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Concurrent Relational Programming

The Sequential (--) and Parallel (||) Combinators

```
relation CommonRel(attr) <- {(0)};
update CommonRel change attr <- attr +1 ||
update CommonRel change attr <- attr -1;
```

This executes the two statements in any order ("parallel"), and leaves *CommonRel* unchanged because the operations cancel.

```
relation CommonRel(attr) <- {(0)};
( LocalRel1 <- CommonRel --
  update LocalRel1 change attr<- attr+1 --
  CommonRel <- LocalRel1
) ||
( LocalRel2 <- CommonRel --
  update LocalRel2 change attr<- attr-1 --
  CommonRel <- LocalRel2
);
```

This has 20 possible interleavings. Two give the right result, 0; 9 give -1; and 9 give 1.

Synchronization

Synchronization is by a blocking T-selector:

if the result of an ordinary T-selector would be empty, the process blocks until the operand is changed to make the result not empty.

The **where** is replaced by **when**.

Synchronization

This idea from *Linda*
(Carreiro & Gelernter, CACM 32 (1989) 444):

out(`"a string", 15.01, 17, "another string"`)
... puts a "tuple" into "tuple space".

rd(`"a string", ? f, ? i, "another string"`)
... reads it, assigning values to the variables;
blocks if no corresponding tuple;
nondeterministically returns one, if many tuples.

in(`"a string", ? f, ? i, "another string"`)
... like **rd** but *consumes* the tuple.

Synchronization

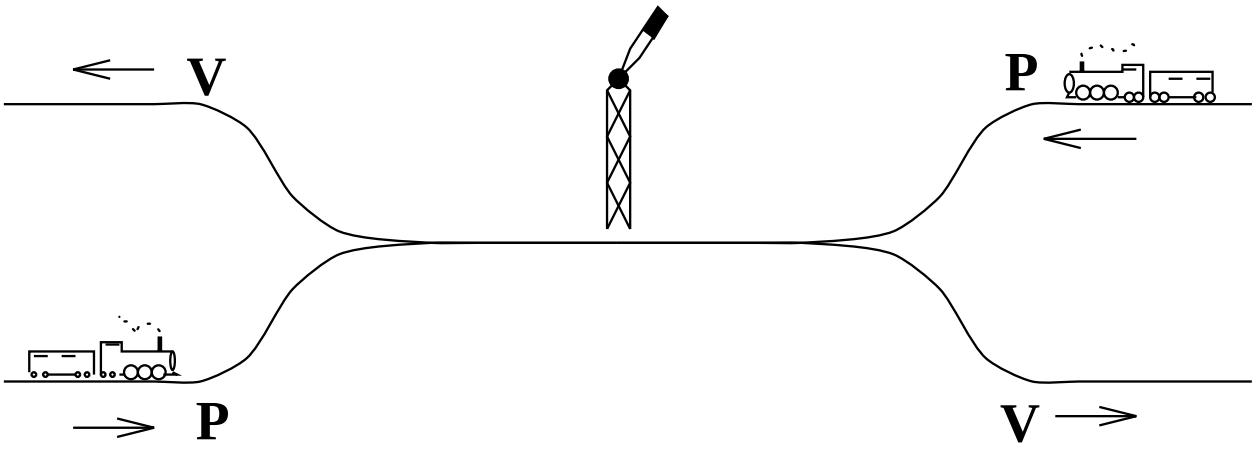
relation *tSpace*(*S1, N1, N2, S2*) <−
{("a string", 15.01, 17, "another string")};
synch <− **when** *S1*="a string"
and *S1*="another string" **in** *tSpace*;

N.B. Does not consume; reads all.
(*Nondeterminism* is from another operator, another syntax, **pick**).

Semaphores (Dijkstra, CACM 11 (1968) 341)

P(s) "proberen" if s.cnt=0 then WAIT
dec(s.cnt)

V(s) "vrijgeven" inc(s.cnt)
waken waiters



Semaphores

Here is a semaphore,

```
relation SEMAPHORE(Sem_name, Sem_count);
proc I(sema) is { SEMAPHORE <+ sema; };
proc P(sema) is
{ S <- when Sem_count > 0 in
      (SEMAPHORE ijoin [Sem_name] in sema);
  update SEMAPHORE change Sem_count <-
    Sem_count - 1 using ([Sem_name] in sema);
};
proc V(sema) is
{ update SEMAPHORE change Sem_count <-
  Sem_count + 1 using ([Sem_name] in sema);
};
```

Semaphores

and here we use it as a *mutex*.

```
relation Sem1(Sem_name, Sem_count)<−
    {("sem1", 1)};
I(in Sem1);
relation CommonRel(attr) <− {(0)};
( P(in Sem1) --
  LocalRel1 <− CommonRel --
  update LocalRel1 change attr<− attr+1 --
  CommonRel <− LocalRel1 --
  V(in Sem1)
) ||
( P(in Sem1) --
  LocalRel2 <− CommonRel --
  update LocalRel2 change attr<− attr−1 --
  CommonRel <− LocalRel2 --
  V(in Sem1)
);
```

A Brief History of Concurrency Mechanisms

Coroutines	Conway, 1963
SIMULA 67	
Semaphores	Dijkstra, 1968
"THE" multiprogramming system	
(Conditional) Critical Region	Brinch Hansen, 1972
(replaced by Monitors)	Hoare, 1972
Monitors	Brinch Hansen, 1973
	Hoare, 1974
Guarded Commands	Dijkstra, 1975
Path Expressions	Campbell
(limited, but cf. ALGOL 68)	& Haberman, 1974
CSP (Communicating Sequential	
Processes	Hoare, 1978, 1985
DP (Distributed Processes)	Brinch Hansen, 1978