} \arrow[u, bend left] \arrow[l, bend left]
\end{tikzcd}$$

$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left] \arrow[d, bend left] & \text{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\text{TTs} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
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\end{tikzcd}$$

forest

$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left] \arrow[d, bend left] & \text{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\text{TTk} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\text{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Dra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
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\end{tikzcd}$$

typed tokens

$$\begin{tikzcd}
\mathrm{Lex} \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\mathrm{TTk} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\mathrm{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Ptr} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & \mathrm{Dra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
\mathrm{Str} \arrow[u, bend left] \arrow[r, bend left] & \mathrm{For} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & \mathrm{Pic} \arrow[u, bend left] \arrow[l, bend left]
\end{tikzcd}$$

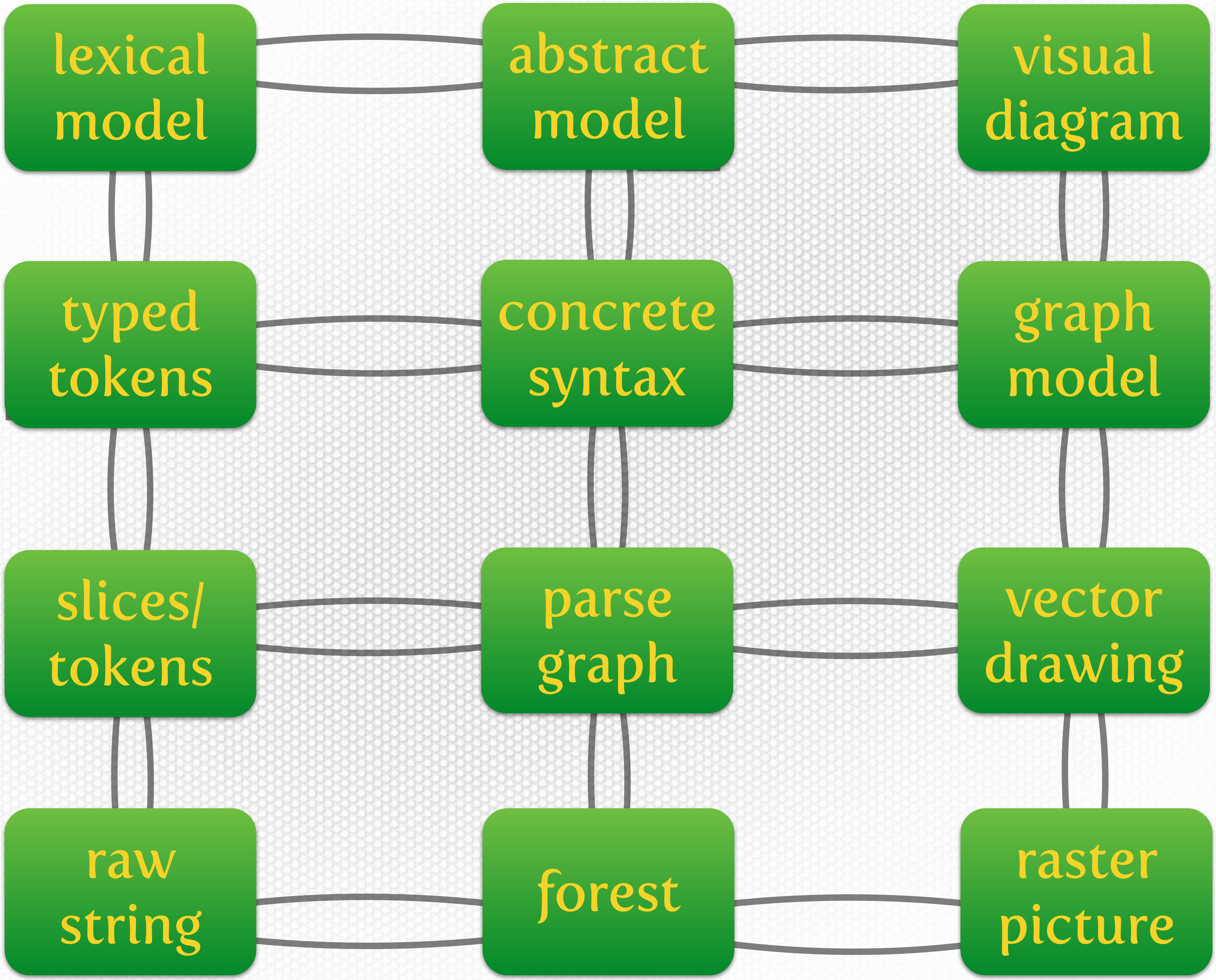
$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left, dashed] \arrow[d, bend left] & \text{Ast} \arrow[l, bend left, dashed] \arrow[r, bend left] \arrow[d, bend left] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \\
\text{TTk} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Cst} \arrow[l, bend left] \arrow[u, bend left] \arrow[r, bend left, dashed] \arrow[d, bend left] & \text{Gra} \arrow[l, bend left, dashed] \arrow[u, bend left] \arrow[d, bend left] \\
\text{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & \text{Ptr} \arrow[l, bend left] \arrow[u, bend left] \arrow[r, bend left, dashed] \arrow[d, bend left, dashed] & \text{Dra} \arrow[l, bend left, dashed] \arrow[u, bend left] \arrow[d, bend left] \\
\text{Str} \arrow[u, bend left] \arrow[r, bend left] & \text{For} \arrow[l, bend left] \arrow[u, bend left] \arrow[r, bend left, dashed] & \text{Pic} \arrow[l, bend left, dashed] \arrow[u, bend left, dashed]
\end{tikzcd}$$

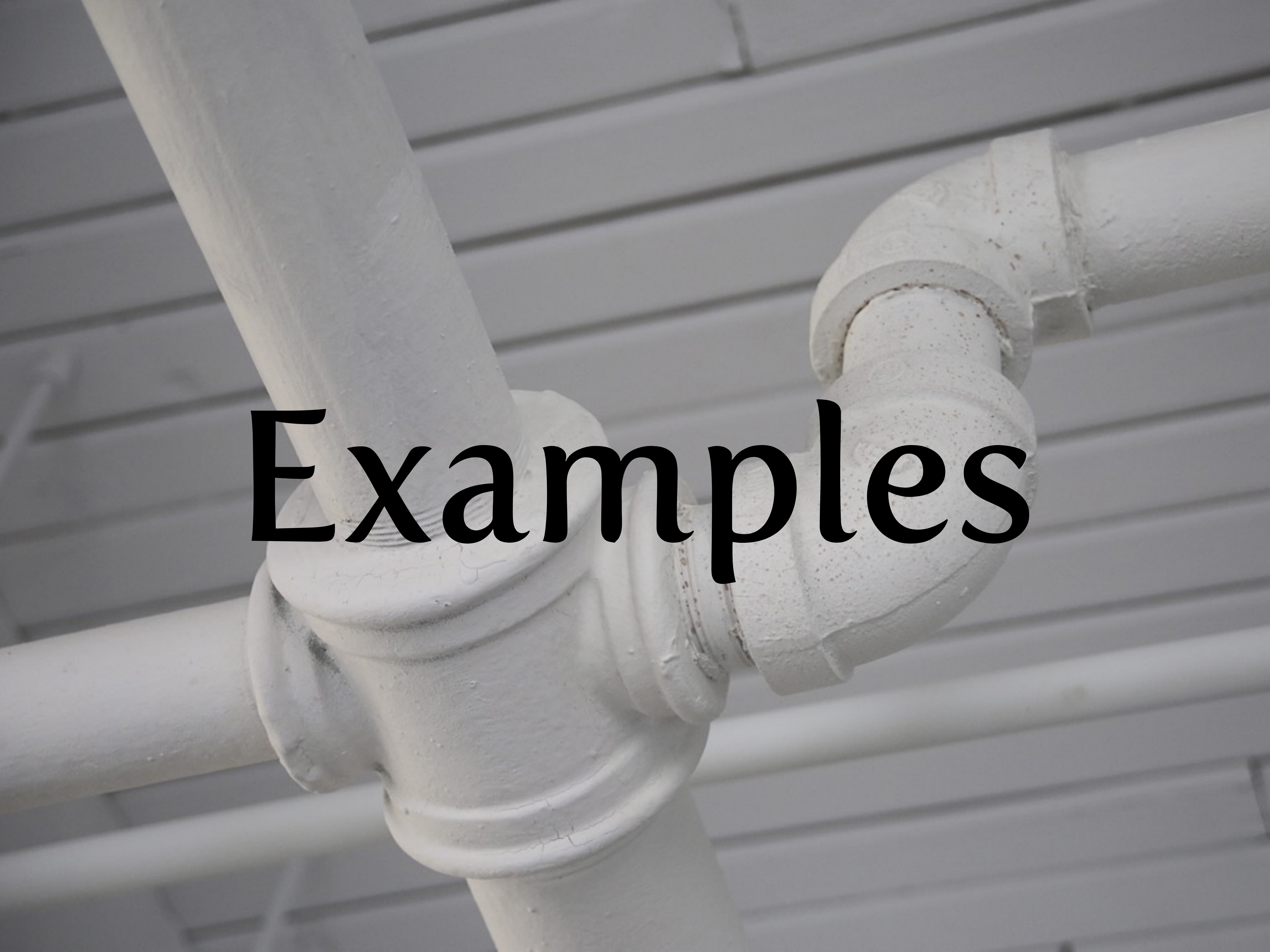
lexical model

$$\begin{tikzcd}
Lex \arrow[r, bend left] \arrow[d, bend left] & Ast \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & Dia \arrow[l, bend left] \arrow[d, bend left] \\
TTk \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & Cst \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] & Gra \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
Tok \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] & Ptr \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & Dra \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \\
Str \arrow[u, bend left] \arrow[r, bend left] & For \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] & Pic \arrow[u, bend left] \arrow[l, bend left]
\end{tikzcd}$$

$$\begin{tikzcd}
\text{Lex} & \text{Ast} \arrow[loop right] & \text{Dia} \arrow[loop right] \\
\text{TTk} & \text{Cst} \arrow[loop right] & \text{Gra} \\
\text{Tok} & \text{Ptr} \arrow[loop right] & \text{Dra} \arrow[loop right] \\
\text{Str} \arrow[loop right] & \text{For} \arrow[loop right] & \text{Pic} \arrow[loop right]
\end{tikzcd}$$

$$\begin{tikzcd}
\text{Lex} \arrow[r, bend left] \arrow[d, bend left] \arrow[loop left] & \text{Ast} \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] \arrow[loop right] & \text{Dia} \arrow[l, bend left] \arrow[d, bend left] \arrow[loop right] \\
\text{TTk} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] \arrow[loop left] & \text{Cst} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] \arrow[loop right] & \text{Gra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \arrow[loop right] \\
\text{Tok} \arrow[u, bend left] \arrow[r, bend left] \arrow[d, bend left] \arrow[loop left] & \text{Ptr} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[d, bend left] \arrow[loop right] & \text{Dra} \arrow[u, bend left] \arrow[l, bend left] \arrow[d, bend left] \arrow[loop right] \\
\text{Str} \arrow[u, bend left] \arrow[r, bend left] \arrow[loop left] & \text{For} \arrow[u, bend left] \arrow[l, bend left] \arrow[r, bend left] \arrow[loop right] & \text{Pic} \arrow[u, bend left] \arrow[l, bend left] \arrow[loop right]
\end{tikzcd}$$


lexical model
abstract model
visual diagram
typed tokens
concrete syntax
graph model
slices/ tokens
parse graph
vector drawing
raw string
forest
raster picture



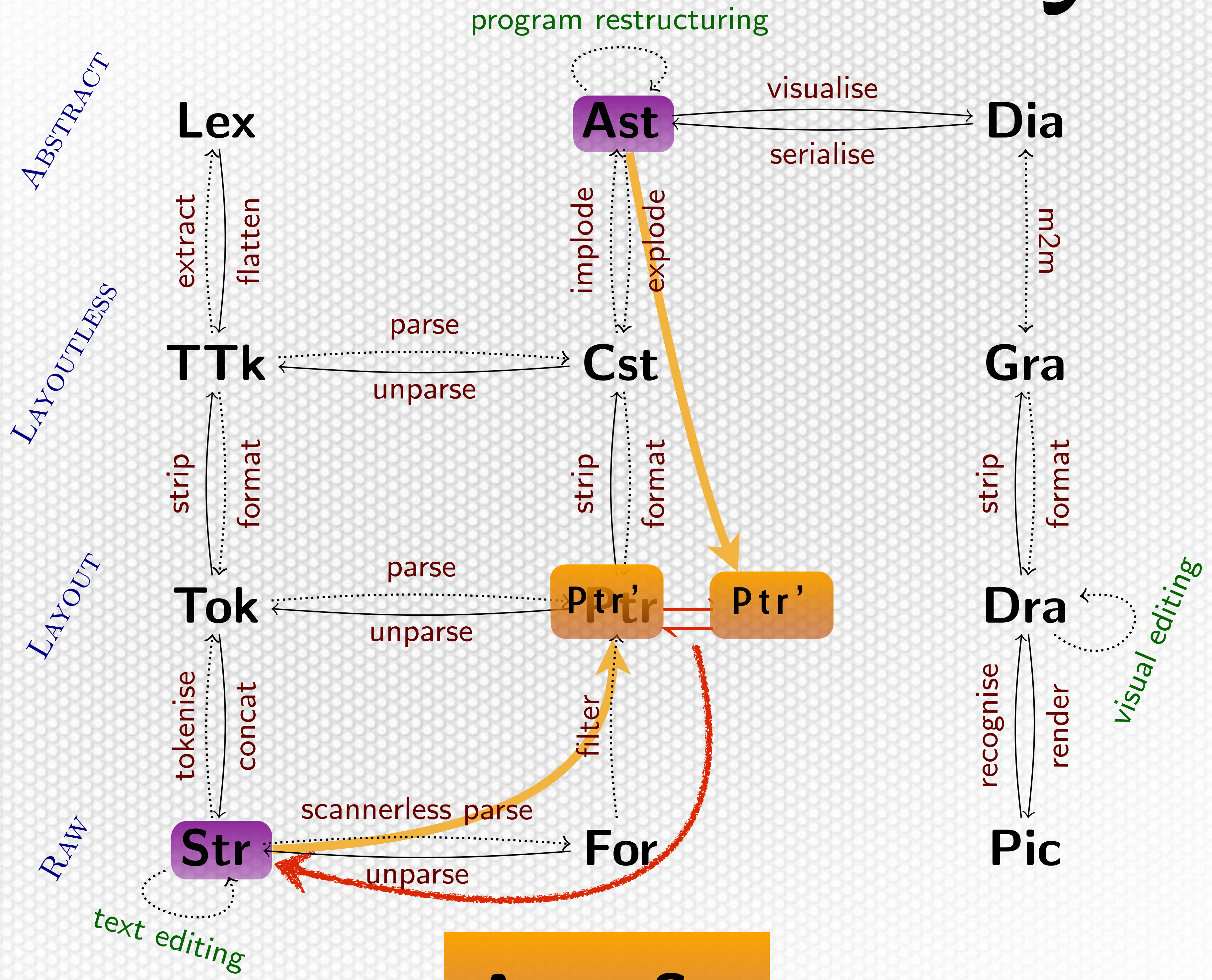
Examples

Lifting & Lowering

$$\begin{tikzcd}
 & \mathsf{Ast} \arrow[r, "\text{transform}"'] & \mathsf{Ast} \arrow[d, "\text{explode}"] & \\
 & \mathsf{Cst} \arrow[u, "\text{implode}"] \arrow[r, dotted, "\text{transform}"'] & \mathsf{Cst} \arrow[d, "\text{format}"] & \\
 & \mathsf{Ptr} \arrow[u, "\text{strip}"] \arrow[r, dotted, "\text{transform}"'] & \mathsf{Ptr} \arrow[dr, "\text{unparse}"] & \\
\mathsf{Str} \arrow[ur, "\text{parse}"] \arrow[rrr, dotted, "\text{transform}"'] & & & \mathsf{Str}
\end{tikzcd}$$

cf. Zaytsev/Bagge, Modelling Parsing and Unparsing, Parsing@SLE, 2014.

Bidirectionality



Ast ▷ Str

cf. Zaytsev, Case Studies in Bidirectionalisation, TFP, 2014.

Renarration

$$\begin{tikzcd}
\text{Lex} & \text{Ast} \; \boxed{\text{programming}} & \text{Dia} \\
\text{TTk} \arrow[r, bend left, "\text{parser}"] & \text{Cst} \arrow[u, bend left, "\text{programming (Java,C++,}\cdots\text{)}"'] & \text{Gra} \\
\text{Tok} \arrow[u, bend left] & \text{Ptr} & \text{Dra} \\
\text{Str} \arrow[u, bend left, "\text{lexer}"] & \text{For} & \text{Pic}
\end{tikzcd}$$

cf. Zaytsev, Understanding Metalanguage Integration by Renarrating a Technical Space Megamodel, GEMOC, 2014.

Conclusion

PARSING in a BROAD SENSE

- Contributions:
  - BX framework classification/extension
  - Megamodel for parsing (in a broad sense)
    - Explain yourself
    - Understand others
    - Find new ground
- More:
  - Usage: TFP'14, Parsing@SLE'14, GEMOC'14, EduSymp'14,…
  - Reach us at: @grammarware, @anyahelene, #models14, …
- Questions?
- Photos are self-made; from PEXELS (CC0); by Eelco Visser (Jean Bézivin).