



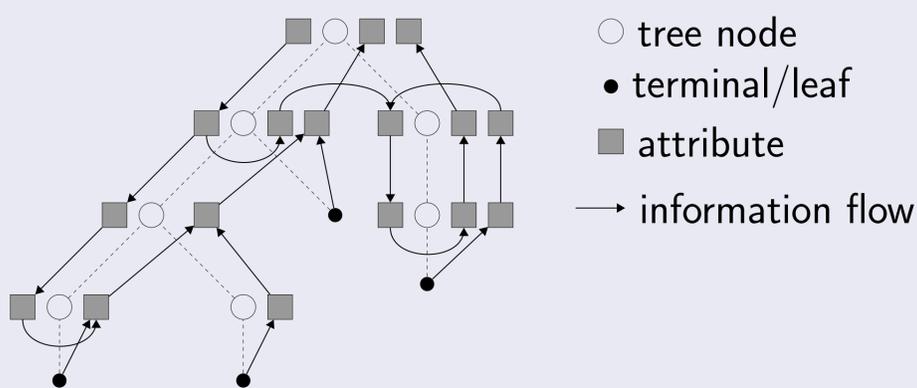
## Semantics with Attribute Grammars

- A grammar describes a set of trees.
- A tree is a program written in a programming language.
- Trees are extended with *attributes*.
- The attributes capture the language's semantics.

## Attributes

- *Synthesized* attributes are results of computations (shown to the right of a non-terminal).
- *Inherited* attributes are parameters of computations (shown to the left of a non-terminal).
- Attributes are defined:
  - In terms of leaf nodes and other attributes.
  - At the level of a production.

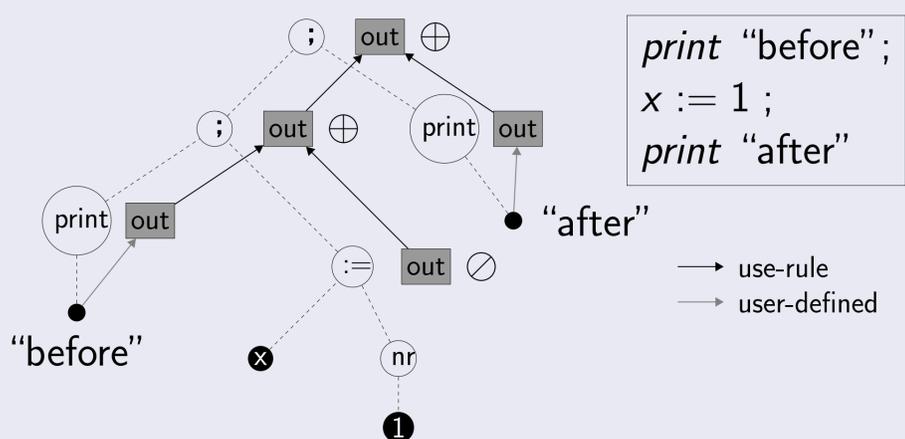
## Example of information flow between attributes



## Use-rule

- A programmer enables the use-rule for a synthesized attribute by specifying:
  - An empty value to be used by default ( $\emptyset$ ).
  - A binary operator for combining two values ( $\oplus$ ).
- The operator is used to combine any  $\#$  of children.
  - Defines a Monoid.

## Use-rule



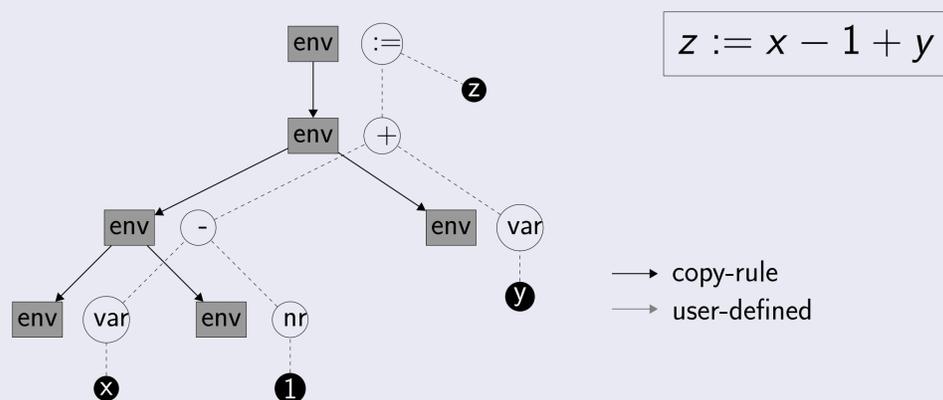
## Higher-order attributes

- Values of leafs and attributes can be trees themselves.
- The value of a *higher-order attribute* is extended with attributes and added as a subtree at runtime.
- The tree is evaluated as if part of the original input.
- The tree can contain a copy of its parent (looping).
  - Leads to possible non-termination.

## Utrecht University Attribute Grammar Compiler

- The UUAGC generates attribute evaluators for UUAG programs.
- Haskell is the UUAGC's main host language.
- UUAG extends Attribute Grammars with useful features for describing program language semantics.
- On this poster: copy-rules, the chain-rule, the use-rule and higher-order attributes.

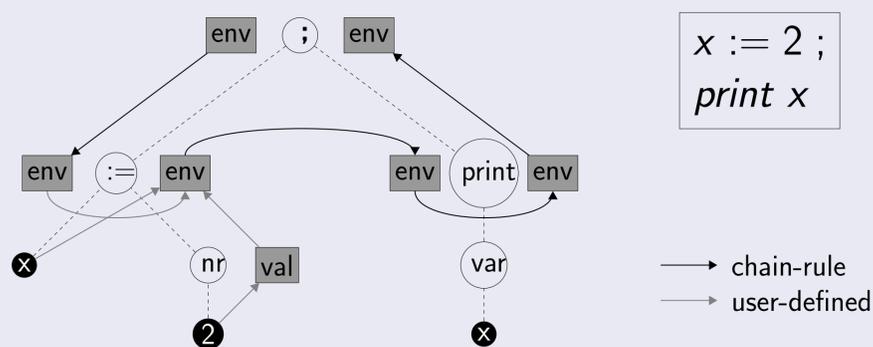
## Inherited copy-rule



## Copy-rules

- Inherited attributes are copied from parent to child.
  - Multiple copies are made in case of multiple children.
- Synthesized attributes are copied from child to parent.
  - The *use-rule* can be applied in case of multiple children.
- A *chained attribute* is both inherited and synthesized.
- Chained attributes are propagated by the *chain-rule*.
- Rules are only applied if a user-definition is missing.

## Chain-rule



## If-then-else using a higher-order attribute

