Parse Forest Disambiguation

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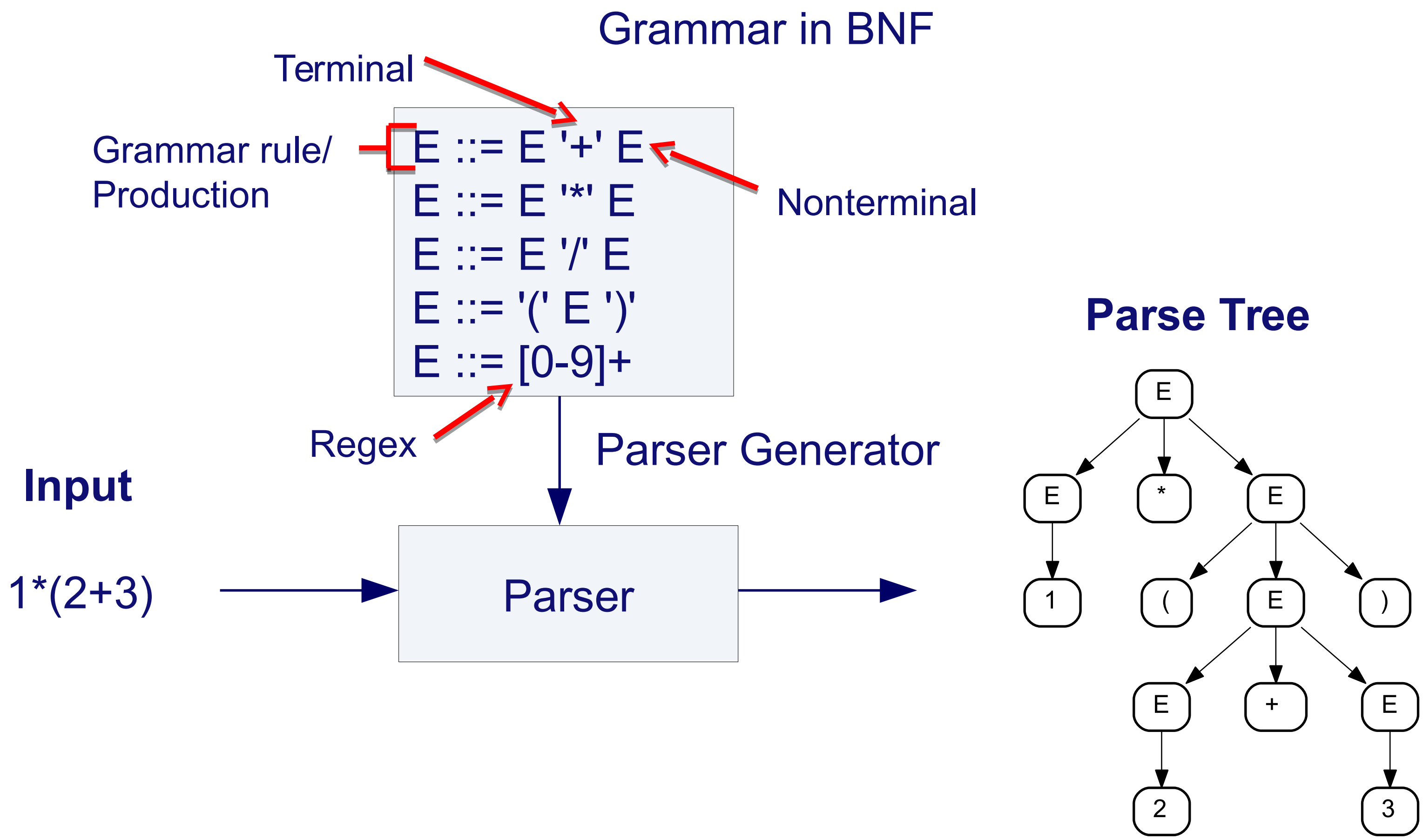
Where innovation starts

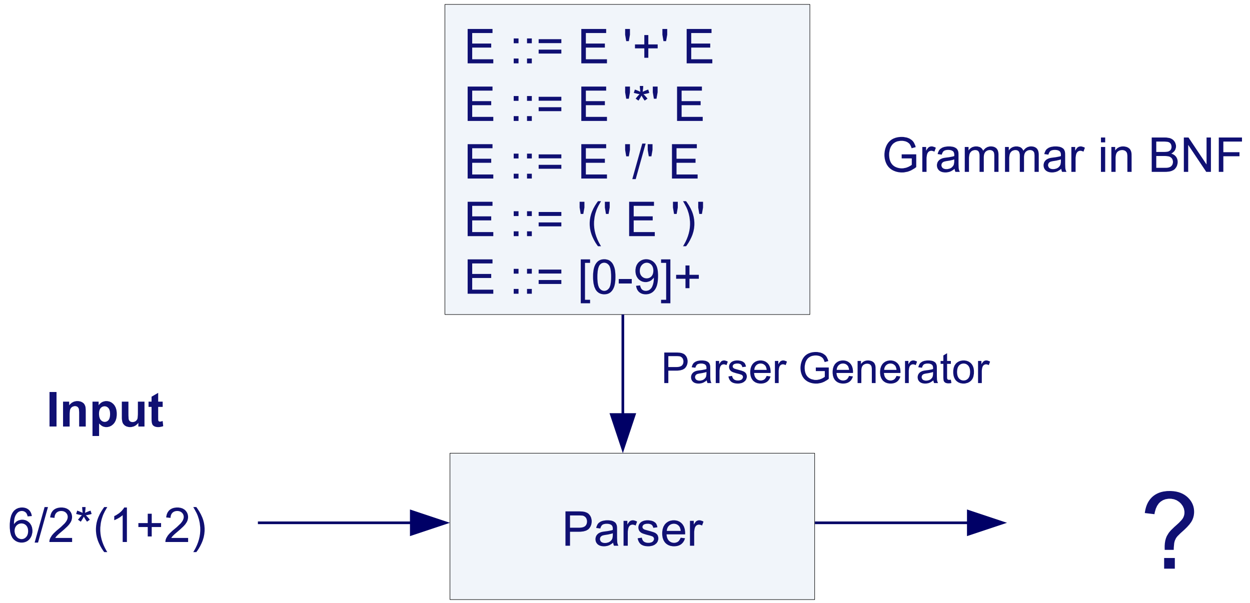
Outline

- Motivation: parsing, ambiguities
- Goal of project and research questions
  - Focus: Ambiguities in expression grammars
  - Questions:
    - Which ambiguities occur in expression grammars?
    - When do they occur?
    - How can we resolve them?
- Resolve ambiguities in parse forest
- Integration of techniques into the parser
- Experimental evaluation
- Conclusions

Motivation: what is parsing?



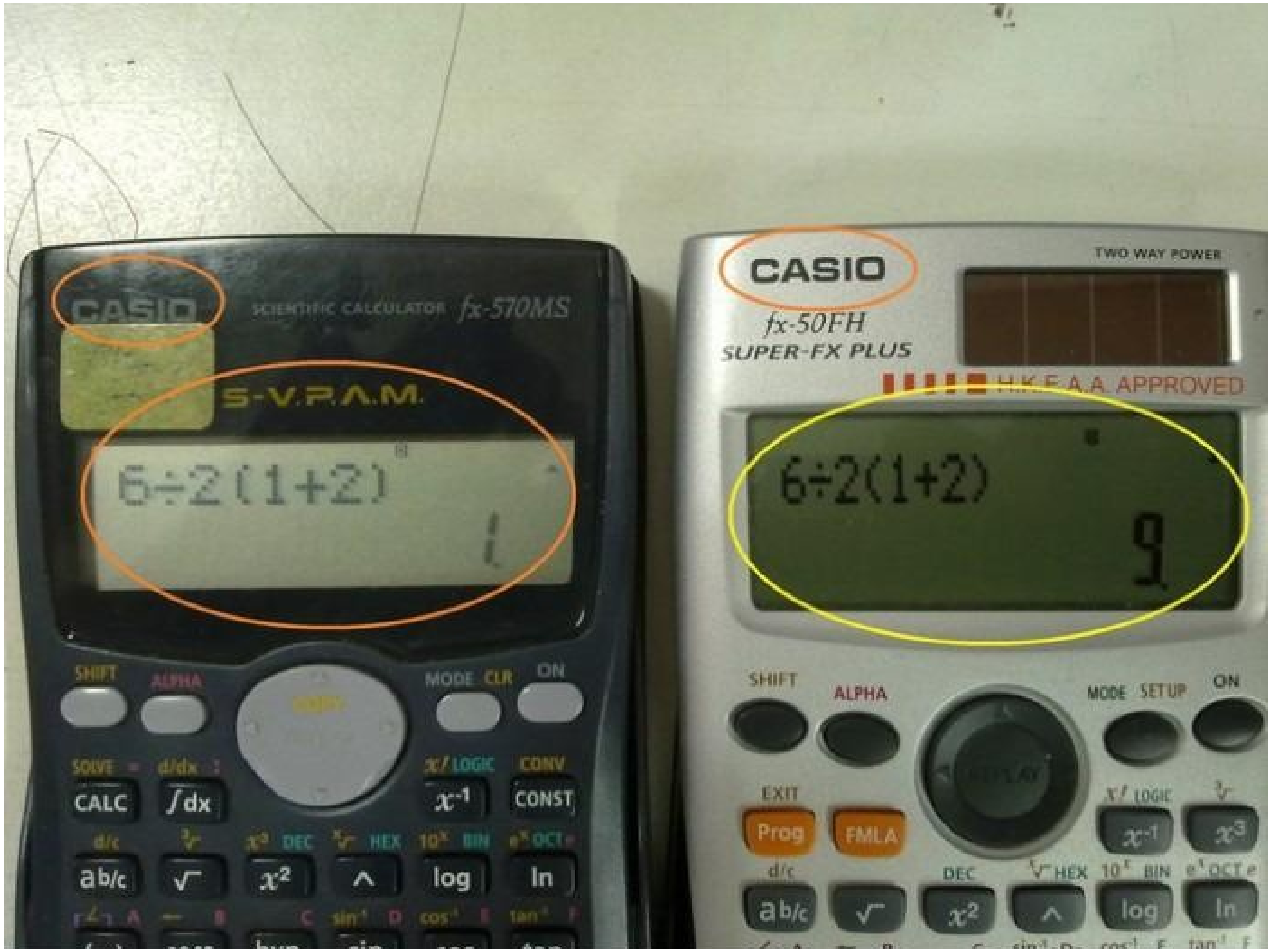
Motivation: ambiguity



Output depends on parser:

- **Generate all derivations: set of parse trees**
- **Generate error**
- **Choose first valid derivation**
- **Use additional information to select derivation**

Motivation: ambiguity



2006

2008

Goal of project

- Disambiguation of expression grammars
- We need: expression grammar with disambiguation rules
- Disambiguation rules specify:
    - Context-sensitive information that guide ambiguity resolving

- Disambiguation rules need:
    - Easy syntax
    - Clear semantics

- Single parse tree as result by discarding incorrect parse trees.

Key questions

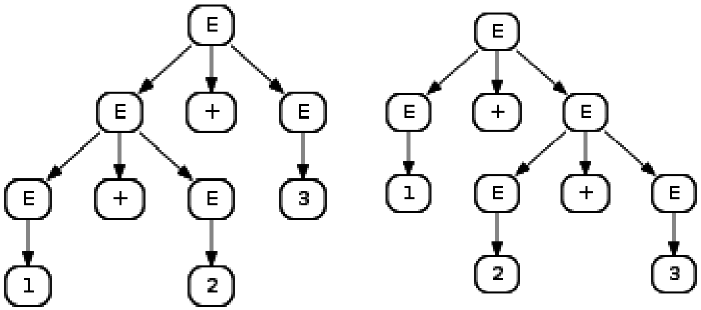
- **What kind of ambiguities occur in expression grammars and how to resolve them?**

  - **Abstract expression grammars:**
    - **unary prefix, unary postfix and binary expressions**
      -E E! E+E
  - **Java expressions**
  - **mCRL2 expressions**
    - **Expressions like E → E ◊ E (if-then-else construction)**

- Resolving by means of **filtering** applied on **parse forests** generated by generalized parsers

What kind of ambiguities occur?

- **Associativity**
  1+2+3; (1+2)+3 or 1+(2+3)?



- **Precedence**
  1+2*3;
  - (1+2)*3 or
  - 1+(2*3)?

- **Dangling else**
  E ::= if E then E
  E ::= if E then E else E
  if a **then if** b **then** c **else** d

```
if a then                 if a then
    if b then                 if b then
        c                         c
    else d                else d
```

- **Ambiguities between prefix and postfix**:
  - 1+++1 with operators
    E+E, E++ and ++E; do we want:
    (E++)+E or E+(++E)?

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Associativity and Precedence

- **When do associativity and precedence conflicts occur?**
  - **Consider the following two grammar rules:**
    - **E ::= E α** — ***left-open*** — **α,β ∈ (T ∪ N)***
    - **E ::= β E** — ***right-open***
  - **Then there are two possible derivations for β E α:**
    - **E ⇒ E α ⇒ (β E) α , and**
    - **E ⇒ β E ⇒ β (E α)**
  - **For instance: E ::= E + E and E ::= - E and input -1+1**
    - **E ⇒ E+E ⇒ (-E) + E ⇒ (-1) + 1**
    - **E ⇒ -E ⇒ -(E+E) ⇒ - (1+1)**

Associativity and Precedence

- **Specify associativity and precedence**

```
E ::= E '+' E
E ::= E '*' E
E ::= E '/' E
E ::= '(' E ')'
E ::= [0-9]+
```

→

```
E ::= E '+' E        {left, 1}
E ::= E '*' E        {left, 2}
E ::= E '/' E        {left, 2}
E ::= '(' E ')'
E ::= [0-9]+
```

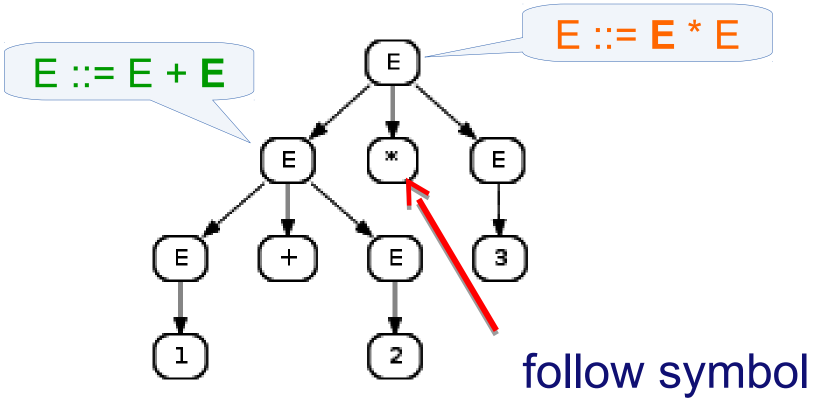
- **Use disambiguation rules to select desired derivation**

- **By inspecting grammar: look if all ambiguities related to assoc. & prec. are covered.**

So, how to implement a filter using these disambiguation rules for disambiguation?

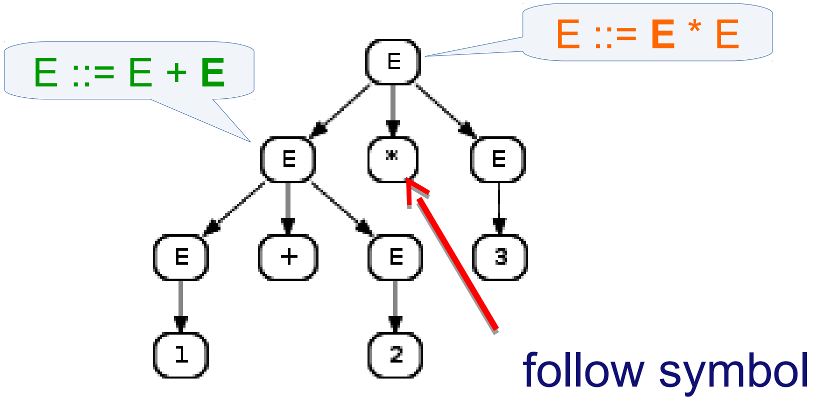
Associativity and Precedence

- Left-open right-open (LORO) filter
  - Looks at precede symbol / follow symbol and corresponding production
  - Node E ::= E+E derives 1+2,
    - Follow symbol: *
    - Follow production: E ::= E * E



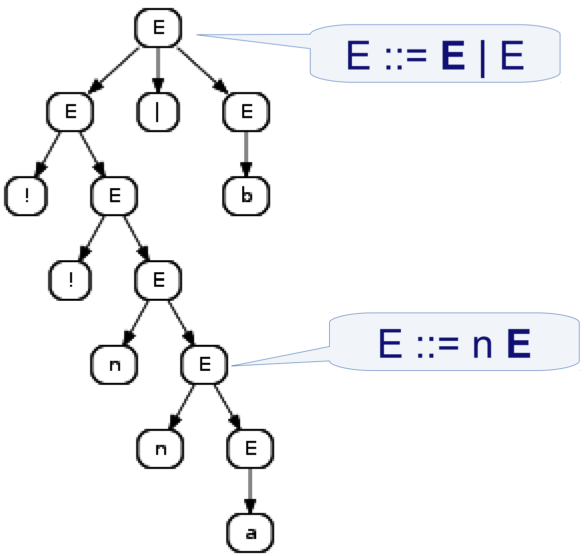
Associativity and Precedence

- Left-open right-open (LORO) filter
  - Given augmented grammar
    - generate Precede-restrictions and Follow-restrictions
    - by looking at left-open right-open rules and their assoc./prio.
  - Given E + E {left, 1} and E * E {left, 2}:
    - Precede restrictions (E+E, E+E) and (E*E, E*E) for associativity
    - Precede restriction (E+E,E*E) and follow restriction (E+E,E*E) for precedence



Associativity and Precedence

- **Left-open right-open (LORO) filter**
  - **Given assoc. + prec. rules, look for restriction violations:**



Finding follow (or precede) production:
path

E ::= n E	{3}
E ::= E | E	{left, 2}
E ::= ! E	{1}

  - **Input: ! ! n n a | b**
  - **Precedence: n E > E | E > ! E**
  - **Follow restriction: (n E, E | E)**

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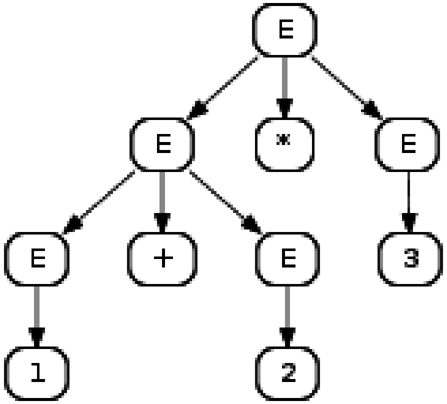
Towards forest filtering: What is a parse forest?

- **Given some input parse forest contains all corresponding parse trees**
  - **each tree corresponds to a derivation**
  - **trees are embedded in the parse forest**
- **Observations:**
  - **Parse trees can share subtrees**
    - **In parse forest: allow a node to have multiple parents**
  - **Part of the input string can be derived in multiple ways: ambiguities**
    - **In parse forest: use special type of node, called a *packed node,* for each derivation**
- **Cubic size with respect to the input string**
- **SPPF: Shared Packed Parse Forest**
- **Generated by generalized algorithms like GLL, GLR, Earley [1]**

[1: Elizabeth Scott, SPPF-Style Parsing From Earley Recognisers, (2008)]

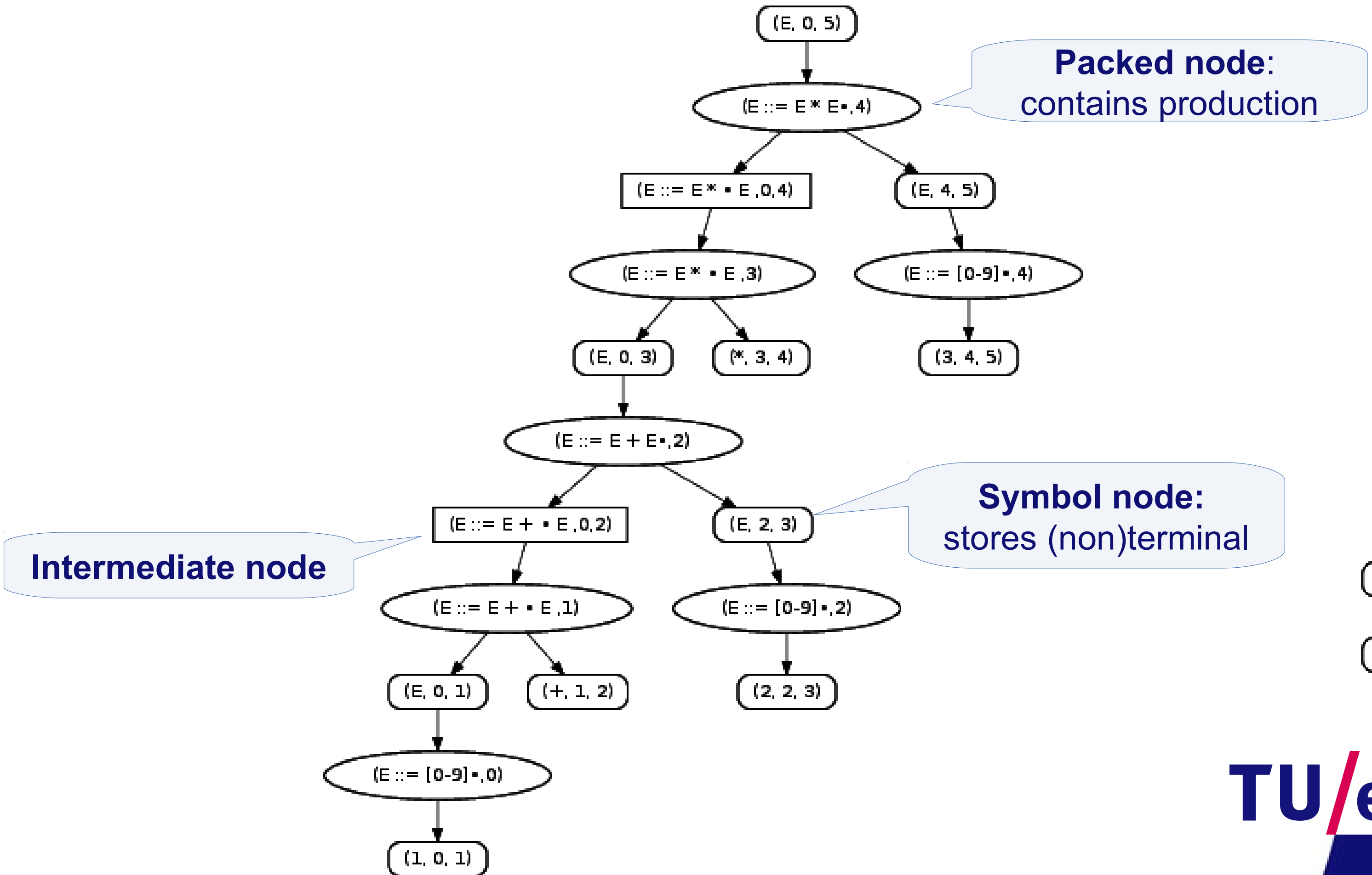
SPPF filtering: Associativity and Precedence

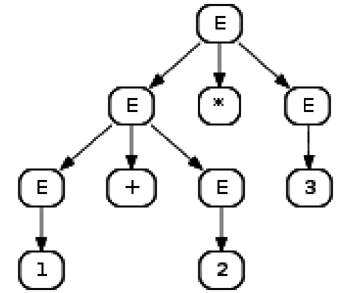
- Recall our invalid parse tree
  - E+E nested below E*E
  - Follow restriction: E+E is followed by E*E



SPPF filtering: Associativity and Precedence

- **SPPF parse tree instead of parse tree**

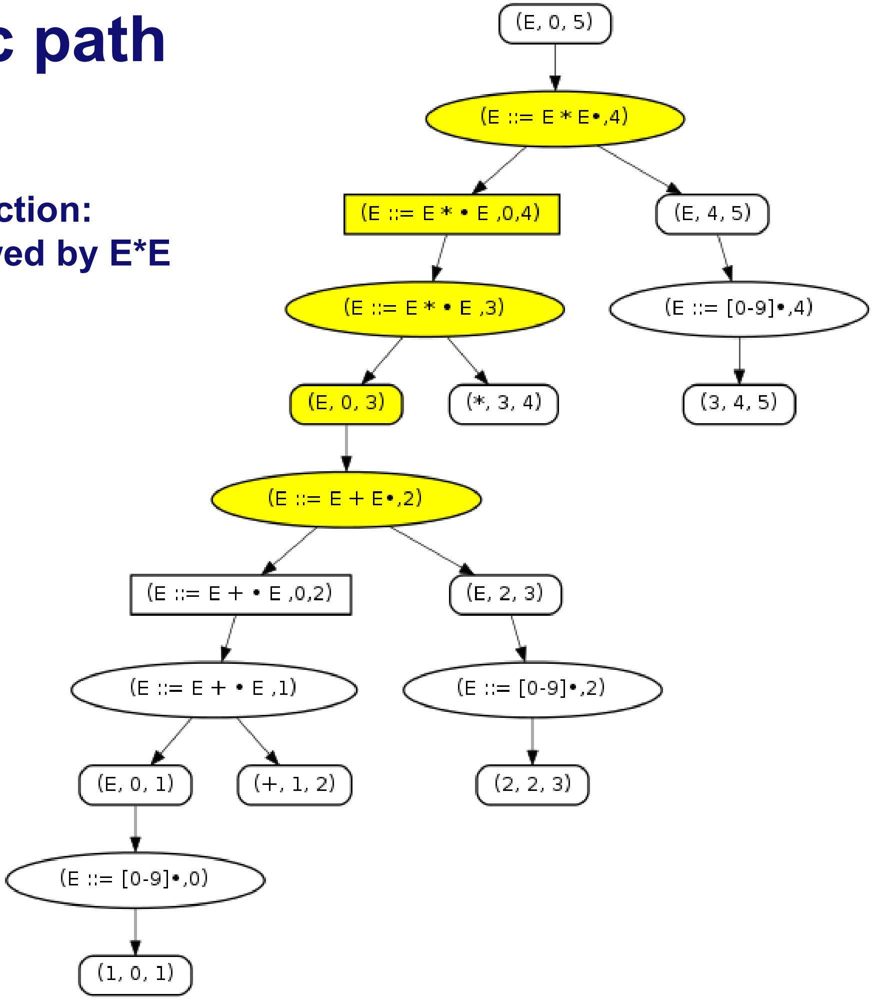




SPPF filtering: Associativity and Precedence

- **SPPF filtering: remove SPPF parse trees containing specific path**

Follow restriction:
E+E is followed by E*E



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SPPF filtering: removing invalid trees

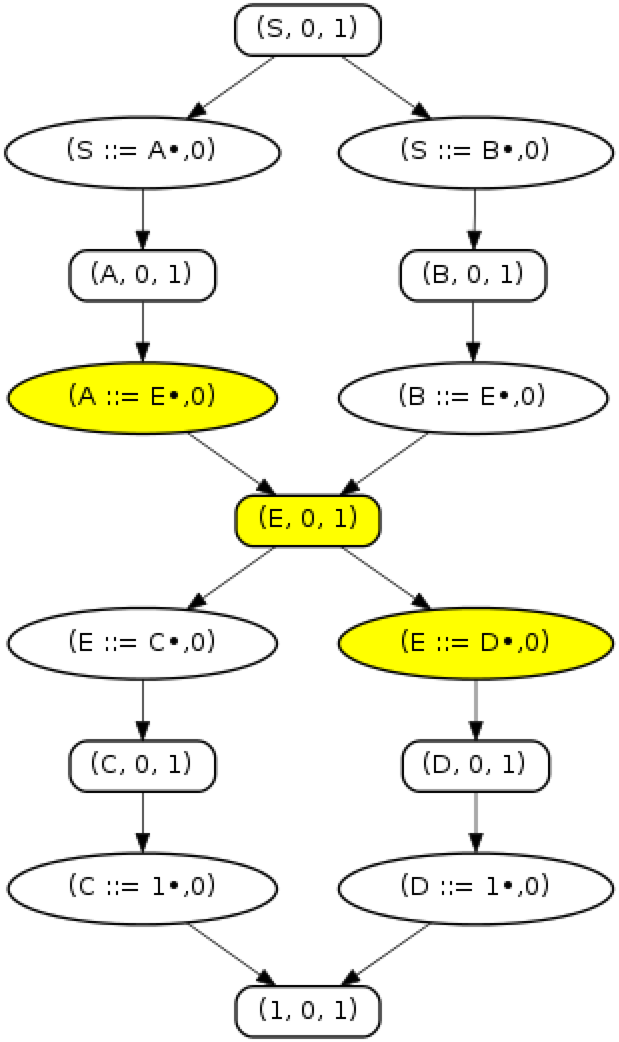
- Naive implementation:
  - Look at each individual SPPF tree embedded in the SPPF
    - Check whether precede or follow restriction applies
  - Unfeasible when many ambiguities are present
    - For several mCRL2 test files, number of SPPF trees becomes astronomic (quintillions (19 digits or more))

- Smart implementation:
  - Remove all SPPF trees containing certain invalid paths in one go
  - Issue: sharing

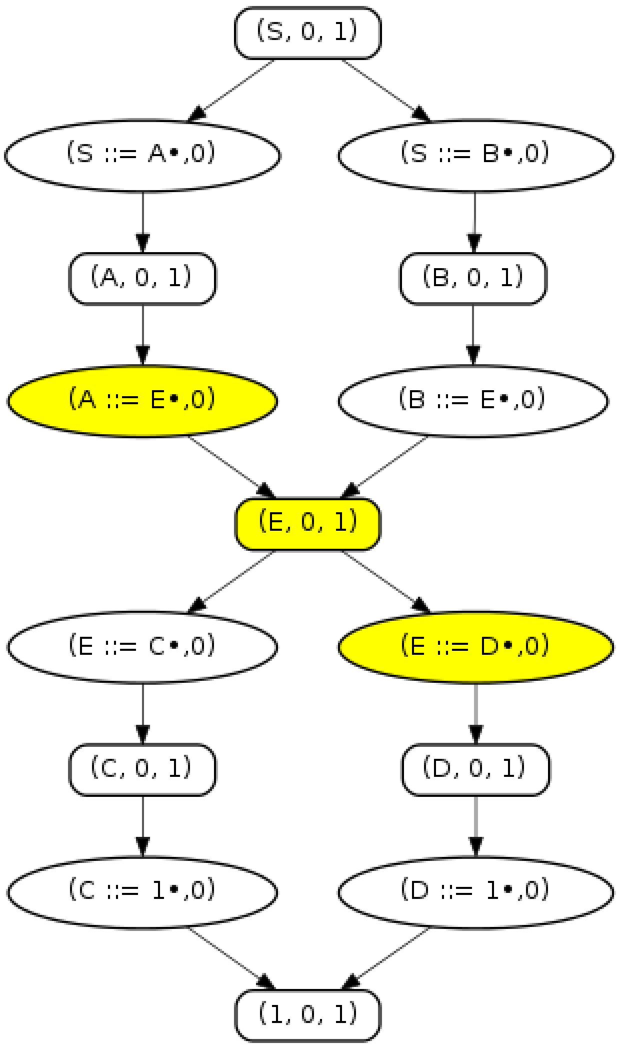
SPPF filtering: sharing

- **Now consider:**
  - **S ::= A | B   E ::= C | D**
    A ::= E   C ::= '1'
    B ::= E   D ::= '1'

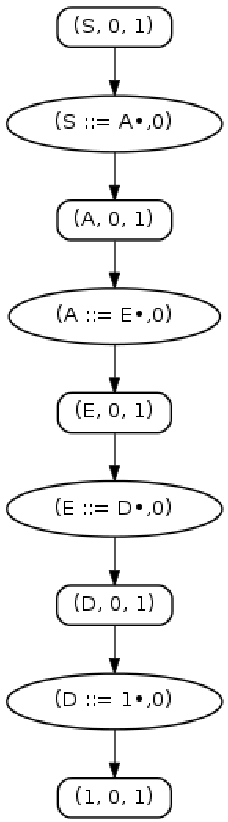
- **Assume production E ::= D below A ::= E not allowed.**



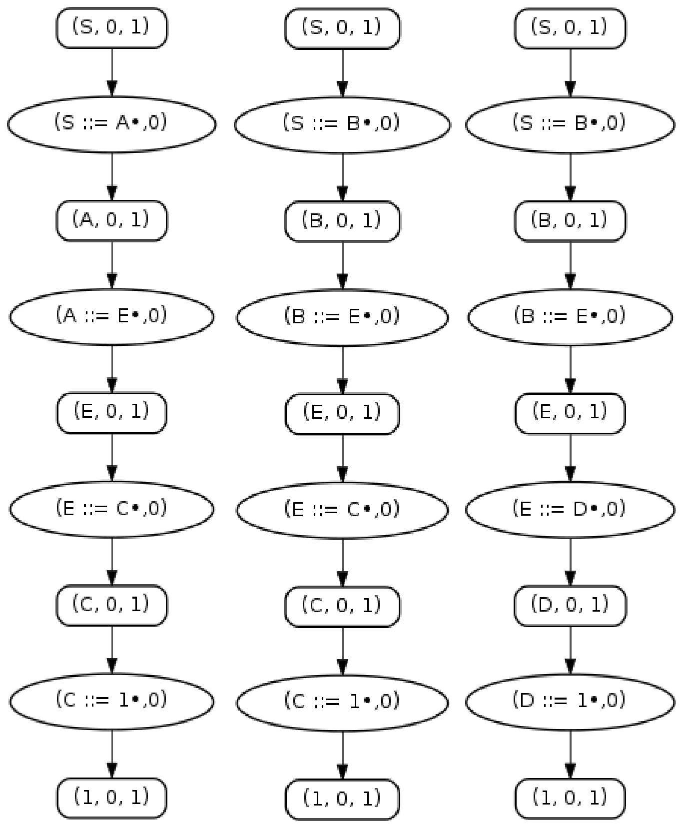
SPPF filtering: sharing



Invalid



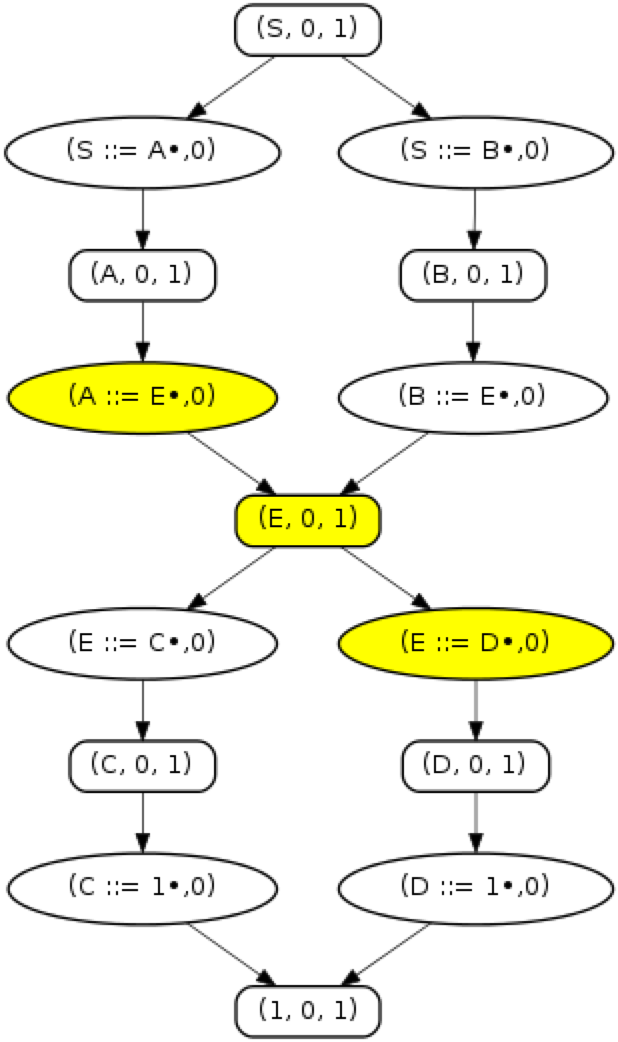
Valid SPPF trees



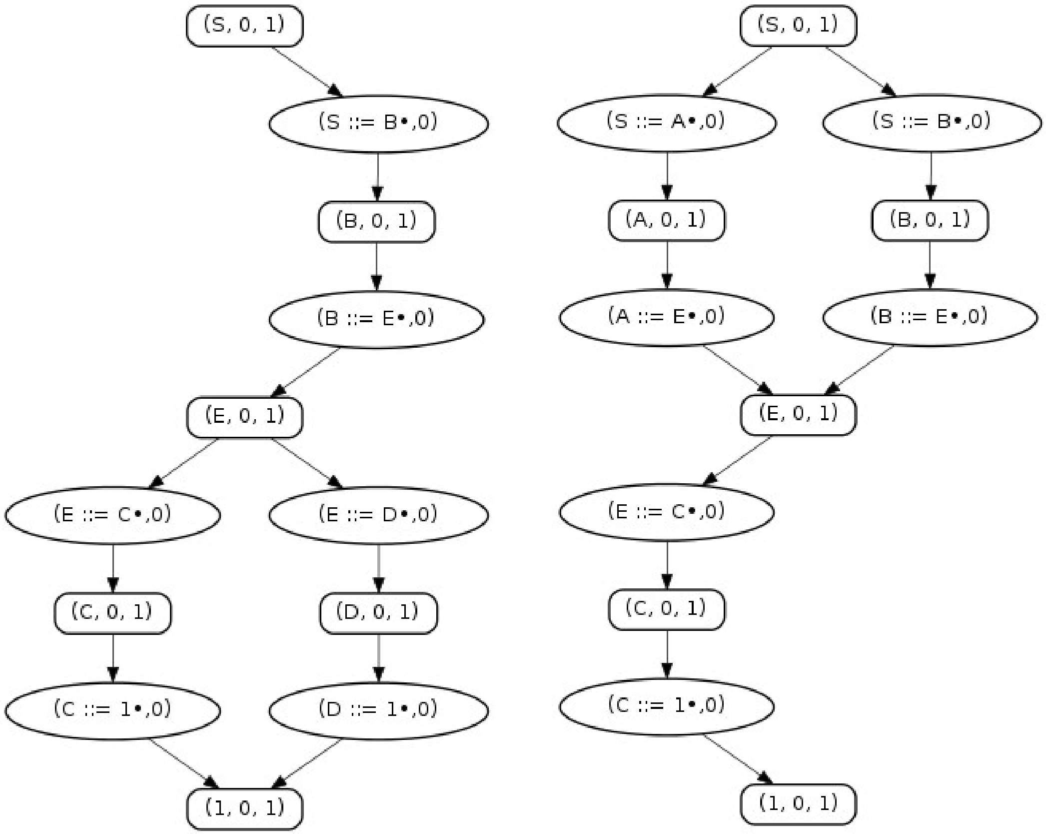
SPPF filtering

- Issue when filtering SPPF: sharing
  - Need algorithms that remove only invalid parse trees from SPPF
  - In some cases:
    - First split SPPF into multiple copies
    - Remove some edges in each copy
    - Resulting copies do not contain invalid parse tree, but together still contain all valid parse trees

SPPF filtering: sharing



Resulting copies:



Apply filtering at an earlier stage

- Filters are defined at parse forest level
- But why not apply them during parsing if possible?

- Same semantics
- Resolve subset of all ambiguities in parse forest

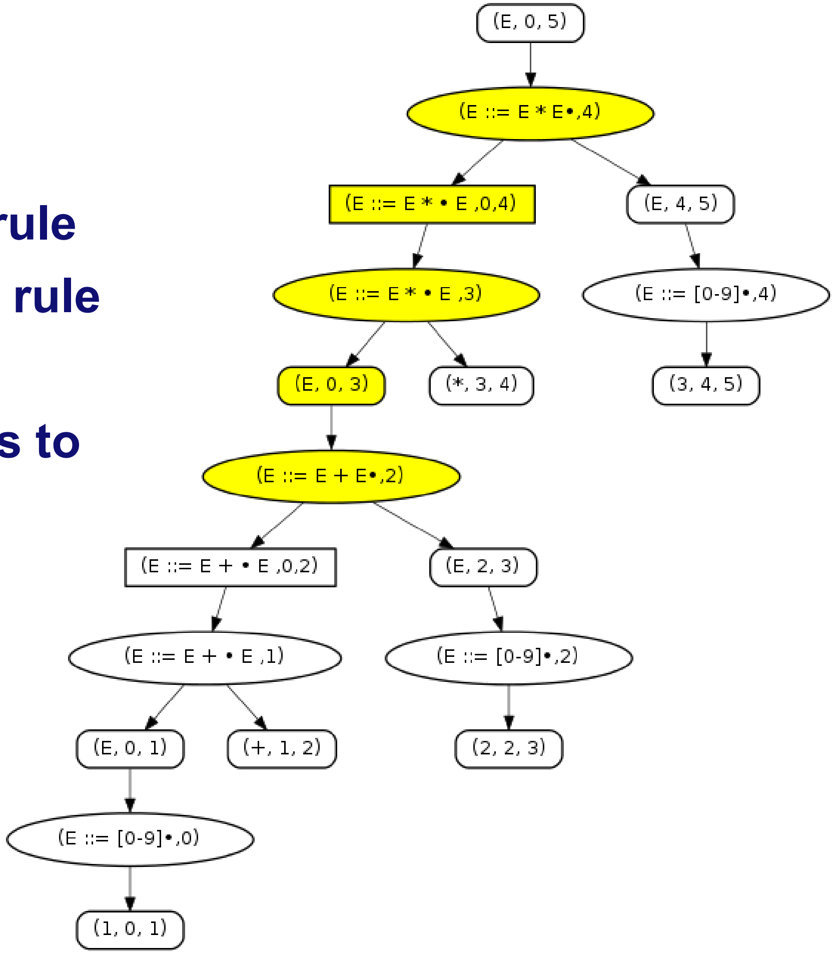
- Advantage: possibly better performance
  - We avoid the creation of undesired parse trees in the first place

- Case study: GLL parsing algorithm

Ambiguity avoidance during parsing

- Limited form of LORO filter:
  - In GLL during parsing we know:
    - Parent grammar slot & grammar rule
    - Current grammar slot & grammar rule
  - Path: parent rule → current rule
  - Try to avoid creating path if it relates to precede or follow violation

  - Filters all ambiguities related to binary operators
  - Filters part of ambiguities related to binary and unary operators



Experimental evaluation

- **Post-parse filtering:**
  - **Works well for small files;**
  - **Large files: lot of SPPF copies, leads to Java runtime exception due to garbage collection**
  - **Solves all described ambiguities in expression grammars**
  - **Future work: use efficient sharing mechanism to relate and store copies**

- **Parsing vs Parsing with parse-time filtering:**
  - **on average 9.4% higher running time**
  - **Running time lower for ambiguous files**
  - **Parse-time filtering solves all ambiguities for binary expressions**
  - **For mCRL2: in test set only 2 files needed additional post-parse filtering**
    - **Invalid path of a longer length**

- **Easy integration of filters into GLL**

Conclusions

- Types of ambiguities in expression grammars
- Disambiguation filters defined on parse forest
- SPPF filtering
- Filters can serve as basis for implementation in parser itself
  - Gives significant speedup for files with ambiguities