Parallel Computing  
CM30225

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### 1. Topics: Linda

Linda: an adaption of the thread pool/worker idea

Like these, it is task based, with threads choosing tasks and executing them

However, now, the tasks have extra structure to guide the choice

And the view of the system is flipped from thinking of it as a thread pool to thinking of it as a task pool

### 2. Linda

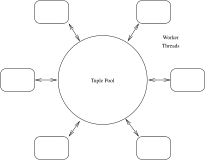
The world is based around *tuples*: these are simple (short) ordered sequences of values

E.g., [1, "hello"] and [2, "goodbye"]

And there is a global pool or *tuplespace* containing these tuples

Threads communicate via the pool by putting tuples in and taking tuples out

### 3. Linda



Linda pool

All communications via the pool

### 4. Linda

There are four operations the threads can execute:

* out send a tuple to the pool
* in get and remove a tuple from the pool
* read get but don’t remove a tuple from the pool
* eval create a new thread

### 5. Linda

The important bit is how in and read work

The arguments to these are either (a) a literal constant (e.g., string, integer) or (b) a pattern variable, e.g., ?s, or something suitable for the language you are using

A matching tuple is returned from the pool where a match is defined by

* the tuple is the same length and
* the contant literals match

Then the pattern variables are set to the corresponding values in the chosen tuple

### 6. Linda

For example, if the pool contains

[1, "hello"], [2, "goodbye"], [1, "world"]

then there are two matches for [1, ?s], namely [1, "hello"] and [1, "world"]

One of these will be chosen, *non-deterministically*

If the former is chosen, then the variable s will be given the value "hello"

### 7. Linda

Note that the matching and choosing done by the pool: a possible bottleneck if the implementation of the Linda library is not careful

Of course, the pool might itself be a multithreaded system

If no matching tuple exists, the call will block until one arrives

If more than one thread simultaneously matches a tuple using in, exactly one will get the tuple

The action of match and removal for an in is atomic

### 8. Linda

If both threads use read, there is no problem, they both get a copy

If one uses an in and the other a read, it can go either way:

* read before in: they both get the tuple
* in before read: the in gets the tuple, the read doesn’t

This non-deterministic outcome would normally be considered a programmer error

### 9. Linda

These subtleties mean you must be quite careful with Linda

A common paradigm is to use an initial *tag*, often an integer, as in [1, "hello"], to impose some structure on the tuples

### 10. Linda

Dining Philosophers in Linda

We have five philosophers and shall prevent deadlock by only letting four sit at a time

Initial conditions:  
out("place ticket") four times;  
out("chopstick", i) for   
eval(phil, i) for

### 11. Linda

defun phil(i) {  
 while true {  
 think()  
 in("place ticket")  
 in("chopstick", i)  
 in("chopstick", i+1 mod 5)  
 eat()  
 out("chopstick", i)  
 out("chopstick", i+1 mod 5)  
 out("place ticket")  
 }  
}

This example contains no patterns, only constant literals

Note Linda does not eliminate the possibility of deadlock in badly written programs: just put the (in "place ticket") after the in of the chopsticks

### 12. Linda

Producers/Consumers is just as easy

defun producer(n) {  
 out(n, make-product())  
 producer(n + 1)  
}  
defun consumer(n) {  
 var prod  
 in(n, (? prod)) ; pattern  
 consume-product(prod)  
 consumer(n + 1)  
}

We use a tag to ensure we consume values in the same order as they are produced (if that is important)

### 13. Linda

**Exercise** Think about the assessed coursework using Linda

Questions of granularity are just as important in Linda as elsewhere

### 14. Linda

Linda is easy to add to existing languages, usually as a library, occasionally with a minor tweak to the syntax for the patterns

Versions exist for C, Perl, Java and Prolog and others

### 15. Linda

Also

* the blocking semantics lead to unwanted non-determinism: see the in vying against the read above
* some implementations have non-blocking variants of in and read, but this just adds to the uncertainty
* the low-level, unstructured nature of Linda can lead to awkward code: every application needs some mechanism to structure the tuples (tags being the simplest)
* there is no fairness on selecting tuples: a tuple can be ignored indefinitely if there are others that can be chosen
* junk can collect in the pool: tuples put in but never taken out. This can slow down the matching
* the pool can be a bottleneck

### 16. Linda

Further

* detecting when the program needs to terminate is a problem: this could be done by putting a special “end of program” tuple in the pool; but then threads have the overhead of constantly checking for that tuple (and you need an non-blocking read to do so). Or have an extra field in every tuple that is a status flag, etc.
* *aliasing* is a problem: careful constructions of name schemes (tags, usually) are needed to ensure that tuples are not accidentally picked up by the wrong threads
* related is *temporal aliasing*, where information about the order tuples were put into the pool is lost: again an enumeration tag can fix this, but it has to be coded

### 17. Linda

So extensions of Linda exist, e.g., using multiple pools to structure, thus avoiding the first kind of aliasing

Now pools become first-class objects, and you can pass pools via pools to other threads

But, as always, this moves away from the initial simplicity of the Linda concept

### 18. Linda

Linda

* is a simple abstract model of parallelism
* can map reasonably well to different kinds of hardware (shared and distributed)
* is explicitly non-deterministic, with the non-determinism mostly well delineated
* is not suited for all kinds of problem
* is not widely used, but you do see Linda being mentioned now and again, mostly for coordination between other systems

### 19. Linda

For example, the computational chemistry (molecule simulation) package Gaussian uses OpenMP on a node and uses Linda between nodes