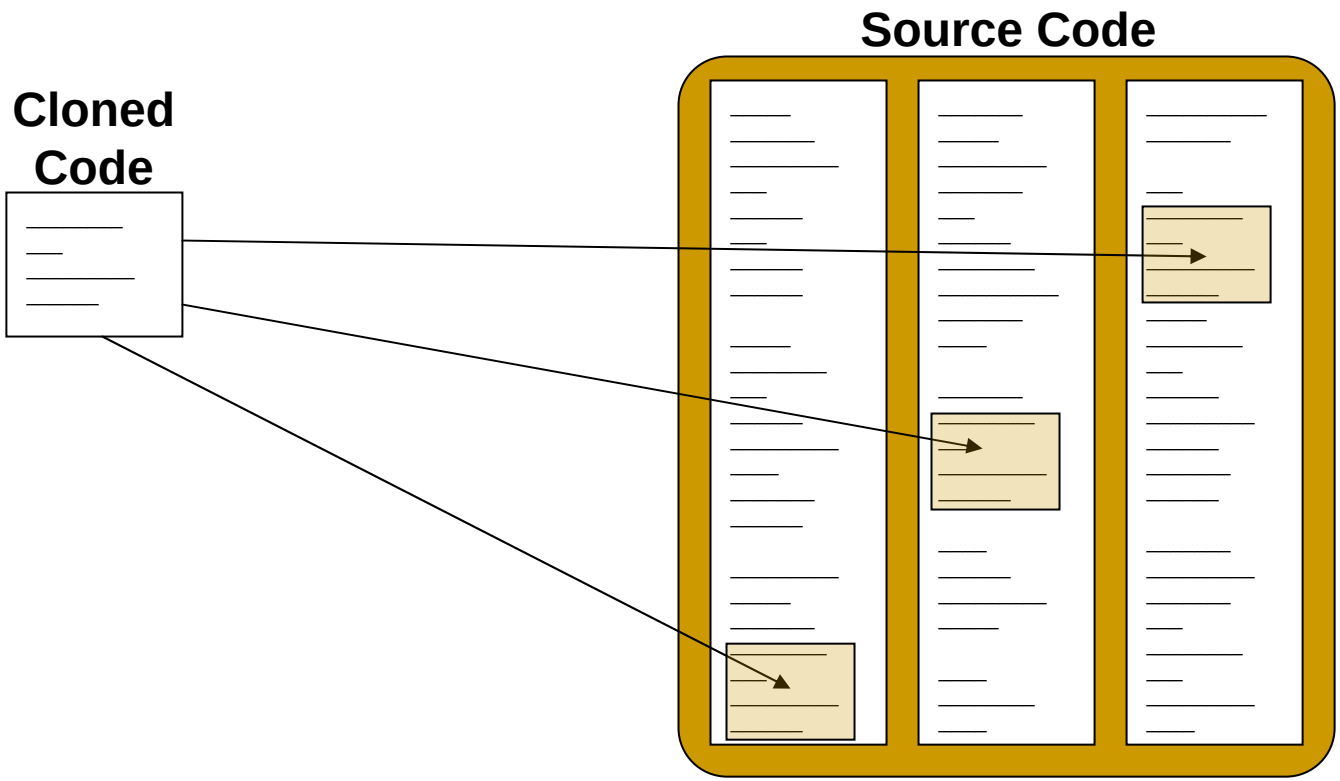
“Phoenix-Based Clone Detection Using Suffix Trees”
and
“Program Behavior Modeling with Event Grammars”

Robert Tairas

Phoenix-Based Clone Detection Using Suffix Trees

Code Clones

- A sequence of statements that are duplicated in multiple locations in a program



Types of Clones

Original code

```
int main() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

```
int func1() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

Exact match

```
int func2() {
   int p = 1;
   int q = p + 5;
   return q;
}
```

Exact match, with only the variable names differing

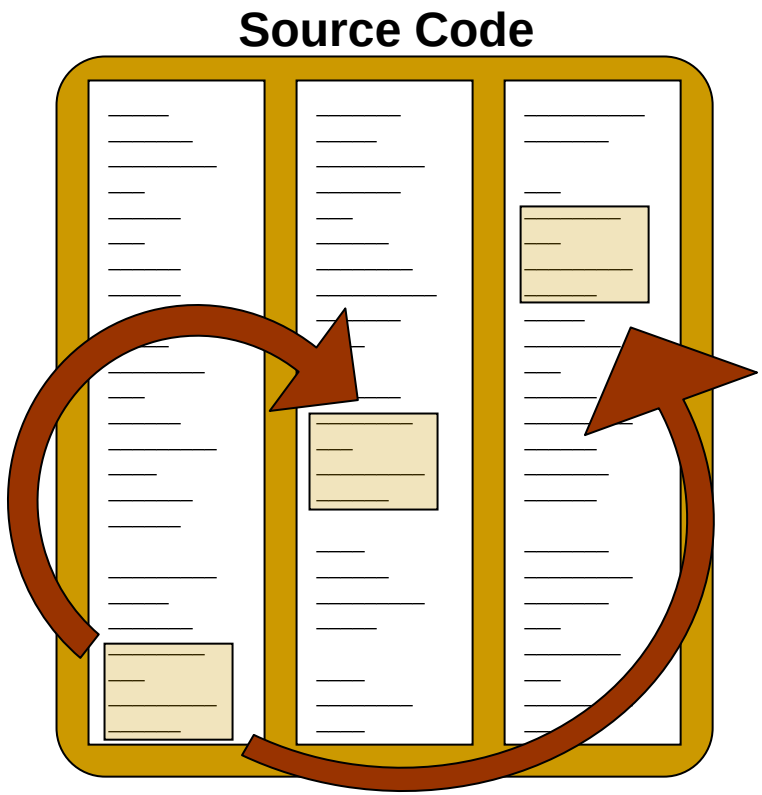
```
int func3() {
   int s = 1;
   int t = s + 5;
   s++;
   return t;
}
```

Near exact match

As defined in an experiment comparing existing clone detection techniques at the 1st International Workshop on Detection of Software Clones (02)

Clones in Source Code

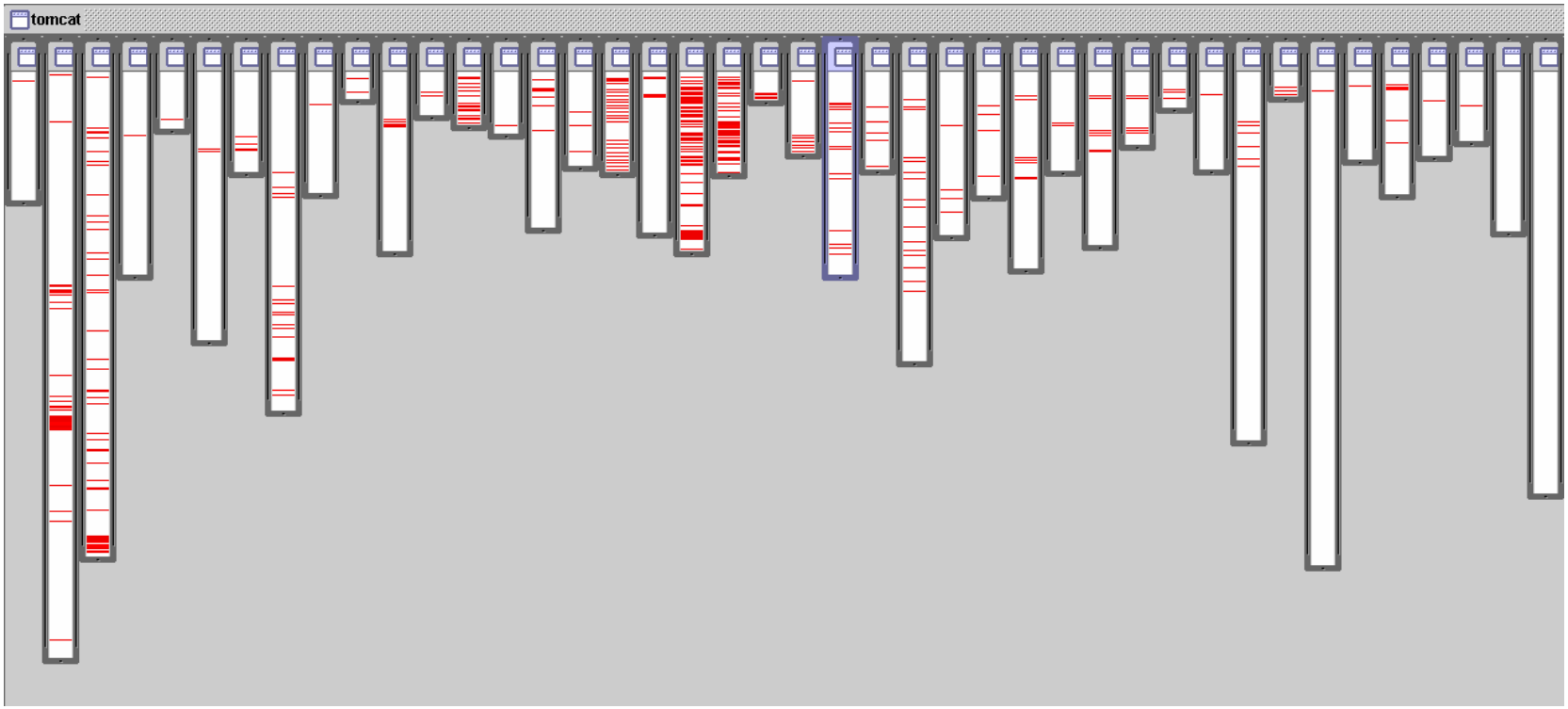
- Copy-and-paste parts of code from one location to another
  - The copied code already works correctly
  - No time to be efficient
- Research shows that 5-10% of large scale computer programs are clones (Baxter, 98)



Clones in Source Code

- *Dominant decomposition*: A block of statements that performs a function/concern dominates another block
  - The two concerns crosscut each other
  - One concern will have to yield to the other
  - Related to Aspect Oriented Programming (AOP)

Clones in Source Code



- logging in org.apache.tomcat
  - red shows lines of code that handle logging
  - not in just one place
  - not even in a small number of places

aspectj.org

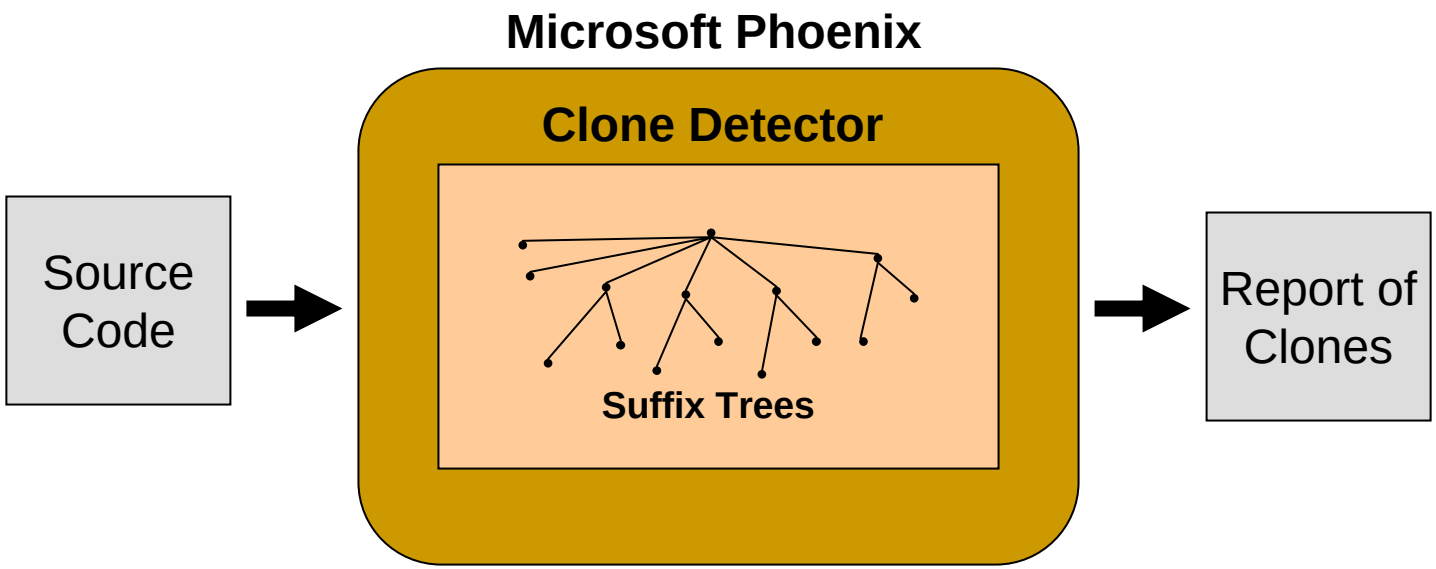
Clone Dilemma

- Maintenance
  - To update code that is cloned will require all clones to be updated
- Restructure/refactor
- Separate into aspects

But first we need to find the clones

Contribution: Automated Clone Detection

- Searches for exact matching function level clones in the Microsoft Phoenix framework utilizing suffix tree structures

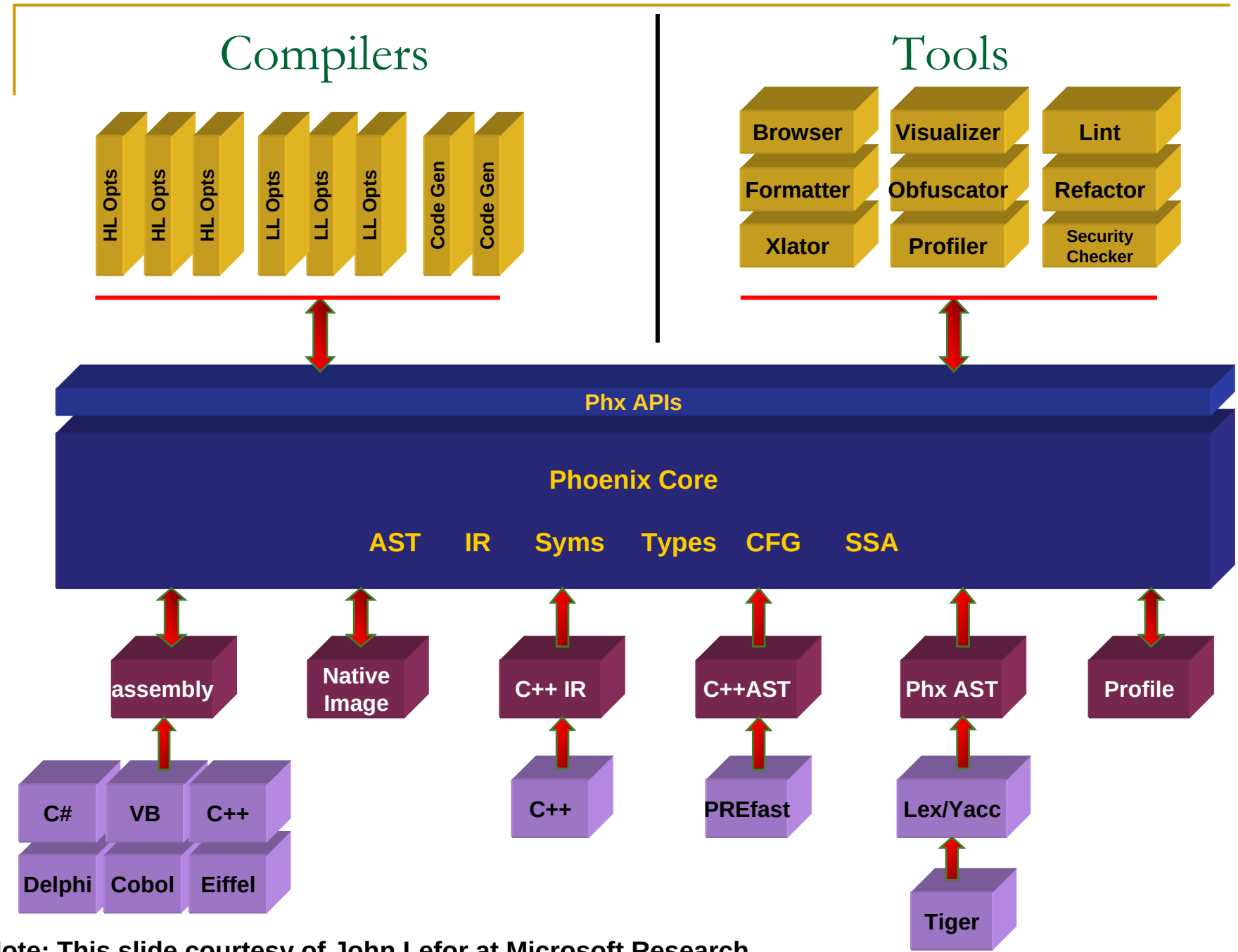


What is Phoenix?

- Next-Generation Framework for
  - building Compilers
  - building Software Analysis Tools
- Basis for Microsoft compilers for 10+ years
- Framework for Academic Research & Teaching

More information:
http://research.microsoft.com/phoenix

Note: Contents of this slide courtesy of John Lefor at Microsoft Research

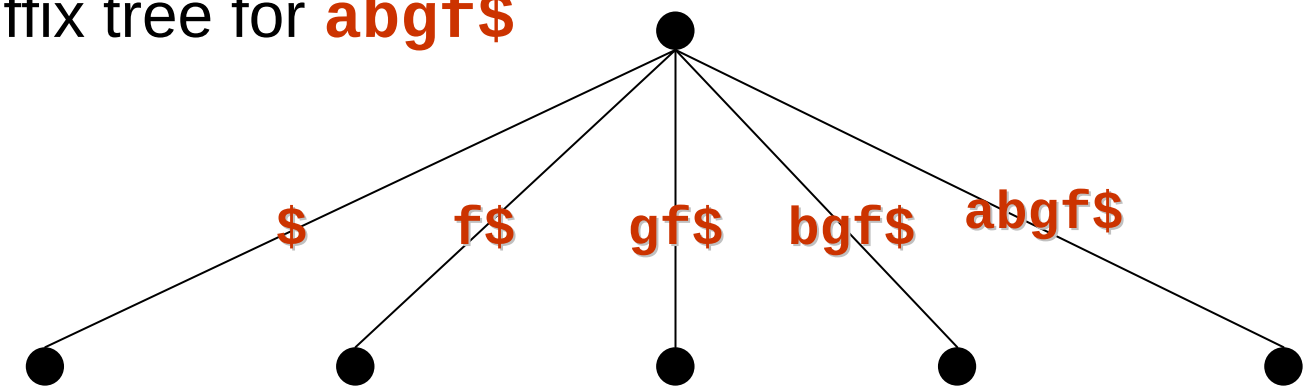


Note: This slide courtesy of John Lefor at Microsoft Research

Suffix Trees

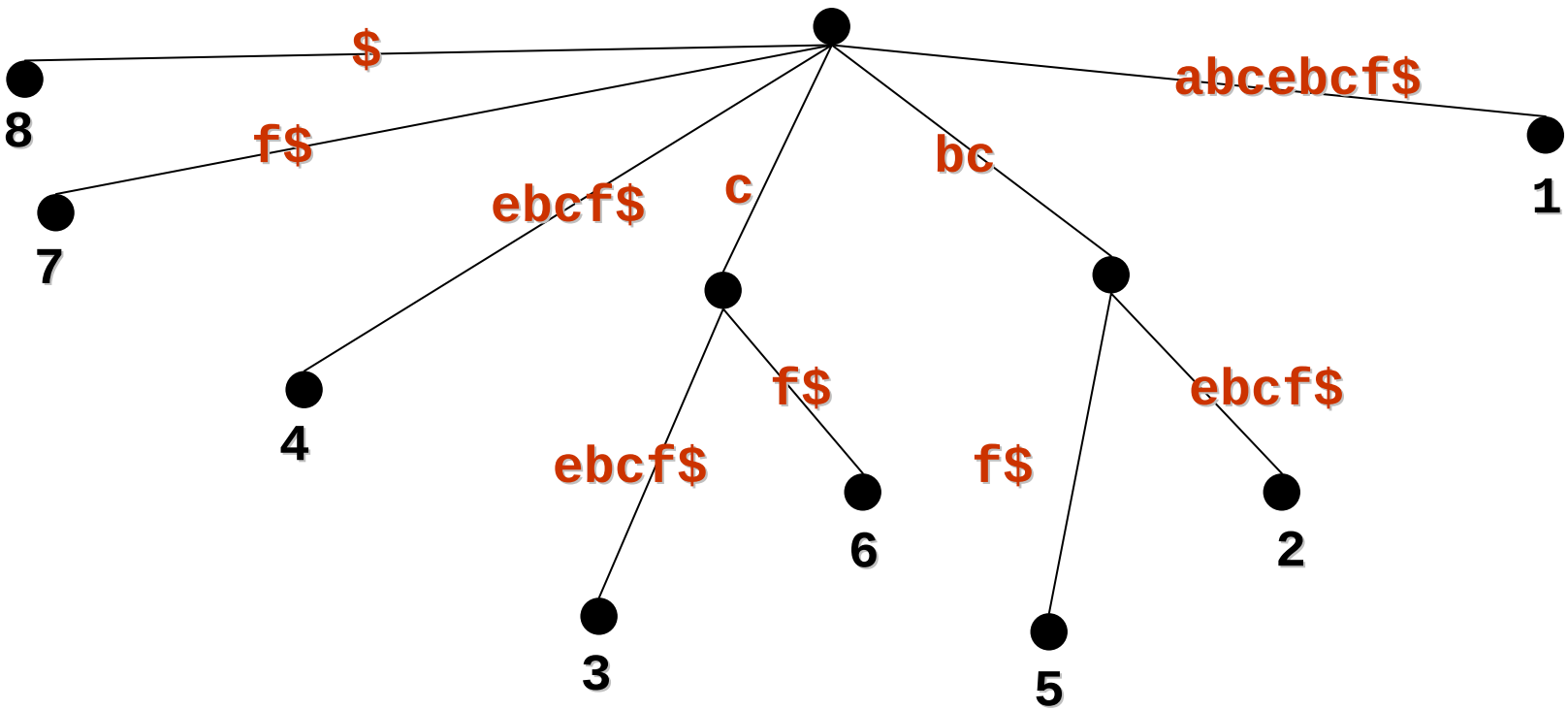
- A suffix tree for a string is a tree where each suffix of the string is represented by a path from the root to a leaf
- In bioinformatics it is used to search for patterns in DNA or protein sequences

Example: suffix tree for **abgf$**



Another Suffix Tree Example

Suffix tree for **abcebcf$**
12345678

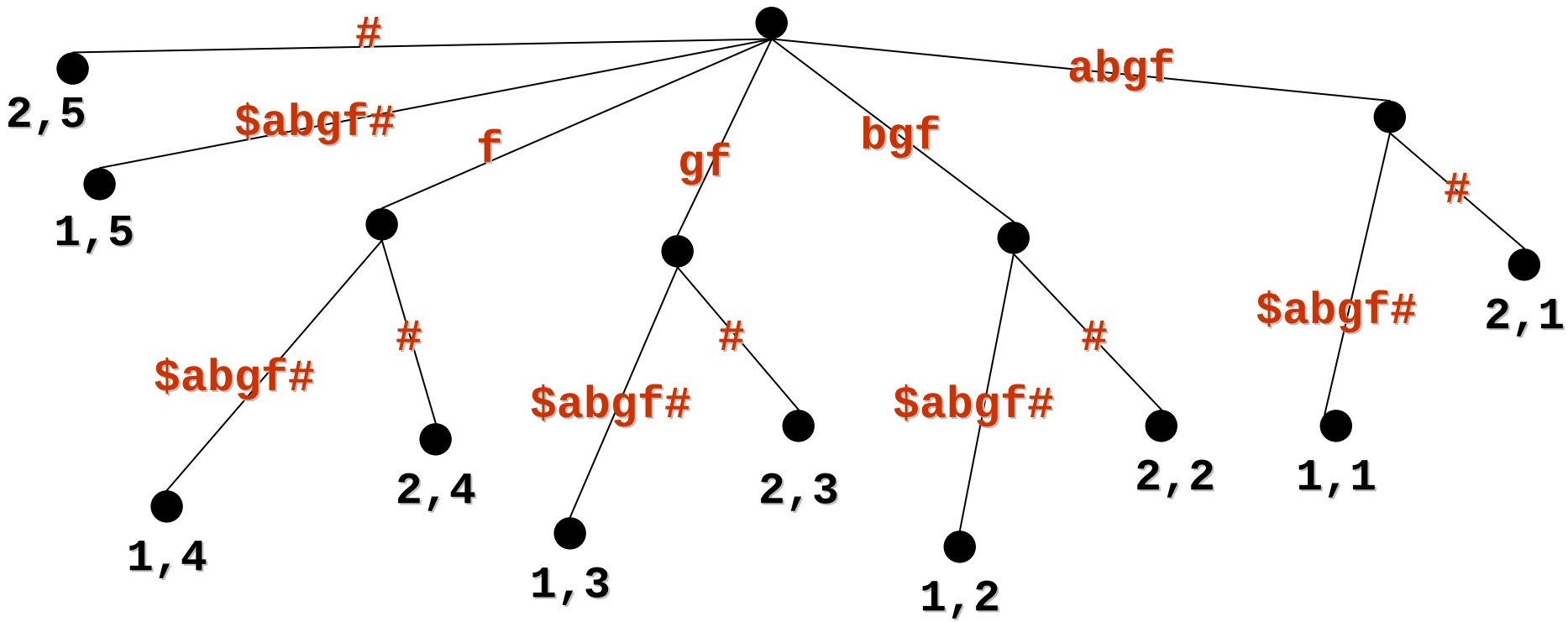


<u>Leaf numbers:</u>
The number indicates the starting position of the suffix from the left of the string.

Another Suffix Tree Example

Suffix tree for **abgf$abgf#**

Two identical strings (abgf) separated by unique terminating characters



<u>Leaf numbers:</u>

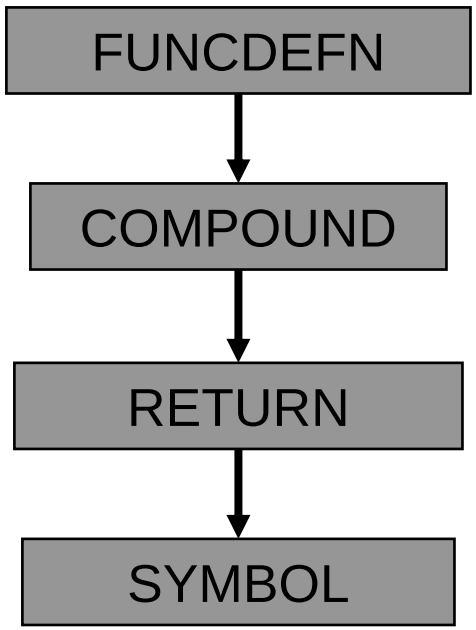
The first number indicates the string.

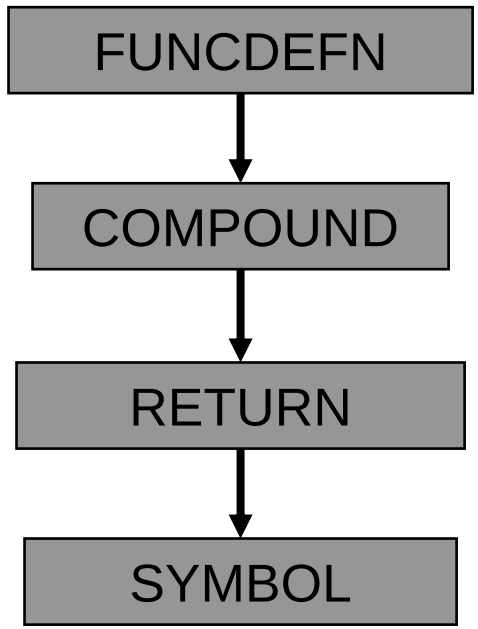
The second number indicates the starting position of the suffix in that string.

Abstract Syntax Tree Nodes

```
int func1() {
   return x;
}
```

```
int func2() {
   return y;
}
```

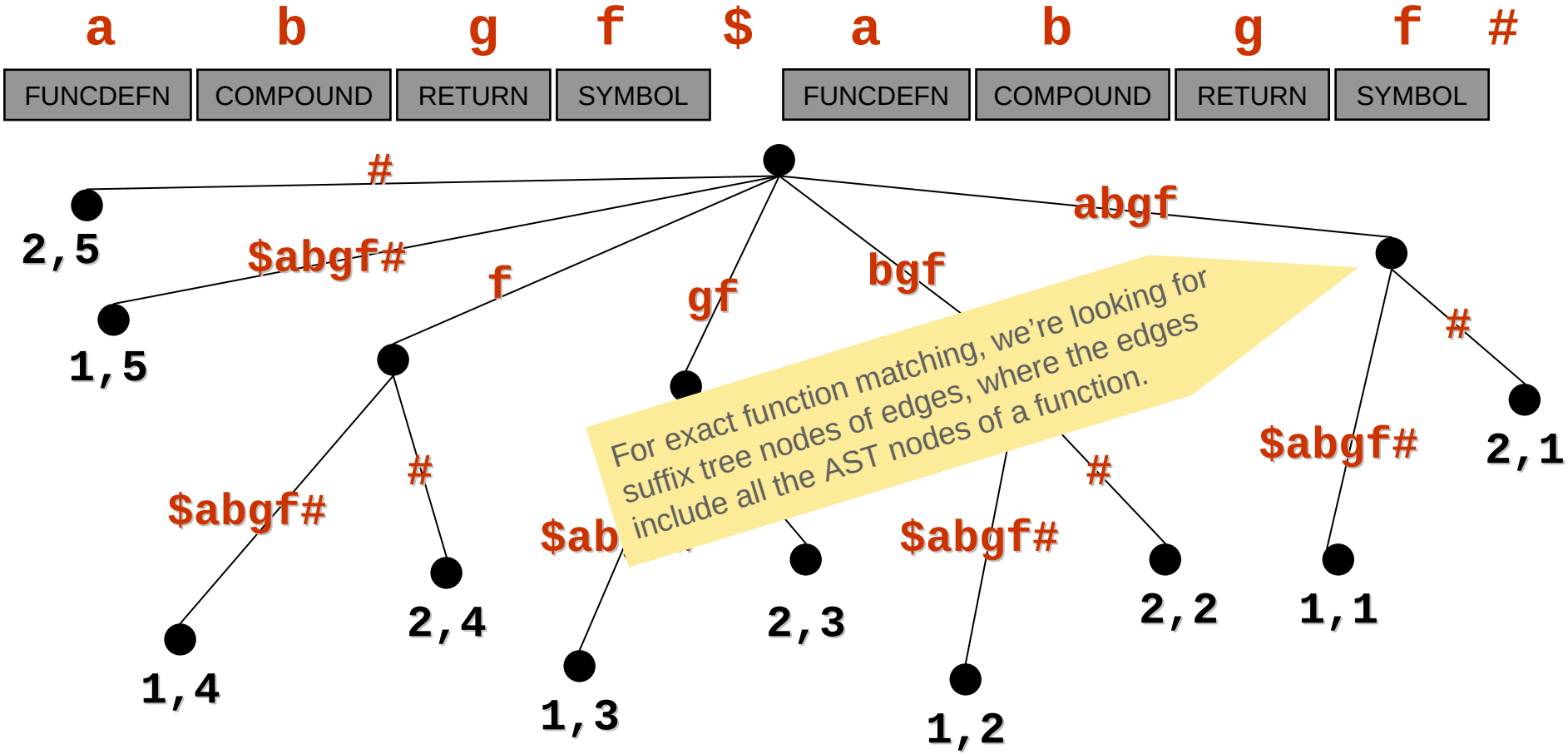




Note: Node names are Phoenix-defined.

Remember This?

Suffix tree for **abgf$abgf#**



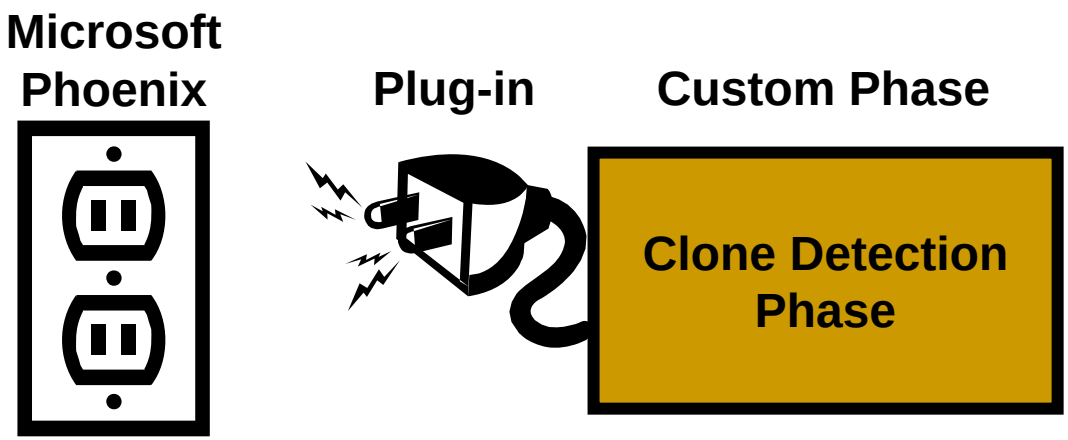
<u>Leaf numbers:</u>

The first number indicates the function.

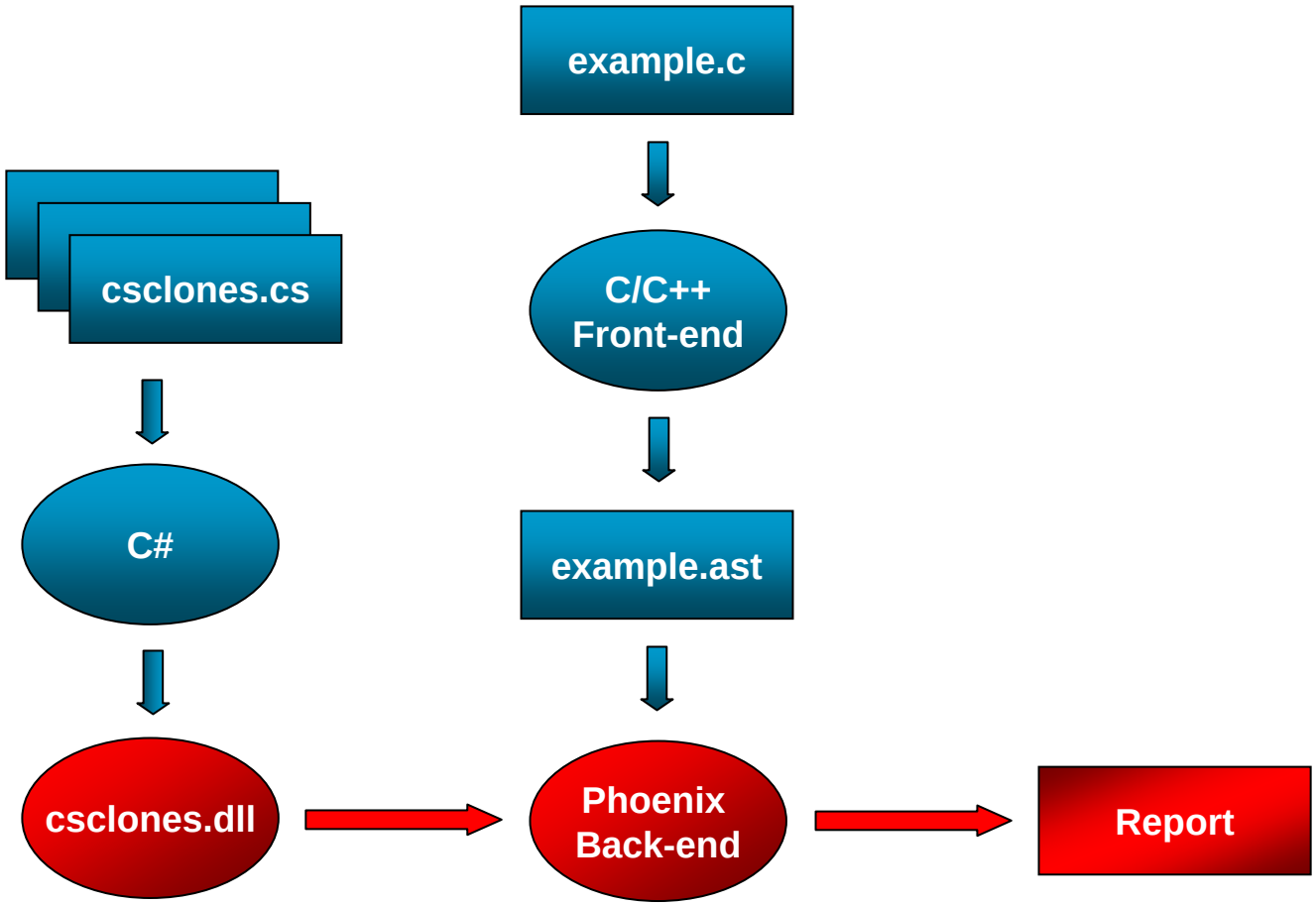
The second number indicates the starting position of the suffix in that function.

Phoenix Phases

- Processes are divided into “phases”
- Custom phases can be inserted to perform tasks such as software analysis
- Phases are inserted through “plug-ins” in the form of a library (DLL) module



Clone Detector in Phoenix



Demo

Limitations and Future Work

- Looks only for exact matches
  - Currently working on a process called hybrid dynamic programming, which includes the use of suffix trees (*k-difference inexact matching*)
- Looks only at the function level
  - Enable multiple levels clone detection
  - Higher: statement level; Lower: program level
- Recognizes only C nodes
  - Coverage for other languages, such as C++ and C#
  - Another approach: language independent

Program Behavior Modeling with Event Grammars

FRAMEWORK FOR SEAMLESS INTEROPERATION OF HETEROGENOUS DISTRIBUTED SOFTWARE COMPONENTS

UniFrame Quality Framework – Event Grammar Approach

Mikhail Auguston

Naval Postgraduate School

Program Behavior Models

- Program monitoring activities can be specified in a uniform way using program **behavior models** based on the event notion
- An **event** corresponds to any detectable action, e.g. subroutine call, message passing, etc. An event corresponds to a time interval
- Two partial order binary relations are defined for events: **precedence** and **inclusion**
- An event has **attributes**: type, duration, program state at beginning or end of the event, value,...

Event Types

Event types and type specific attributtes for the Unicorn language

Event Type	Description	Attributes
prog_ex	whole program execution	
expr_eval	expression evaluation	value, operator, type, failure_p
func_call	function call	func_name, paramlist
input, output	I/O	file
variable	variable reference	
literal	reference to a constant	
lhp	lefthand part, assignment	address
rhp	righthand part, assignment	
clause	then-, else-, or case execution	
test	test evaluation	
iteration	loop iteration	

Program Behavior Models

- **Event grammar** specifies the constraints on configurations of events generated at the run time (axioms, or “lightweight semantics” of the target language)
- Some axioms are generic, e.g. transitivity

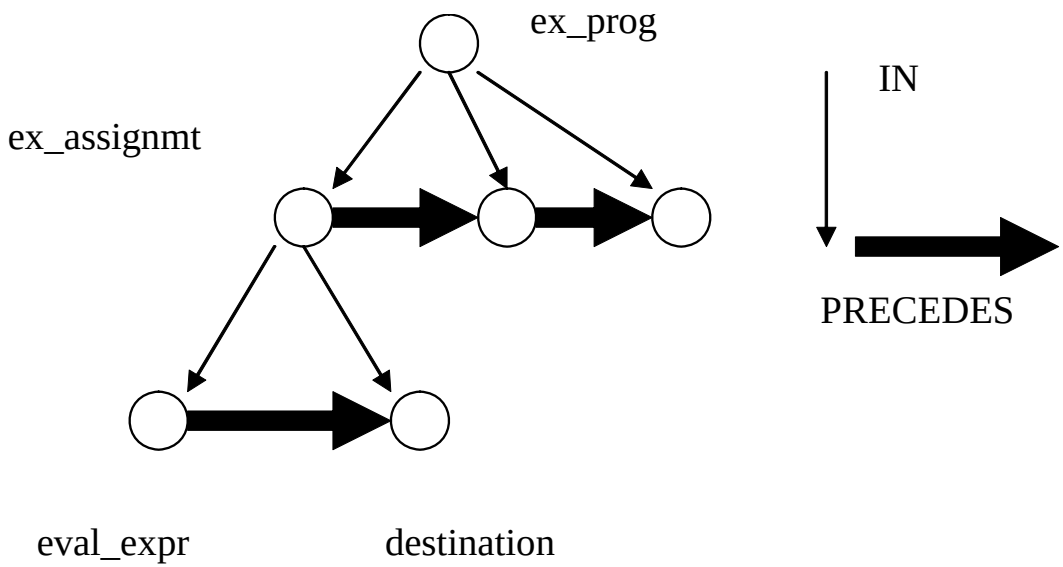
A PRECEDES B **and** B PRECEDES C ➔ A PRECEDES C

A IN B **and** B IN C ➔ A IN C

Example of Event Grammar

```
ex_prog:: ex_stmt *
ex_stmt:: ex_assignmt | ex_read_stmt | …
ex_assignmt:: eval_expr  destination
```

Example of an event trace



Program Monitoring

- **Monitoring activities**: assertion checking, profiles, performance measurements, dynamic QoS metrics, visualization, debugging queries, intrusion detection
- Program monitoring can be specified in terms of **computations over event traces**
- We introduce a specific language **FORMAN** to specify computations over event traces (based on event patterns and aggregate operations over events)

Examples

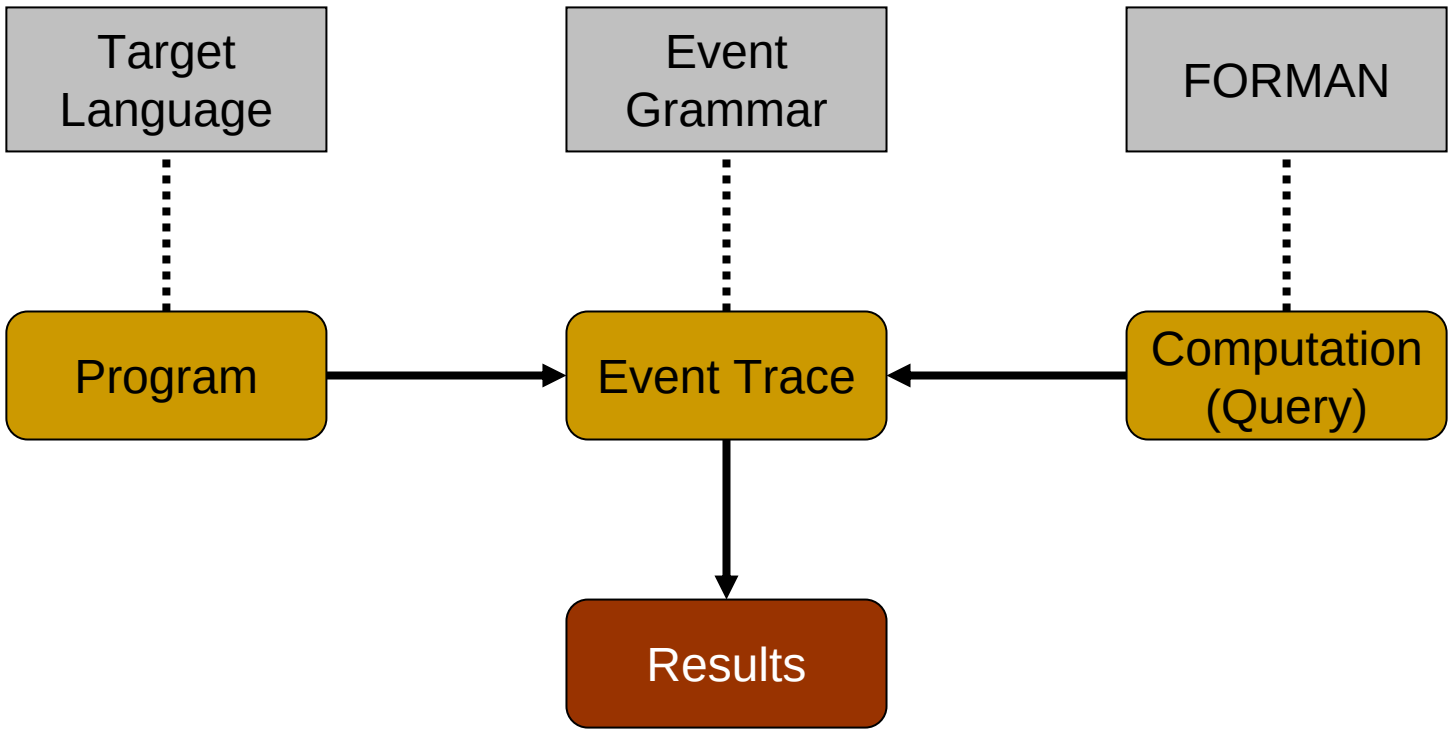
1) Profile

```
SAY( "Number of function A calls is "
    CARD[ x: func_call & x.name == "A"
                          FROM ex_prog ]
```

2) Generic debugging rule (typical error description)

```
FOREACH e: eval_expr :: (v: variable)
      FROM ex_prog
  EXISTS d: destination FROM e.PREV_PATH
    v.source_code = d.source_code
    ONFAIL SAY("Uninitialized variable "
    v.source_code "is used in expression " e)
```

Process


Target Language
Event Grammar
FORMAN
Program
Event Trace
Computation (Query)
Results

Examples

3) Debugging query

```
SAY("The history of variable x "
[d: destination & d.source_code == "x"
    FROM ex_prog APPLY d.value ] )
```

4) Traditional debugging print statements

```
FOREACH f: func_call & f.name == "A"
      FROM ex_prog
    f.value_at_begin(
      printf("variable x is %d\n", x) )
```

The novelty claims of our approach

- **Uniform framework** for program monitoring based on precise behavior models and event trace computations
- Computations on the event traces can be implemented in a **nondestructive** way via automatic instrumentation of the source code or even of the executables (Dyninst approach)
- Can specify **generic trace computations**: typical bug detection, dynamic QoS metrics, profiles, visualization, ...
- An alternative approach to **aspect-oriented** paradigm

Accomplished projects and work in progress

- Assertion checker for Pascal subset (via interpereter)
- Assertion checker for the C language (via source code instrumentation)
- Assertion checker and visualization tool for the Unicon language (via Virtual Machine monitors)
- UniFrame dynamic QoS metrics, UniFrame project (via glue and wrapper instrumentation), funded by ONR
- Intrusion detection and countermeasures (via Linux kernel library instrumentation), funded by the Department of Justice Homeland Security Program