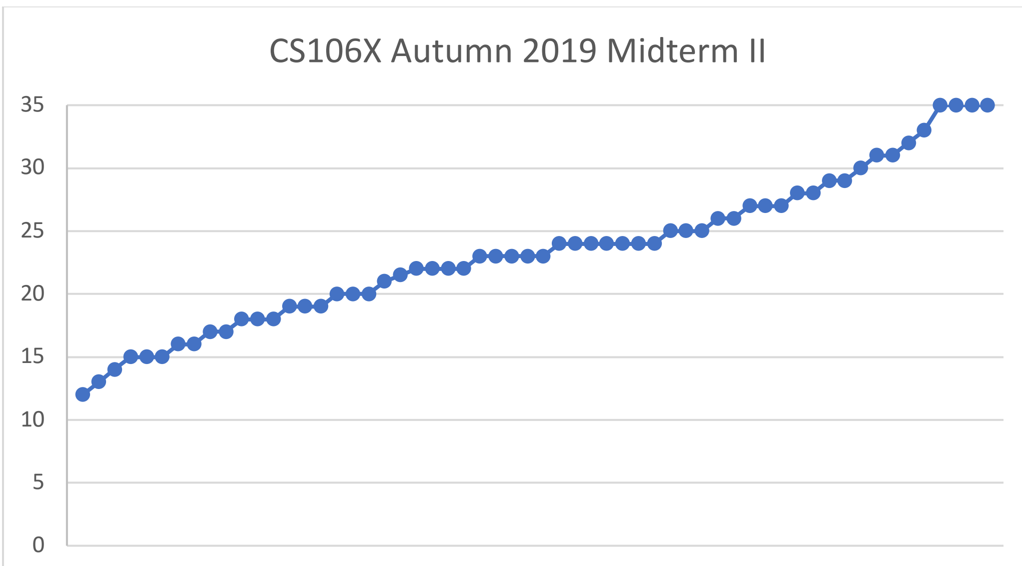
CS106X Midterm Examination Solution

Your section leading staff collaboratively graded all of the midterms over Thanksgiving break, and scores will be published later tonight via Gradescope.

The midterm was a tough one and required a mastery of pointers, dynamic memory allocation techniques, and linked structures. The second problem precisely underscored why it's so very important to get the minutiae of single pointers, double pointers, and references to pointers correct, as mistakes are unforgiving and lead to difficult-to-triage bugs. Here's the histogram showing how everyone did:



Each circle represents a single exam, and scores ranged from 12 to a perfect 35, and the median grade was a 23. Because the median was below 80%, the 23's curves up to an 80%, the 35s curve stay put at 100%, and everything else scales up accordingly—that is, 35 ⇒ 100, 29 ⇒ 90, 23 ⇒ 80, 17 ⇒ 70, 11 ⇒ 60.

The rest of this handout includes my own solutions and the criteria we used to grade. Of course, we recognize these exams count for a large portion of your grade, so we try to be as transparent as possible about the criteria. If you have a legitimate concern about how your midterm was graded, come talk to Jerry during his office hours or engage me over email.

All regrade requests must come in by December 9th, which is CS106X Final Project Presentation Day. ☺ After that, all scores are frozen, since I'll want to submit all final grades on the 10th or 11th.

Solution 1: Linked Lists

a. [5 points] My solution uses a **`node **`**, though we're perfectly fine if you use **`prev`** and **`curr`** pointers as our initial linked list examples did.

```
struct node {
   int value;
   node *next;
};

static bool contains(node *& list, int value) {
   node **currp = &list;
   while (*currp != NULL and (*currp)->value != value) {
      currp = &(*currp)->next;
   }

   bool found = *currp != NULL;
   if (found && *currp != list) {
      node *curr = *currp;
      *currp = curr->next;
      curr->next = list;
      list = curr;
   }
   return found;
}
```

Problem 1a Criteria:
- Correctly crawls the list to find the matching node: 1 point
- Correctly compiles the information needed to splice a matching node out: 1 point
- Properly rewires the matching node's predecessor and successor to be neighbors: 1 point
- Correctly rewires the matching node to lead the list: 1 point
- Properly handle the situation where the matching node is at the front: 1 point (it's possible code that doesn't need to be run is fine when it runs)

b. [5 points] This function is trickier than it might seem, because you need to not only build the reverse linked list, but you also need to identify the very last next field of the original list and update it to address the reverse.

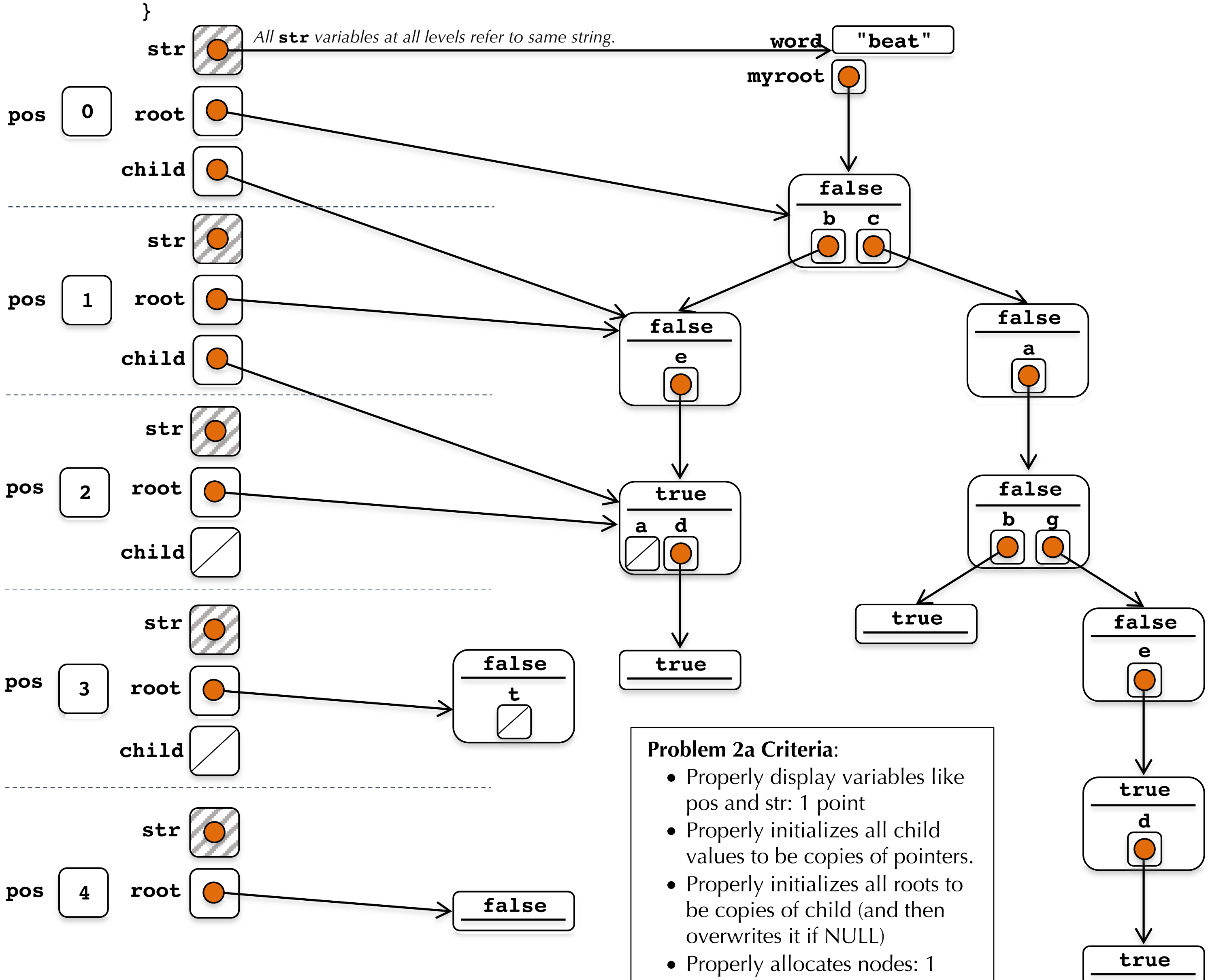
```
static void mirror(node *list) {
   node *reverse = NULL;
   for (node *curr = list; curr != reverse; curr = curr->next) {
      node *n = new node;
      n->value = curr->value;
      n->next = reverse;
      reverse = n;
      if (curr->next == NULL)
         curr->next = reverse;
   }
}
```

Problem 1b Criteria:
- Correctly visits every node in the original list: 1 point
- Correctly allocates a new node for every value in the original and populates its value field: 1 point
- Properly wires the accumulation of new nodes to be the reverse of the original list: 1 point
- Properly concatenates the reverse to the original just as everything finishes
- Correctly handles both the empty list and the singleton list (ideally without special casing): 1 point

Solution 2: Trie Insertion Trace

a. [5 points] This is the more interesting half of the problem, because it's clear how the first version breaks down. (The new nodes in both part a and part b have uninitialized **bool**s, but I draw them as **false**, since the trie node we relied on in class had a constructor and set the **isWord** bool to **false**. We were equally happy with false or with questions marks.

```
node *ensureNodeExists1(node *root, const string& str, int pos = 0) {
   if (root == NULL) root = new node;
   if (pos == str.size()) return root;
   node *child = root->suffixes[str[pos]];
   return ensureNodeExists1(child, str, pos + 1);
}
```



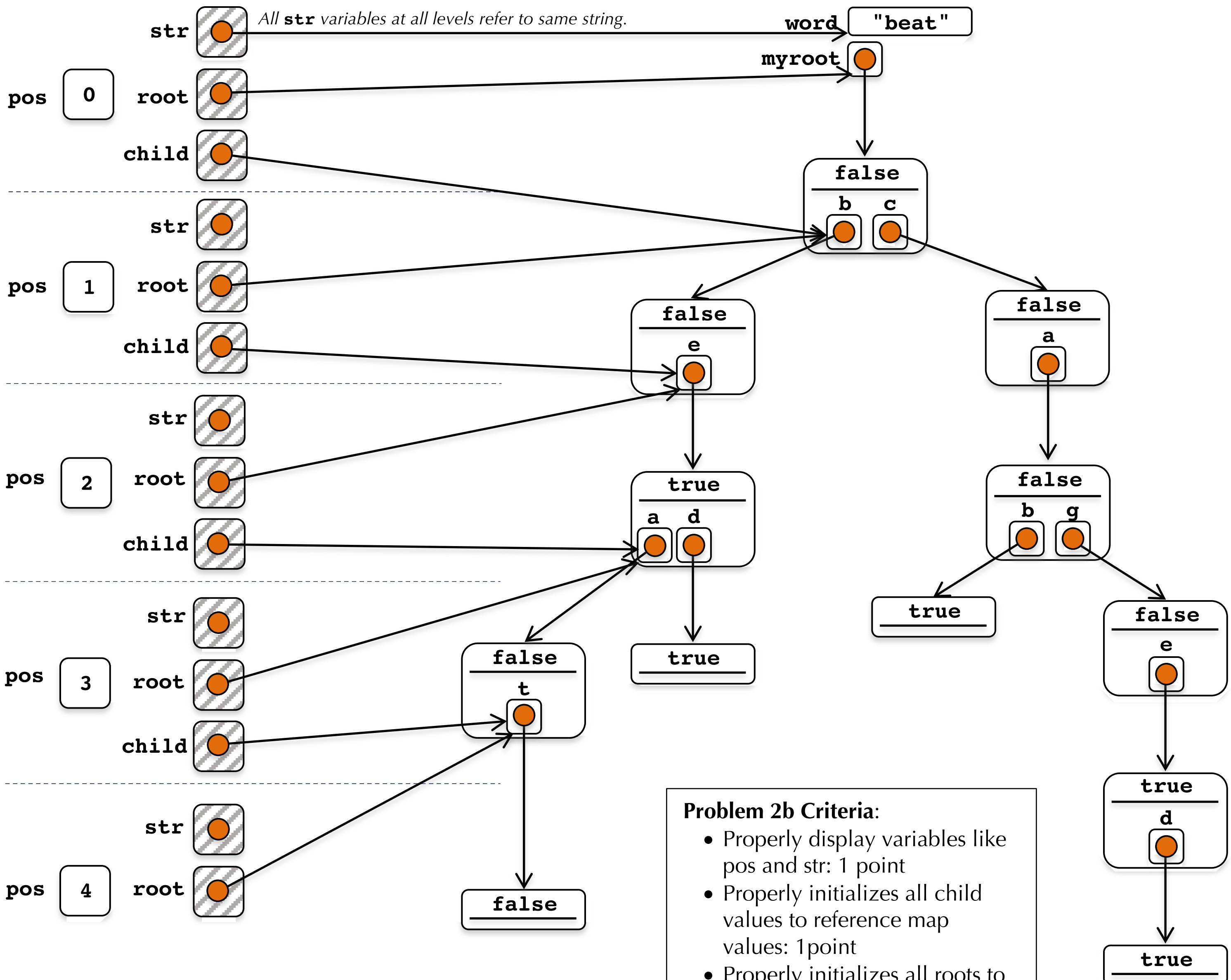
Problem 2a Criteria:

- Properly display variables like pos and str: 1 point
- Properly initializes all child values to be copies of pointers.
- Properly initializes all roots to be copies of child (and then overwrites it if NULL)
- Properly allocates nodes: 1 point
- Properly inserts missing letters and maps them to NULL.

Solution 2: Trie Insertion Trace [continued]

b. [5 points] As the problem statement implied this version worked as expected, you shouldn't be surprised very much of the diagram below.

```
node *ensureNodeExists2(node *& root, const string& str, int pos = 0) {
   if (root == NULL) root = new node;
   if (pos == str.size()) return root;
   node *&child = root->suffixes[str[pos]];
   return ensureNodeExists2(child, str, pos + 1);
}
```



Problem 2b Criteria:

- Properly display variables like pos and str: 1 point
- Properly initializes all child values to reference map values: 1point
- Properly initializes all roots to reference whatever child references: 1 point
- Properly allocates nodes: 1 point
- Properly inserts missing letters and ultimately has each map to new nodes: 1 point

Solution 3: All Things Tree

a. [7 points]

```
static void contract(node *& root) {
   if (root == NULL) return;
   contract(root->left);
   contract(root->right);
   if ((root->left == NULL && root->right == NULL) ||
      (root->left != NULL && root->right != NULL)) return;

   node *child = root->left;
   if (child == NULL) child = root->right;
   delete root;
   root = child;
}
```

Problem 3a Criteria:
- Identifies the NULL base case (the original tree may be empty, so it's necessary): 1 point
- Recursively contracts the left and right subtrees: 2 points
- Correct returns without surgery if the root was a leaf or was full: 1 point
- Correctly identifies the child that should be hoisted up a lever: 1 point
- Correctly rewires the tree around the one-child node: 1 point
- Correctly levies the **`delete`** call against the removed node: 1 point

b. [8 points]

```
static Set<node *> construct(int low, int high) {
   Set<node *> trees;
   if (high < low) {
      Set<node *> trees;
      trees += NULL;
      return trees;
   }

   for (int divider = low; divider <= high; divider++) {
      Set<node *> lefts = construct(low, divider - 1);
      Set<node *> rights = construct(divider + 1, high);
      for (node *left: lefts) {
         for (node *right: rights) {
            node *root = new node;
            root->value = divider;
            root->left = cloneTree(left);
            root->right = cloneTree(right);
            trees.add(root);
         }
      }
   }
   return trees;
}

static Set<node *> construct(int n) {
   return construct(1, n);
}
```

Problem 3b Criteria:
- Properly reframes the primary call to be a wrapper function with lower and upper bounds: 1 point
- Properly handles the empty-range situation by returns a singleton set that's the empty tree: 1 point
- Correctly considers every single value in the range [low, high] as root values, including low and high: 1 point
- For each choice of divider, recursively constructs the set of all legal binary search trees that can hang to the left and right: 2 point
- Properly allocates a new node for each left-right pairing and embeds copies of divider, left, and right: 2 points
- Properly adds each tree to the set and ultimately returns it: 1 point