CS11 – Introduction to C++

Winter 2011-2012

Lecture 5

Today's Topics

- Lab 4b: Sparse-vector arithmetic
- **`gdb`** – the GNU Debugger

This Week's Homework

- Complete the **`SparseVector`** functionality
- Equality/inequality operations
  - Should be straightforward
- Vector addition/subtraction
  - Should be… *possible?!*

Comparing Linked Lists

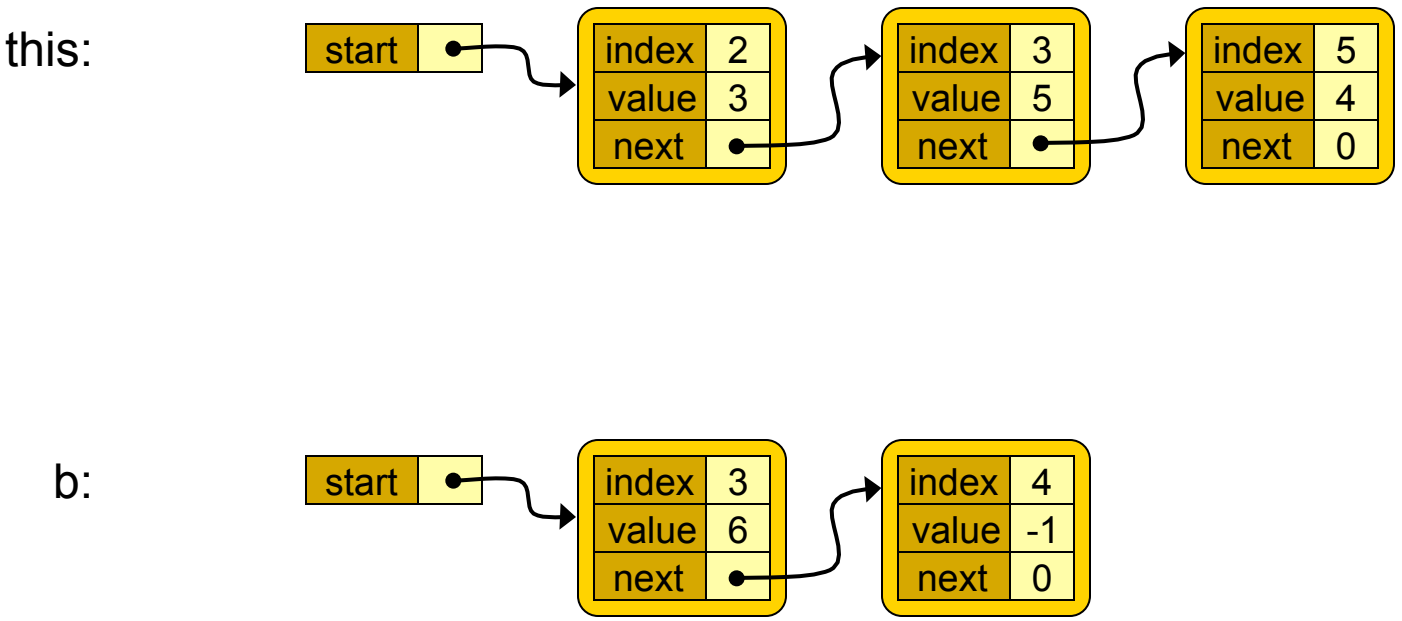
- Similar pattern to before
  - Must iterate over both lists at same time
  - The lists are the same if all nodes are the same
- Two main criteria:
  - If two nodes being compared have different indexes, or different values, the lists are different.
  - If one list ends before the other, the lists are different.

Efficient Addition and Subtraction (Sparse Vector Style)

- Sparse vectors can be added and subtracted
  - Implementation should be efficient
  - Time proportional to number of non-zero values
- Concept:
  - Implement as `a += b` (only one vector changes)
  - Traverse both vectors' node-lists simultaneously, calculating the result as you go
  - Only works if the lists are ordered by index!
  - This approach is *mostly* straightforward
    - There are other approaches, but all similar complexity

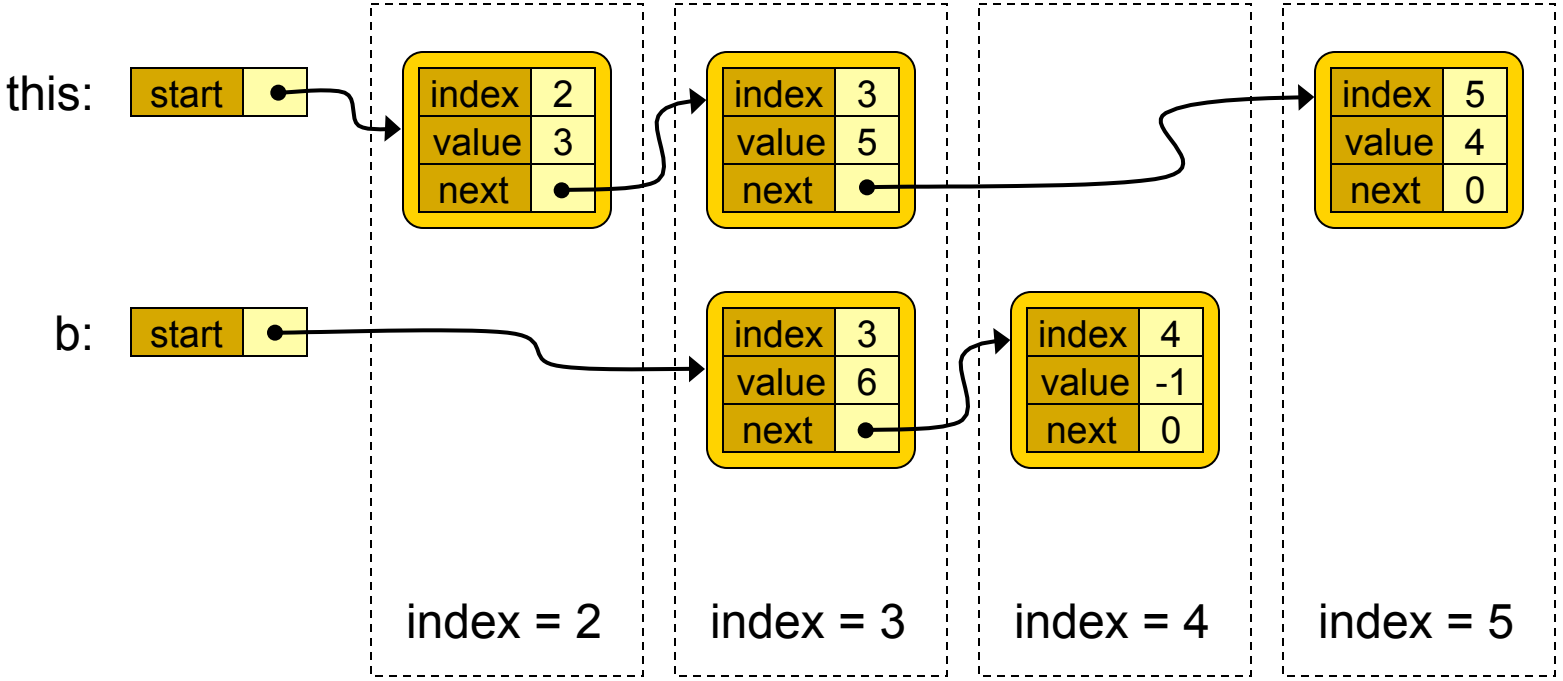
Efficient Adding

- Add these two vectors together



Efficient Adding (2)

- Each loop iteration handles the next index-value separately



Vector Arithmetic

- Traverse both vectors in a single loop

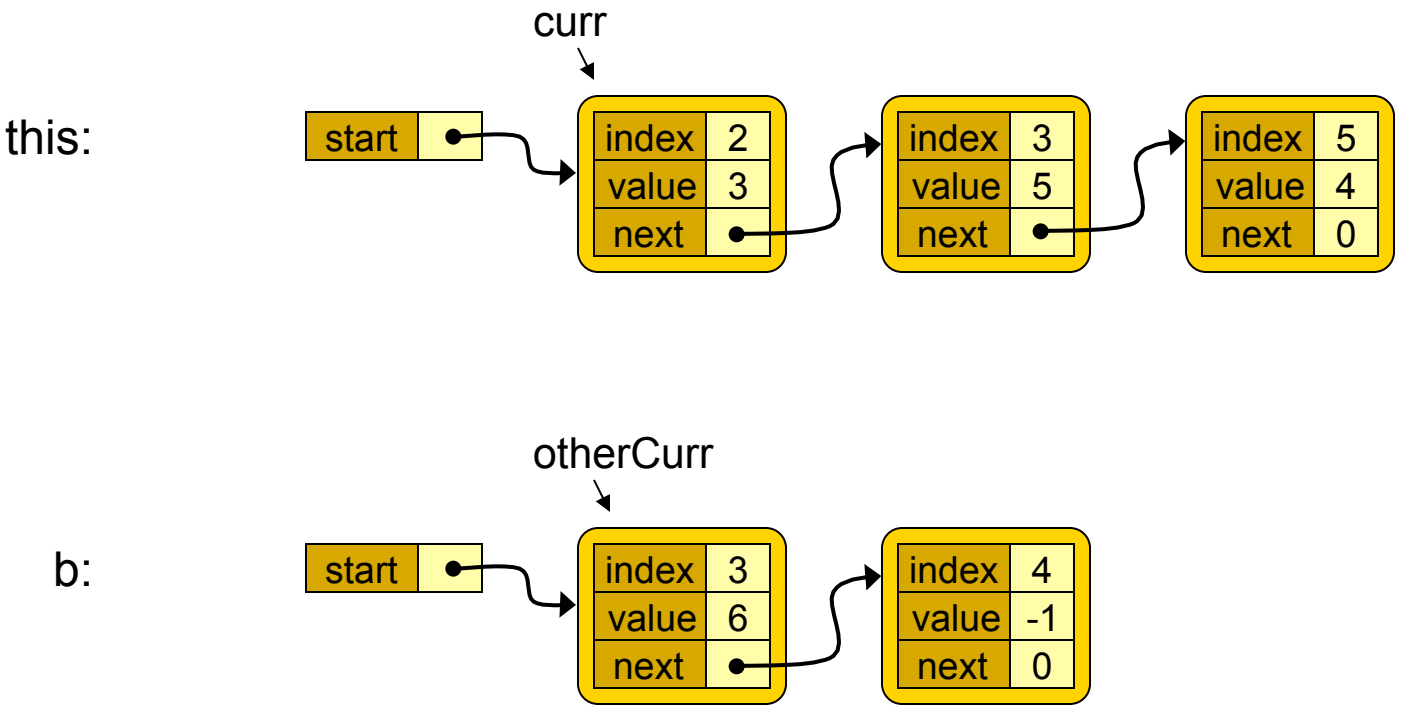
```
node *curr = start;
node *otherCurr = other.start;

while (curr != 0 && otherCurr != 0) {
  ...
}
...
```

- For each loop iteration:
  - Perform addition/subtraction of element at index *i*
    - *i* = min(**`curr->index`** , **`otherCurr->index`**)

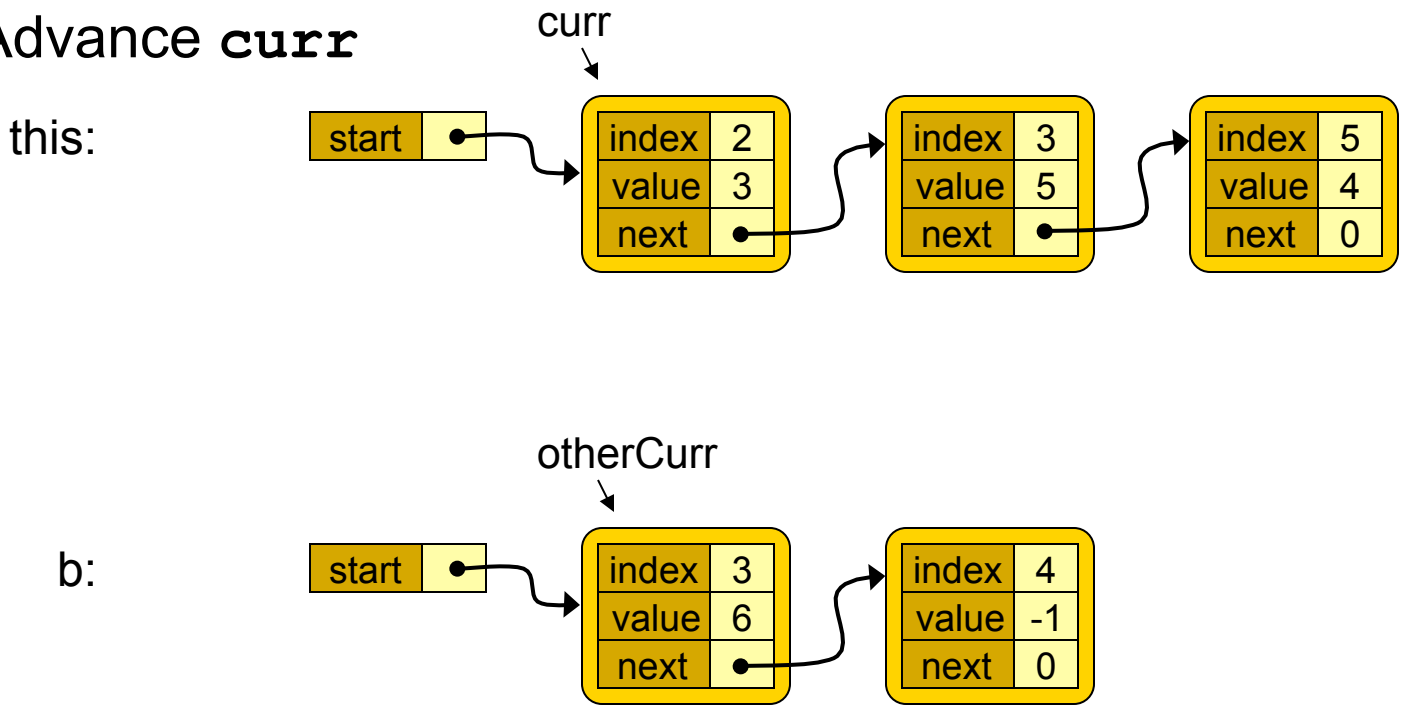
Efficient Adding (3)

- Start iterating over the list.



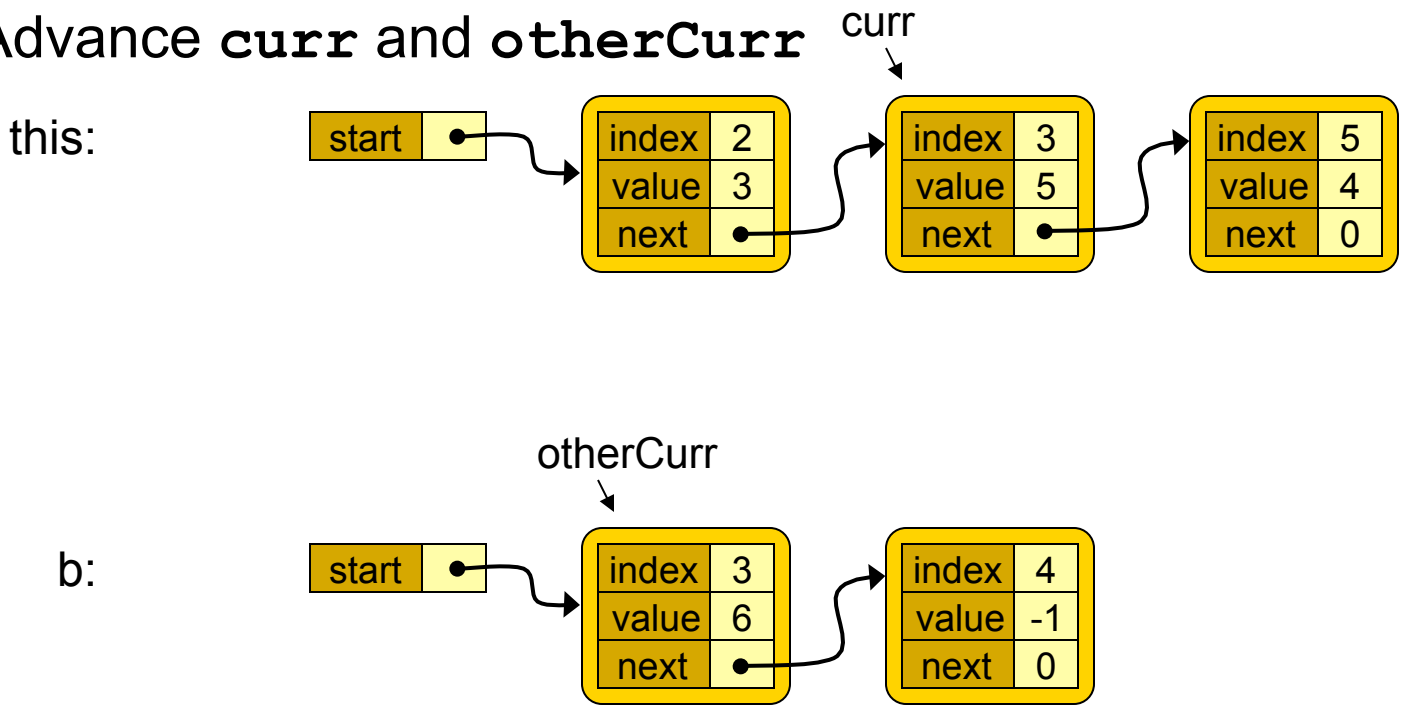
Efficient Adding (4)

- **`b`** doesn't have a value for index 2, so it's 0.
  - 3 + 0 = 3
  - Advance **`curr`**



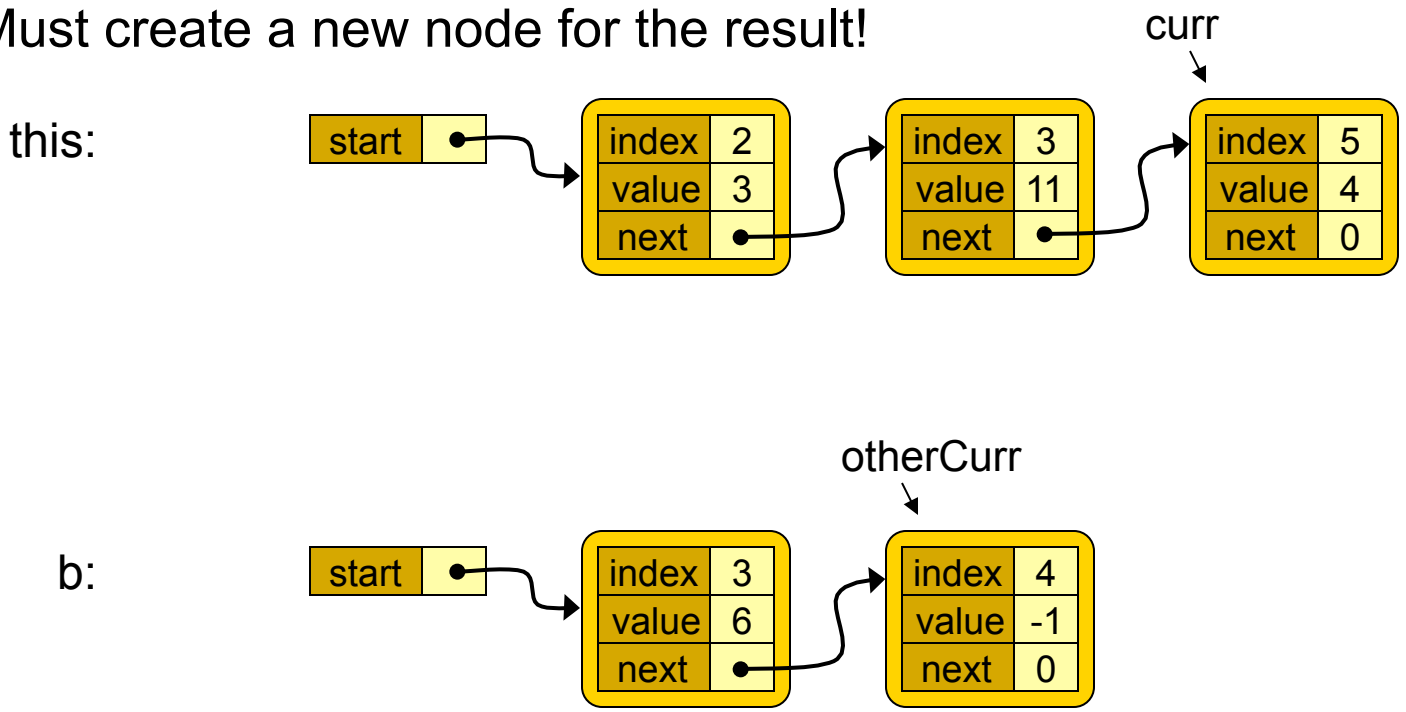
Efficient Adding (5)

- Both vectors have a value for index 3.
  - 5 + 6 = 11
  - Advance **`curr`** and **`otherCurr`**



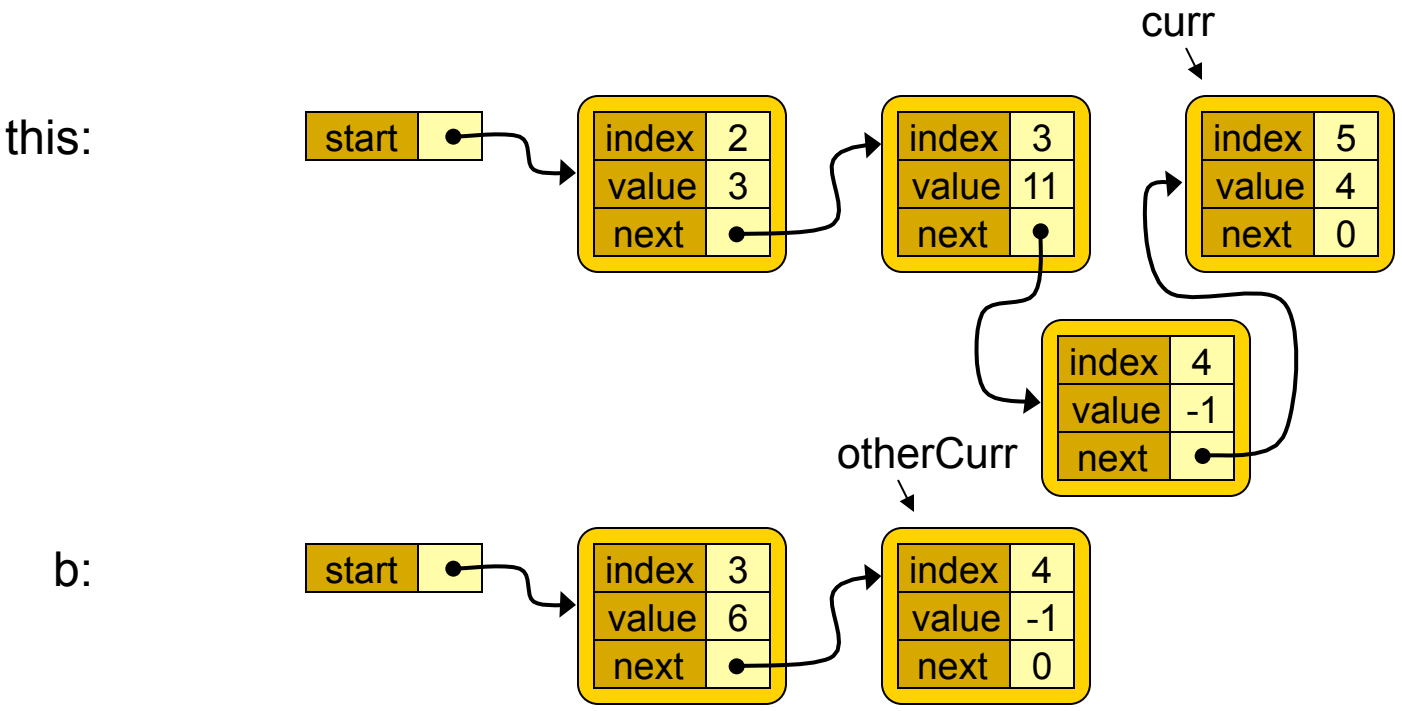
Efficient Adding (6)

- Only `b` has a value for index 4.
  - 0 + (-1) = -1
  - Must create a new node for the result!



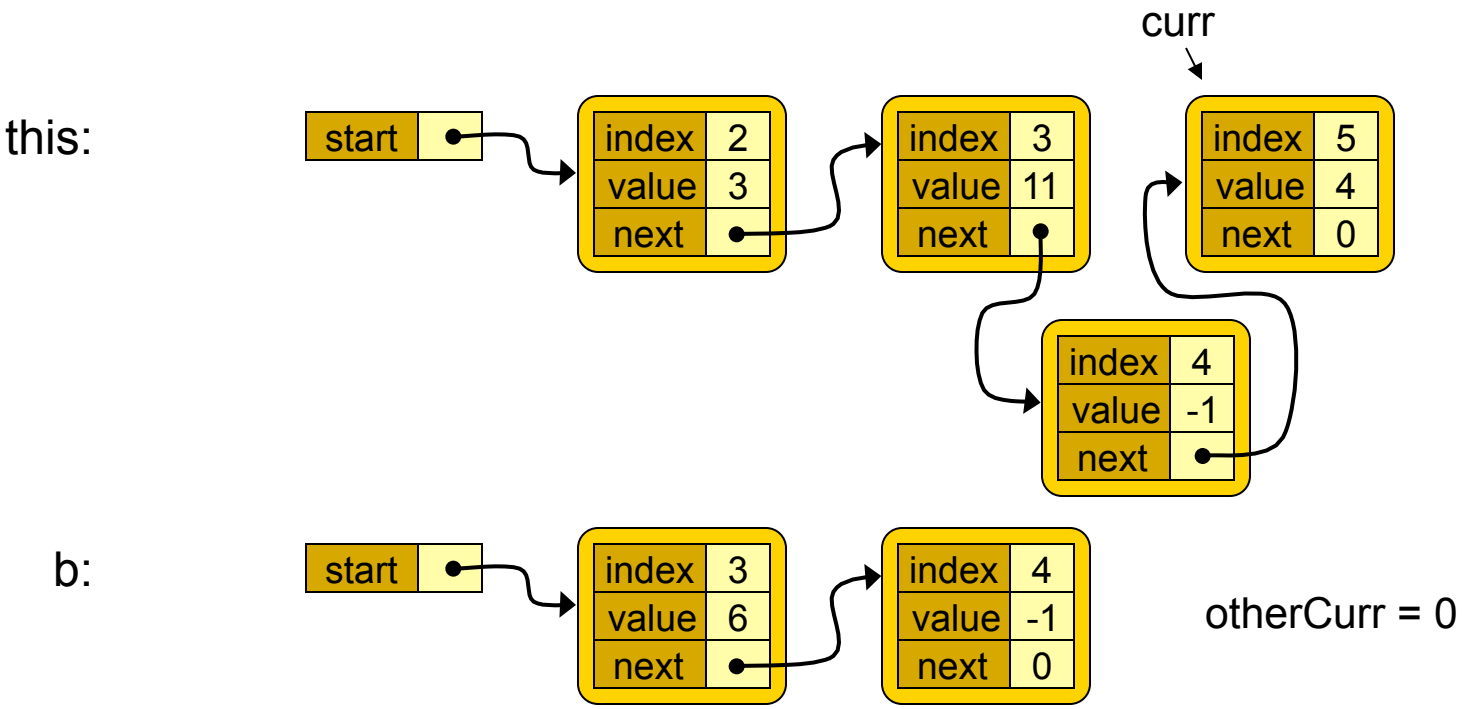
Efficient Adding (7)

- New node is *before* **`curr`**
- Now increment **`otherCurr`**



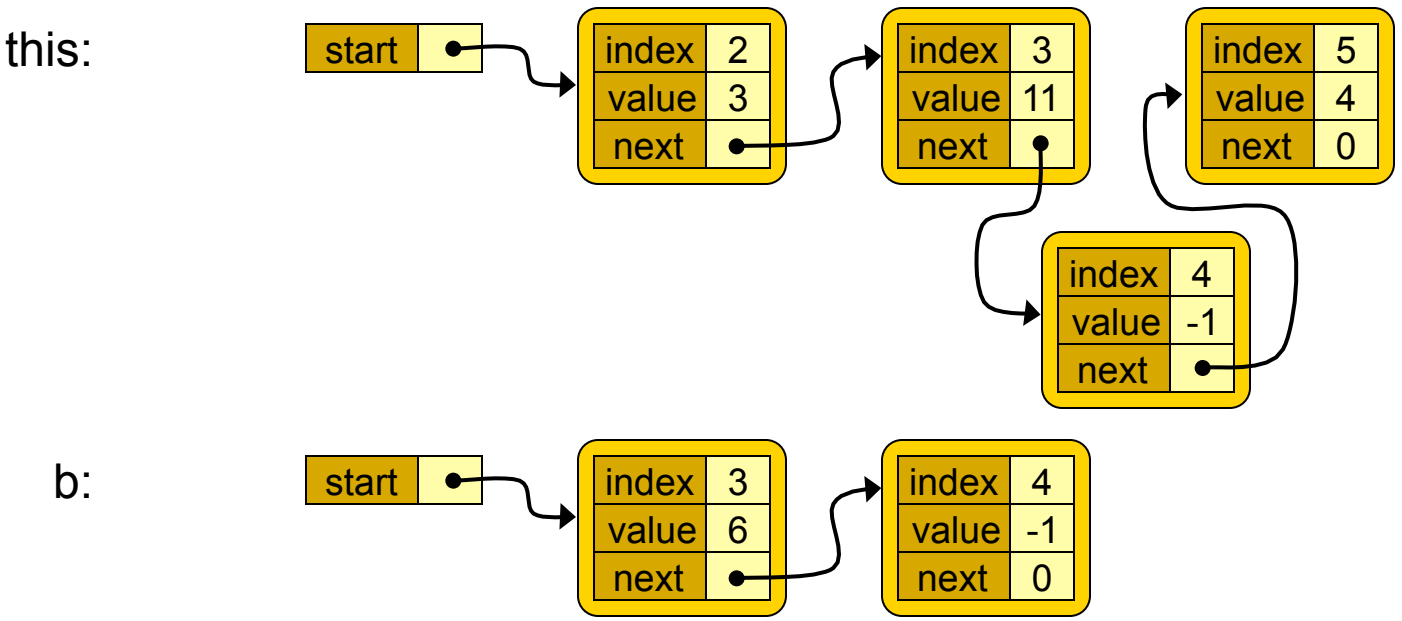
Efficient Adding (8)

- Reached end of `b`, so we're done.



Efficient Adding

- Final result:



Vector Arithmetic (1)

- Our loop has three cases to handle:
  1. My node's index is less than other node's index
     - Can assume that corresponding value in other list is zero!
     - Nothing to add/subtract – my node's value doesn't change.
     - Move my node-pointer forward down the list
  2. My node's index is equal to other node's index
     - Perform addition/subtraction operation with the two values
     - Store result into my node
     - Move *both* node-pointers forward down the list
  3. My node's index is greater than other node's index
     - (My node's index = i, other node's index = j)
     - My value for index j is zero, but the result will be nonzero!
     - Add a *new* node to my list, for index j, containing result
     - Move other node-pointer forward down the list

Vector Arithmetic (2)

- Case 3 is the tricky one!
  - Add a new node to the list, right before **`curr`**
  - Need a **`prev`** node-pointer that chases **`curr`** through the list
  - Make sure to update **`prev`** properly, when a new node is added!
    - **`curr`** doesn't move…
    - …but there's a new "previous node!"
    - Set **`prev`** to be the newly added node

Vector Arithmetic (3)

- Finally: What happens at end of loop?
  - Again, three cases

1. Reached end of both lists at the same time
   - This is easy! Do nothing.
2. Reached end of other list first
   - Also easy, since rest of elements in other list are zero.
   - Do nothing.
3. Reached end of my list first
   - **`curr == 0`**, but **`otherCurr != 0`**
   - Copy remaining nodes in other list to end of my list
   - (Of course, make sure they reflect sum or difference…)
   - Again, **`prev`** comes in handy!

Other Notes about Efficient Adding

- Adding/subtracting vectors can produce nodes with value = 0
  - Vector 1: (0, 3, 5, 2, 0, 0)
  - Vector 2: (0, -3, 4, -2, 0, 5)
  - Sum is: (0, 0, 9, 0, 0, 5)
- An easy approach:
  - Don't worry about culling those out *during* the addition/subtraction itself
  - Can write a helper-fn that removes zero-value nodes, and call it at end of add/subtract operation

Zero-Value Nodes (2)

- Another approach:
  - Vector 1: (0, 3, 5, 2, 0, 0)
  - Vector 2: (0, -3, 4, -2, 0, 5)
  - Sum is: (0, 0, 9, 0, 0, 5)
- A zero-result is only generated when both inputs are nonzero
  - Exactly one of our cases can produce a zero-value node (second case, slide 16)
  - Already have a “previous node” pointer for adding in new nodes… could handle in main-loop too

Finding Bugs

- Several ways to find bugs
  - Use assertions to “catch” them
  - Print out info as your program runs (logging)
  - Use a debugger to watch your program execute
- These approaches are complementary
  - Each has different strengths/weaknesses
- Lab 4 is a great opportunity to practice your debugging skills. ☺

The Debugger: **gdb**

- **gdb** is the GNU Debugger
  - Plays very well with **gcc** and **g++**
- *Very* sophisticated debugging features
  - Can step through your program line by line
  - Can set breakpoints in your program
    - Tell program to "break" (stop) when it hits a certain point
  - Can examine or modify your program's data
  - *Many* more features too…
- Interface is command-line only!
  - Several front-ends have been built onto **gdb**

Preparing to Debug

- **`gdb`** needs extra information about your code
  - Called “debug symbols”
- Compiler usually leaves this info out
  - Takes up extra space…
- Also want to turn off all optimizations!
  - Compiler may reorder your code to make it faster
- Compiler arguments for debugging:
  - `g++ -Wall -O0 -g source.cc -o execfile`
  - **`-g`** means “include debug symbols”
  - **`-O0`** means “don’t optimize anything”

Starting the Debugger

- You start your program in the debugger:
  - **`gdb checksv`**
  - Debugger loads your program
  - Reads the debug information out of the file
- Debugger doesn't automatically run your program
  - Gives you a chance to set breakpoints, specify command-line arguments, etc.
- To start your program:
  - **`run`** (no command-line args)
  - **`run` *`arg1 arg2 ...`*** (to specify command-line args)

Breakpoints

- Setting breakpoints is easy:
  - **`break filename:line`**
  - **`break function`**
  - **`break classname::function`**
  - Can use tab-completion with classes/functions!
- Can only set breakpoints when program is stopped
- Example 1: Debug the destructor

```
break 'SparseVector::~SparseVector()'
```

- Example 2: Debug the copy-constructor

```
break 'SparseVector::SparseVector(SparseVector const&)'
```

  - Use tab-completion for this kind of thing

When the Breakpoint Is Hit

- Debugger stops when it hits any breakpoint
  - **`list`** - Lists the code
  - **`where`** - Shows the call-stack
  - **`step`** - Steps to next line of code
    - (Steps ***into*** function calls)
  - **`next`** - Steps to next line of code
    - (Steps ***over*** function calls)
  - **`cont`** - Continue running!
- For help on commands:
  - **`help`** or **`help`** ***`command`***
- To end the madness:
  - **`quit`**

Examining Variables

- Use **`print`** to examine variables
  - **`print`** understands **`*`**, **`->`**, **`&`**, etc.
- Example: debugging your list code
  - **`break SparseVector::getElem`**
  - **`run`**
  - **`...`**
  - **`print curr`** Shows pointer value
  - **`print *curr`** Shows node's contents
  - **`print curr->next`** Shows next pointer value
  - **`print *(curr->next)`** Shows next node

Debugging Crashes!

- If your program crashes when you run it:
  - Compile with debug symbols & no optimizations
  - Run it in the debugger
  - Debugger will tell you that it has crashed
  - Use **`where`** to find out where crash is occurring
  - Figure out where to set breakpoints, then restart
    - **`run`** command restarts your program at the beginning

Next Week!

- C++ templates
- Using exceptions to report errors