Path Expressions

- a declarative specification of the synchronization desired among...
- a set of procedures that may be executed concurrently where...
- automatic enforcement of the synchronization is provided by automatically generated code that uses (an extended form of) semaphores.

With declarative approaches there is usually a tradeoff between the power of the expressions (i.e., the class of problems to which a solution can be expressed) and the feasibility of the expressions (i.e., the extent to which the expression can be translated into an (efficient) implementation).

General Scheme
General Form

The general form of a path expression is:

\[
\text{path } \langle \text{exp} \rangle, \langle \text{exp} \rangle, \ldots, \langle \text{exp} \rangle \text{ end}
\]

where \( \langle \text{exp} \rangle \) is an expression formed from the following operators:

- **sequencer:** \( x ; y \)
  - synchronizes the beginning of \( y \) with the completion of \( x \)
- **restrictor:** \( n : ( x ) \)
  - limits to \( n \) the number of concurrent invocations of \( x \)
- **derestrictor:** \( [ x ] \)
  - allows an unlimited number of concurrent invocations of \( x \)
- **grouping:** \( ( \ldots ) \)
  - to express precedence or nesting

Examples

- **sequencing**
  
  \[
  \text{path } \text{put; get end}
  \]
  The get procedure cannot begin its \( i \)th invocation until the put procedure has completed its \( i \)th invocation.
  
  No synchronization is implied about concurrent executions of put or concurrent executions of get.

- **restriction: mutual exclusion**
  
  \[
  \text{path } 1 : ( \text{write} ) \text{ end}
  \]
  only 1 procedure at a time can execute the procedure write.

- **restriction: mutual exclusive choice**
  
  \[
  \text{path } 1 : ( \text{write, read} ) \text{ end}
  \]
  the procedures write and read cannot both be executing concurrently
Examples

• restriction: limited concurrency

  path 10: ( read ) end

  up to 10 invocations of the read procedure can be in progress concurrently

• simple readers-writers

  path 1: ( write ), [ read ] end

  Either exactly one write procedure is executed or an unbounded number of concurrent executions of read

Examples

• The producer-consumer problem for a buffer of size n has three constraints that can be stated in a single path expression:

  mutual exclusion
  of put and get

  path 1: ( put, get ), n: ( put ; get ) end

  buffer
  overflow

  buffer
  underflow
Translating Path Expressions

\[ \text{path 1: ( put , get ) , n: ( put ; get ) end} \]

1: ( put , get )

\[ \text{P(S1) put , get V(S1)} \]

\[ \text{P(S1) put V(S1)} \]
\[ \text{P(S1) get V(S1)} \]

n: ( put ; get )

\[ \text{P(S2) put ; get V(S2)} \]

\[ \text{P(S2) put V(S3)} \]
\[ \text{P(S3) get V(S2)} \]

\[ \text{P(S2) P(S1) put V(S3) V(S1)} \]
\[ \text{P(S3) P(S1) get V(S2) V(S1)} \]

semaphore S1 initially 1;
semaphore S2 initially n;
semaphore S3 initially 0;