Shareable Data Structures

MALCOLM CROWE

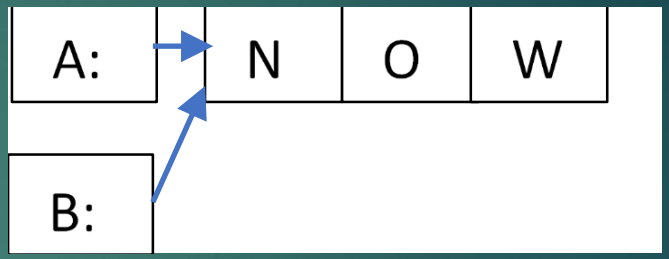
OCTOBER 2018

Shareable data structures

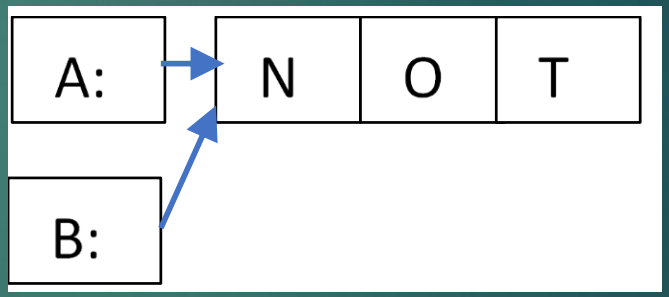
- Data Structures are in all Computing courses
  - Revisited when student has reached Threading
- Threading examples show need for locking
  - Students learn this is why strings are immutable
    - At least in C# and Java – "value semantics"
- But why do we use unsafe data structures?
  - In this course we focus on SAFE data structures
  - For sharing and copying between threads
- The reduces the need for complex locking

What is unsafe?

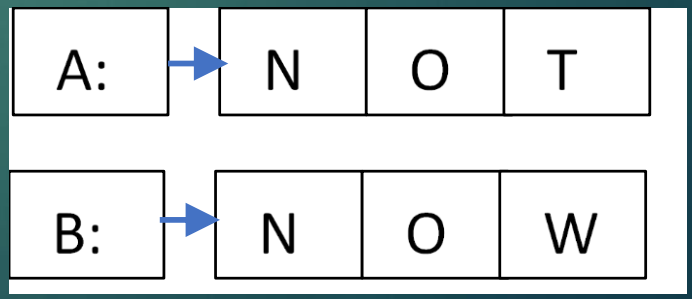
- Example: Arrays A and B – in Java (say)
- After B=A we have



- Then A[2]='T' gives
- (correct, maybe?)



- A safe array would give
- A=A.Set(2,'T')
- Change is just to A



We learn about cloning?

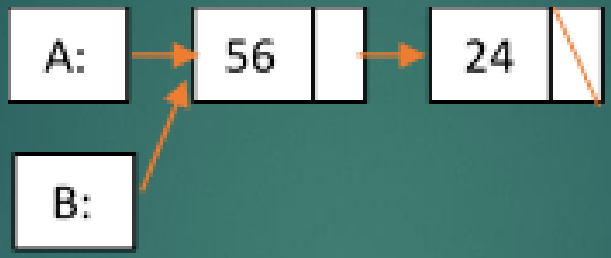
- A concept often not grasped by students
- When a list is passed "by value" to a proc
- There is nothing to stop the proc changing it
- With value semantics this shouldn't occur
- So maybe we need to stop using lists!
- Immutable strings are still useful, so
  - Our data structures have immutable contents
- We will still need locking for mutable things
  - We keep it to a minimum to simplify our design

In database technology

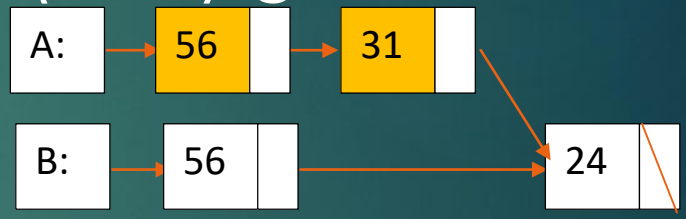
- Once we have enough structures
  - We show how a full DBMS can be built
- Taking a snapshot is as easy as B=A above
  - People with copies can consider changes
  - On ROLLBACK they can simply be forgotten
    - For B=A example, simply restore by A=B
  - On COMMIT we need to check for conflicts
    - And the DBMS can accept the changes in master copy
- The list of master copies of databases in use
  - Will be the DBMS' only unsafe data structure!

Example: a safe linked list

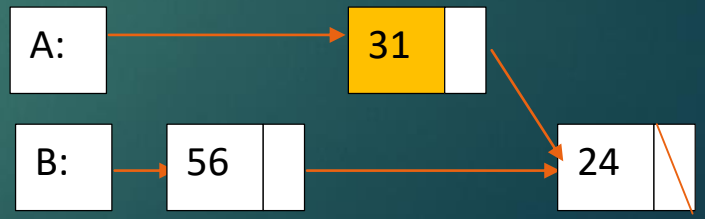
- After B=A suppose we have linked list (56,24)



- For a safe list, A=A.InsertAt(1,31) gives:
- Coloured nodes are new



- Then A=A.RemoveAt(0):
- Note B still has the old list



Implementation in Java

- Shareable data structures have all fields `public final`
- So a safe linked list of integers might be:

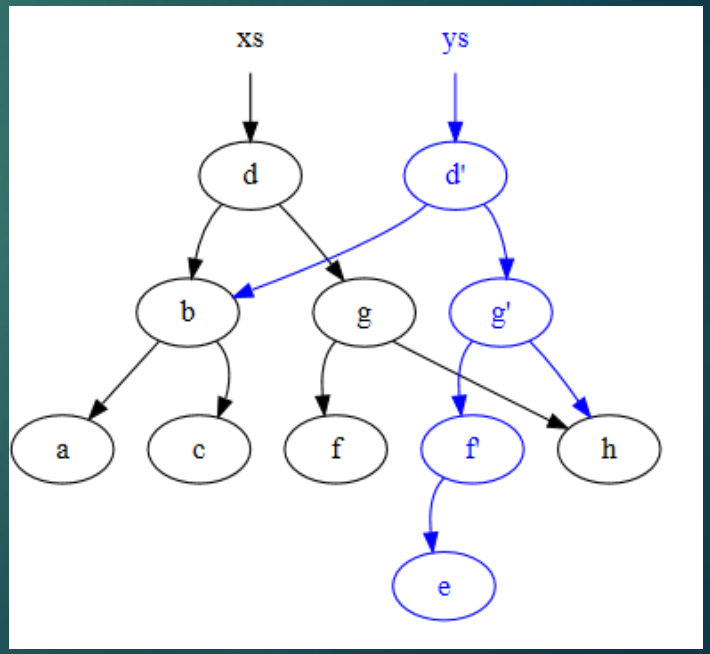
```
public class SListOfInt {
   public final int element;
   public final SListOfInt next;
//.. And we need at least one constructor
//    and the methods InsertAt, RemoveAt
}
```

Memory blocks are shared

- Thinking about the shareable linked-list
- The versions share nodes after the change
- Similarly for a shareable tree structure
  - For each change the new nodes are a path
  - From the root to the nodes that were changed
- More complex data structures are better
  - Even more efficient since more is shared
- Contrast with mutable structures
  - Where the whole thing needs to be cloned

How new is this?

- "Persistent Data Structures"
  - "Fully Functional" [Okasaki]
  - "Multi-version", "Concurrent" etc
- These have a similar idea, but a fatal flaw
- A mutable root node
- The Wikipedia article has:
  - But this misses the point



Is it faster?

- The memory allocator works harder
- But we avoid recursive copying
  - Top parts of structures are cheapest to change
  - Cheapest of all are stacks
- Structures such as queues are expensive
  - Since we always add at the end
- But I find that queue helpers in algorithms
  - Can be replaced with recursive calling
- This would be something worth analysing

Towards Strong DBMS

- Too much locking is a real pain
- DBMS (say they) use locking all the time
  - Deadlocks are a plague and very hard to avoid
  - Normally detected by inactivity!
- Pyrrho DBMS uses optimistic execution
  - Locks and checks everything only during commit
  - Uses shareable data structures for trees, rows
- The Strong DBMS will use them for most things
  - Especially the database and transaction objects

Strong DBMS so far

- Every change changes at two levels:
  - The in-memory versions of the indexes (etc)
  - The list of transaction steps
- To have a single pointer to this state
  - Modified objects must be within the transaction
- It is a bit confusing to program
  - A C# constructor for each kind of change
- Always get from one consistent state to next