Compilers

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Objectives

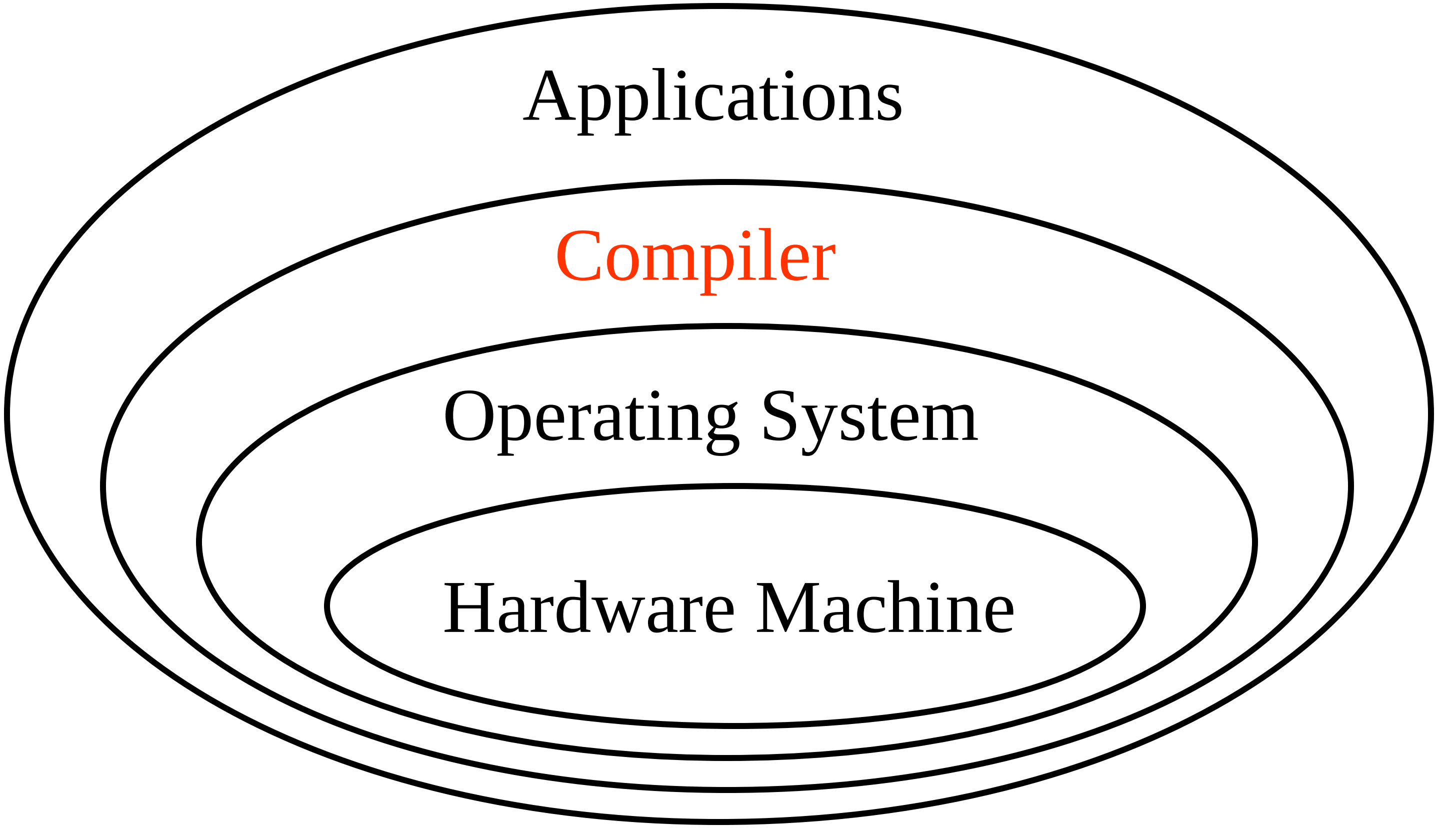
- ♠ Introduce principles and techniques for compiler construction
- ♠ Introduce principles and techniques for compiler-compiler construction
- ♠ Use a compiler-compiler to exercise the compiler construction for a small language

Introduction

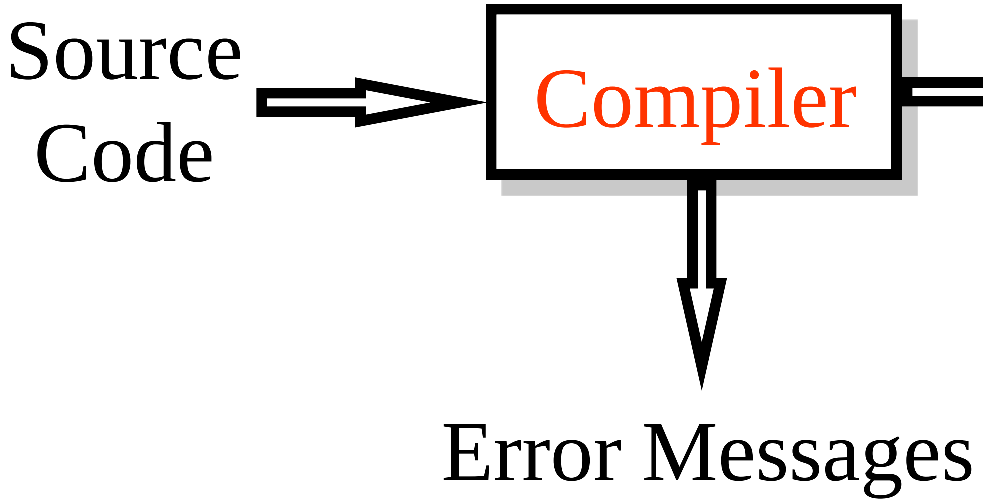
Programming Languages

- Human use *nature languages* to communicate with each other
  - *Chinese*, *English*, *French*
- Human use *programming languages* to communicate with computers
  - *Fortran*, *Pascal*, *C*

Computer Organization



Compiler



Components of a Compiler

- Analysis
  - *Lexical Analysis*
  - *Syntax Analysis*
  - *Semantic Analysis*
- Synthesis
  - *Intermediate Code Generation*
  - *Code Optimization*
  - *Code Generation*

Lexical Analysis

S o m e o n e   b r e a k s
t h e   i c e

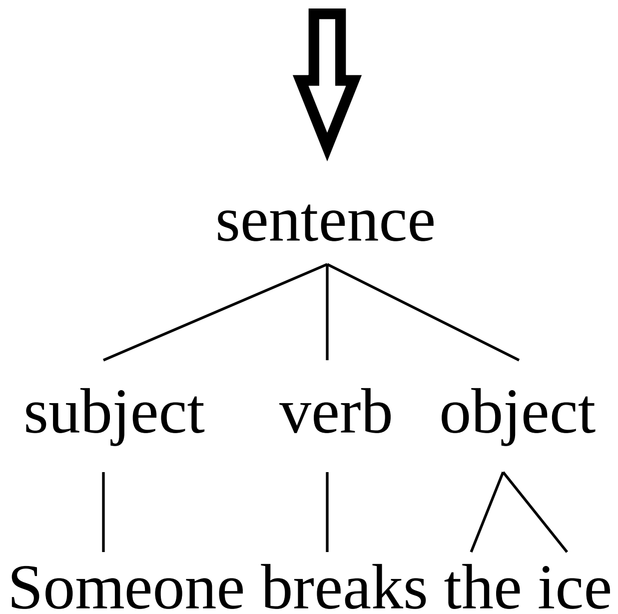
Someone breaks the ice

final := initial + rate * 60

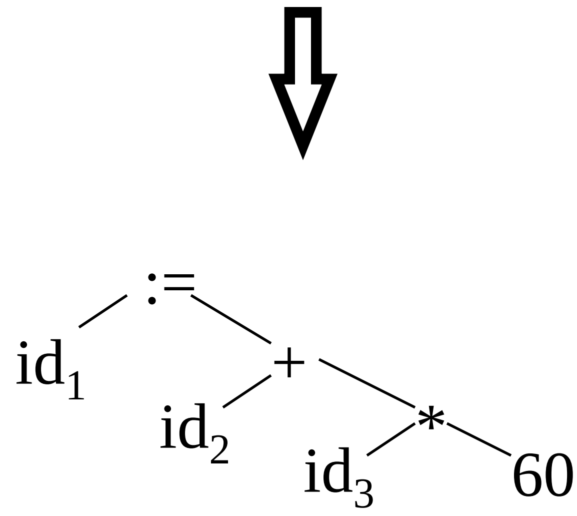
id_1 := id_2 + id_3 * 60

Syntax Analysis

Someone breaks the ice



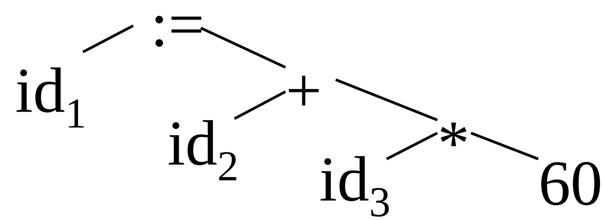
$id_1 := id_2 + id_3 * 60$



Semantic Anaysis

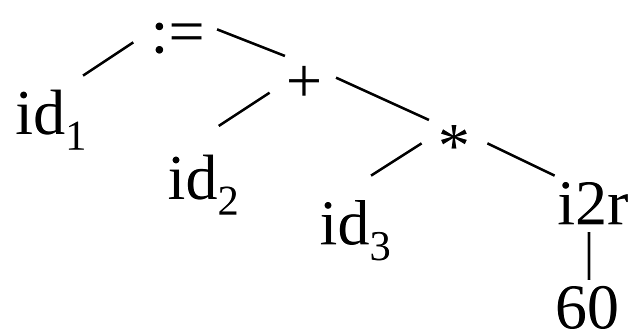
Someone plays the piano

(meaningful)

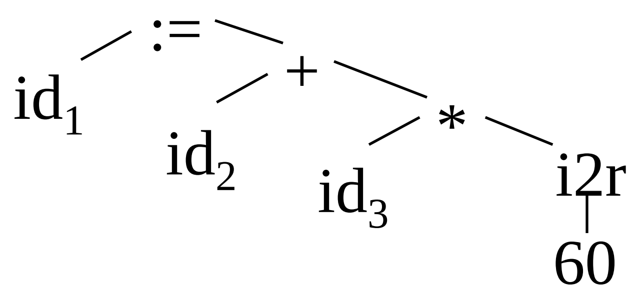


The piano plays someone

(meaningless)



Intermediate Code Generation



Someone breaks the ice

有人打破冰

temp1 := i2r (60)
temp2 := id_3 * temp1
temp3 := id_2 + temp2
id_1 := temp3

Code Optimization

有人打破冰

temp1 := i2r (60)
temp2 := id_3 * temp1
temp3 := id_2 + temp2
id_1 := temp3

⇓ ⇓

有人打破沉默

temp1 := id_3 * 60.0
id_1 := id_2 + temp1

Code Generation

有人打破沉默

$temp1 := id_3 * 60.0$
$id_1 := id_2 + temp1$

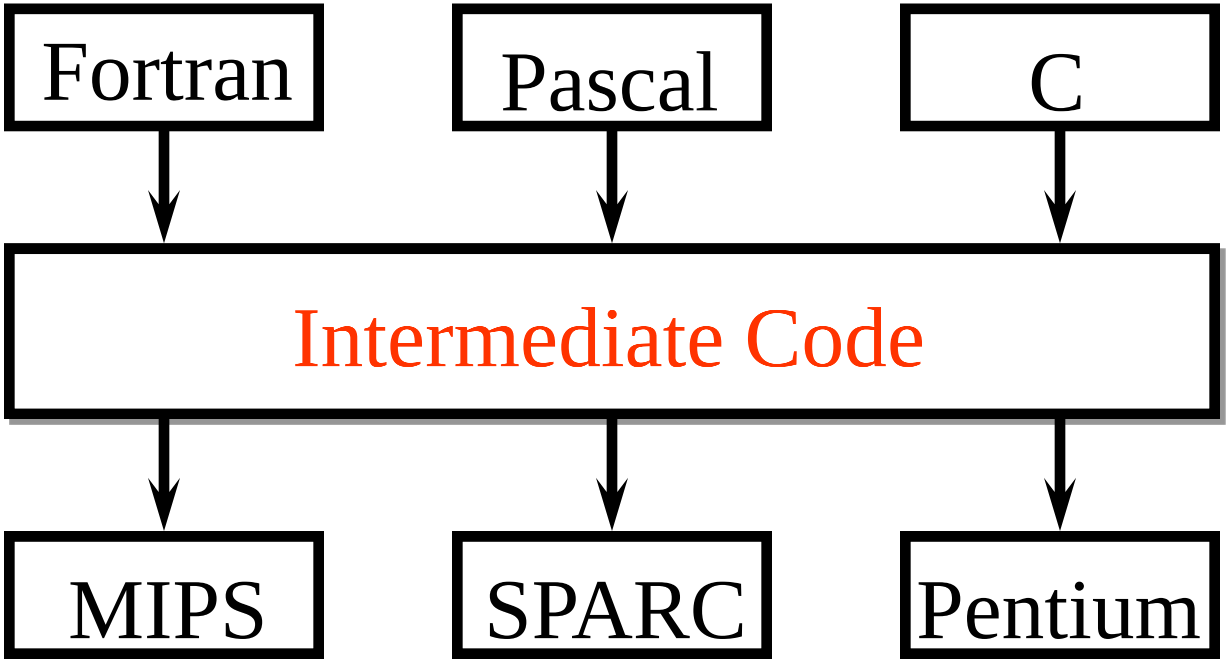
有人打破沉默

movf id_3, r2
mulf #60.0, r2
movf id_2, r1
addf r2, r1
movf r1, id_1

Structure of a Compiler

- Front End
  - *Lexical Analysis*
  - *Syntax Analysis*
  - *Semantic Analysis*
  - *Intermediate Code Generation*
- Back End
  - *Code Optimization*
  - *Code Generation*

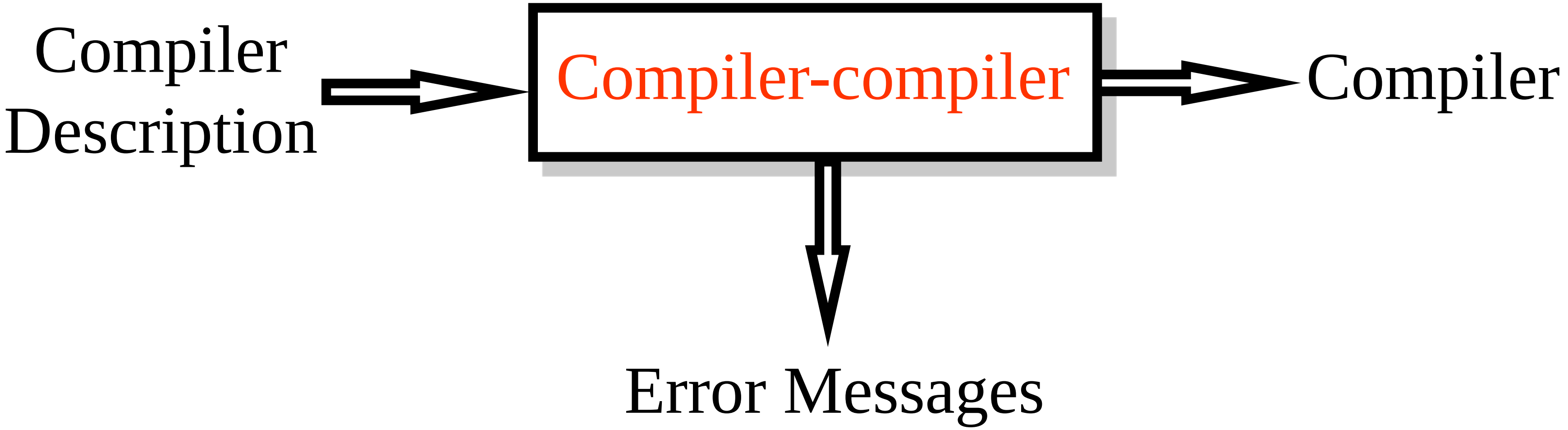
Reuse of Components



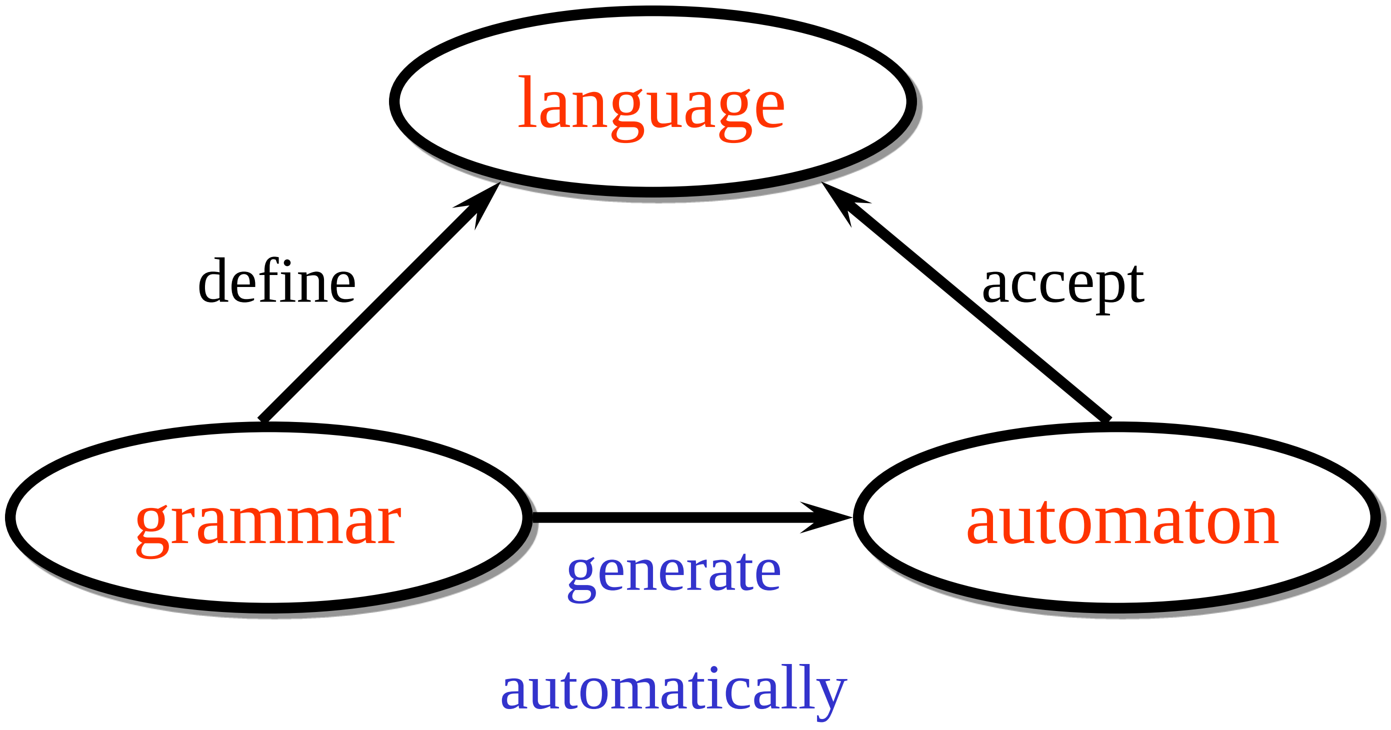
Applications

- ♠ Interpreters
- ♠ WWW Browsers
- ♠ Word Processors
- ♠ Computer-Aided Design
- ♠ Computer-Aided Manufacture

Compiler-Compiler



Formal Language Theory



Grammars

- The sentences in a language may be defined by a set of rules called a *grammar*

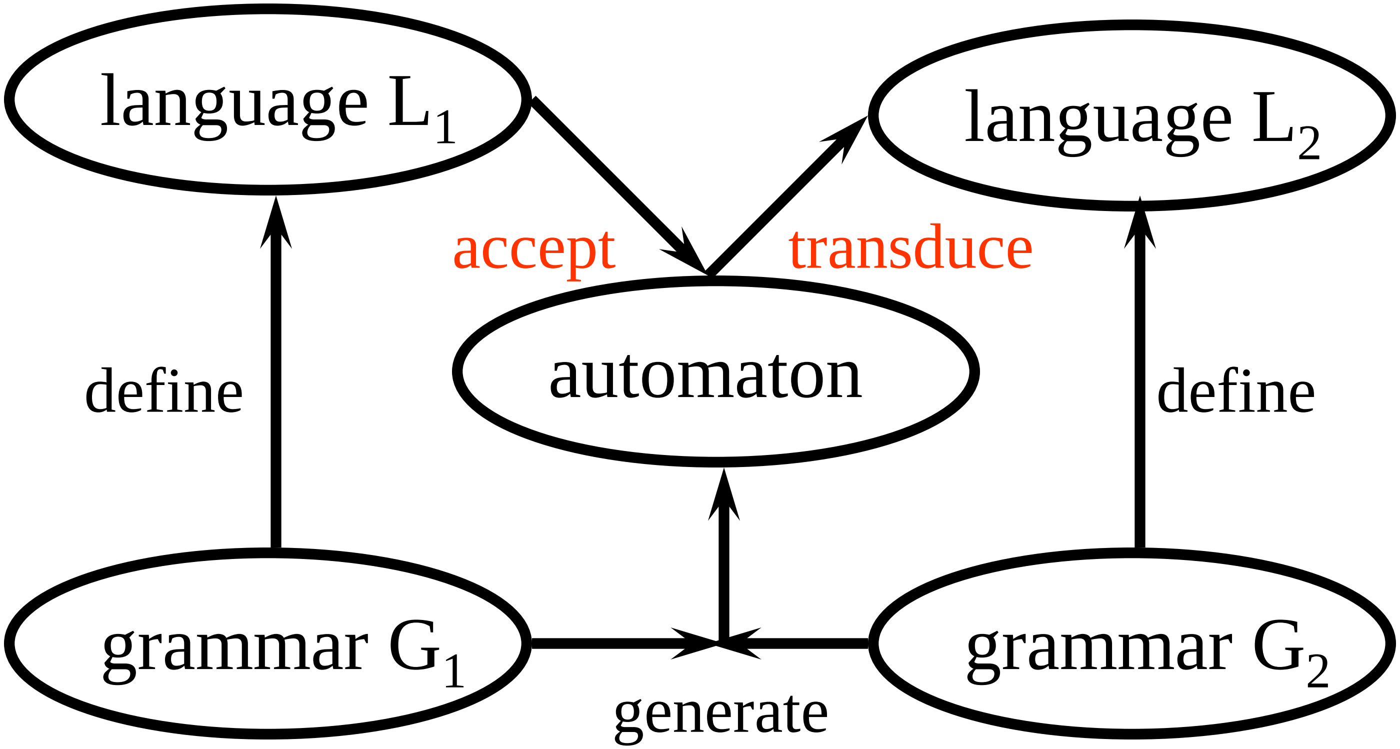
  L: {00, 01, 10, 11}

  G: the set of binary strings of length 2

Automata

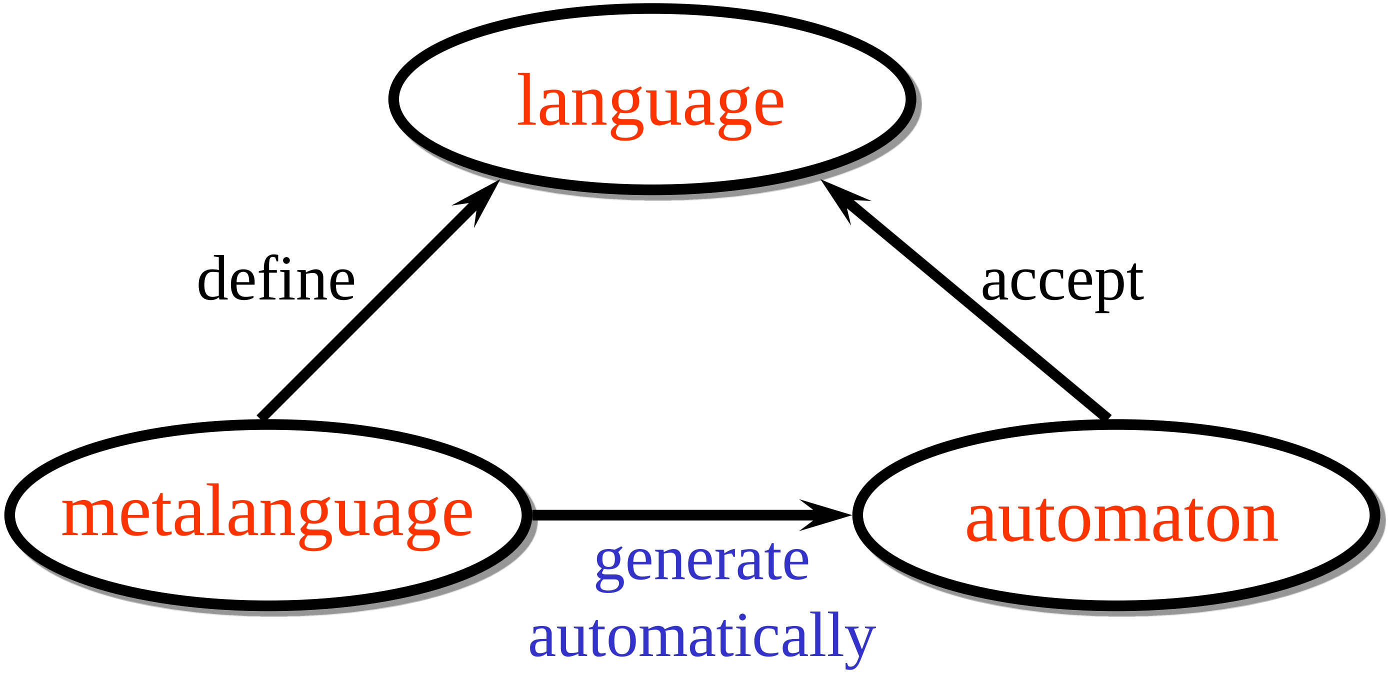
- An *acceptor* of a language is an automaton which determines if an input string is a sentence in the language
- A *transducer* of a language is an automaton which determines if an input string is a sentence in the language and may produce strings as output if it is in the language

Transducers



Metalanguage

- **Metalanguage**: a language used to define another language



Automatic Compiler Generation

- We will use different *metalangauges* to define the various components of a programming language so that these components can be generated *automatically*

Definition of Programming Languages

- *Lexical syntax*: regular expressions
- *Syntax*: context free grammars
- *Semantics*: attribute grammars
- *Intermediate code generation*:
  attribute grammars
- *Code generation*: tree grammars

Languages

- **Alphabet** - any finite set of symbols

  {0, 1}: *binary alphabet*

- **String** - a finite sequence of symbols from the alphabet

  1011: *a string of length 4*

  ε : *the empty string*

- **Language** - any set of strings on the alphabet

  {00, 01, 10, 11}: *the set of strings of length 2*

  ∅ : *the empty set*

Terms for Parts of a String

- *string*: banana
- *(proper) prefix*: ε, b, ba, ban, ..., banana
- *(proper) suffix*: ε, a, na, ana, ..., banana
- *(proper) substring*:

  ε, b, a, n, ba, an, na, ..., banana
- *subsequence*:

  ε, b, a, n, ba, bn, an, aa, na, nn, ..., banana
- *sentence*: a string in the language

Operations on Strings

- *concatenation*:

  x = dog

  y = house

  xy = doghouse

- *exponentiation*:

  $s^0 = \varepsilon$

  $s^1 = s$

  $s^2 = ss$

Operations on Languages

- *Union of* L *and* M, $L \cup M$

  $L \cup M = \{ s \mid s \in L \text{ or } s \in M \}$

- *Concatenation of* L *and* M, LM

  $LM = \{ st \mid s \in L \text{ and } t \in M \}$

- *Kleene closure of* L, L^*

  $L^* = \bigcup_{i=0}^{\infty} L^i$

- *Positive closure of* L, L^+

  $L^+ = \bigcup_{i=1}^{\infty} L^i$

Implementation of Programming Languages

- ♠ *Regular expressions*:

  finite automata, lexical analyzer

- ♠ *Context free grammars*:

  pushdown automata, parser

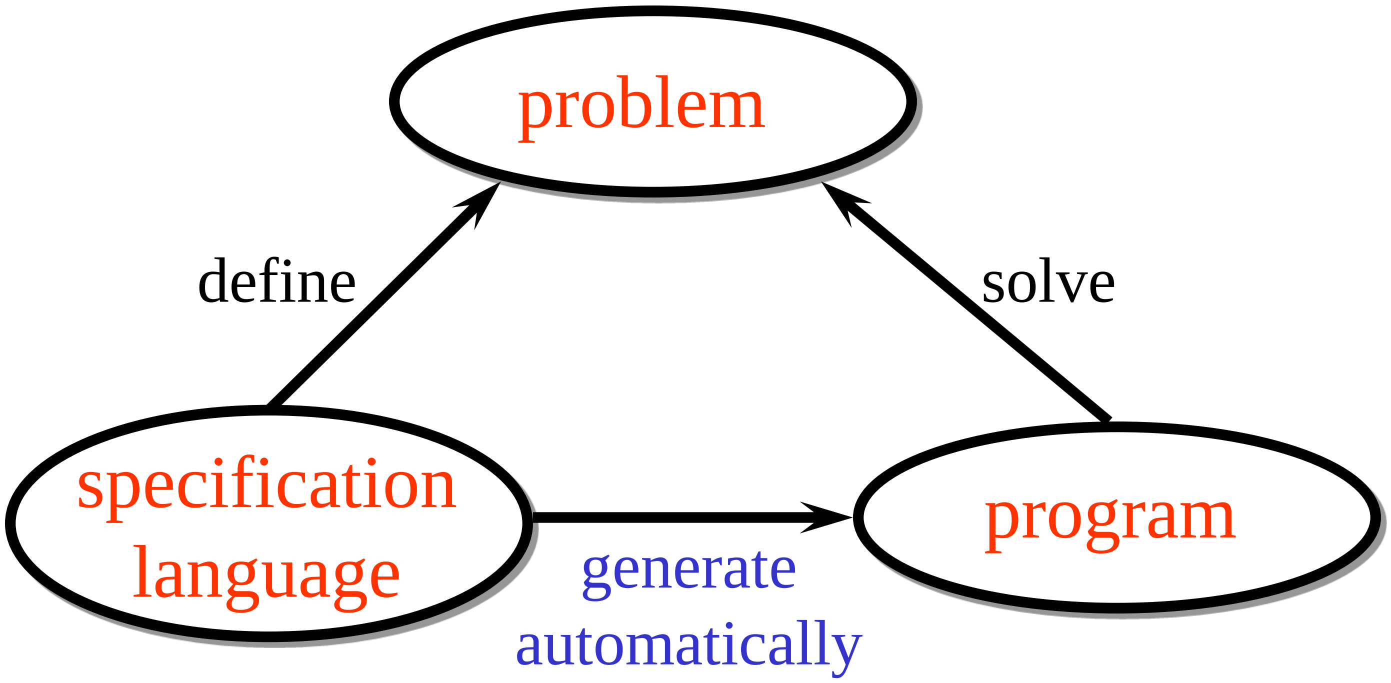
- ♠ *Attribute grammars*:

  attribute evaluators, type checker and intermediate code generator

- ♠ *Tree grammars*:

  finite tree automata, code generator

Automatic Program Generators



Content

- ♠ Lexical analysis
- ♠ Syntax analysis
- ♠ Semantic analysis
- ♠ Intermediate code generation
- ♠ Code generation

共勉

子曰：

「學而時習之，不亦說乎？」

-- 論語