CSE 333 Midterm Exam Sample Solution 7/29/13

Question 1. (44 points) C hacking – a question of several parts.

The next several pages are questions about a linked list of 2-D points. Each point is represented by a `Point` struct containing the point's x and y coordinates:

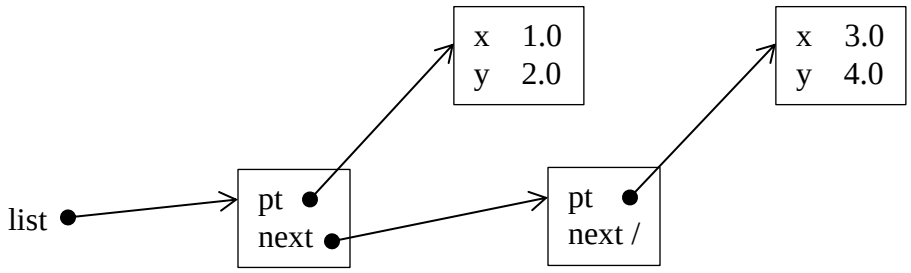
```
typedef struct point {     // a 2-D point
  double x;                // x and y coordinates
  double y;
} Point;
```

A list of points is a single-linked list, where each node contains a pointer to its associated `Point` struct and a pointer to the next node in the list, if there is one.

```
typedef struct pt_node {  // node in a linked list of Points
  Point * pt;             //   point owned by this node
  struct pt_node * next;  //   next list node, or NULL if none
} Ptnode;
```

All of the data in the list (points and nodes) is owned by the list and allocated on the heap. Point and node structs are created and initialized when they are added to the list.

Example: A list containing the points (1.0, 2.0) and (3.0, 4.0) would be drawn like this:



Answer the questions that use this list structure on the following pages. You can detach this page from the test for reference while you are working if that is convenient.

Question 1. (cont.) (a) (15 points) The distance of a point (x,y) from the origin is calculated as `sqrt(x*x+y*y)`. Implement the function `max_distance` below so it calculates the distance from the origin of each point in the list and returns the largest distance found. If the list is empty, the maximum distance returned should be 0.0.

Restriction: for full credit your function must use an appropriate loop to traverse the list and may not use recursion or any additional functions besides `sqrt`.

Example: if the list contains the points (1, 2) and (3, 4), the max distance returned should be 5.0 (= sqrt(3*3+4*4)).

```
#include <math.h>    // for sqrt
#include <stdlib.h>  // for NULL

// return max distance from origin of any point in the list
// (return 0.0 if the list is empty)
double max_distance(Ptnode * list) {
  double max = 0.0;
  Ptnode * p = list;
  while (p != NULL) {
    double dist = sqrt(p->pt->x * p->pt->x +
                       p->pt->y * p->pt->y);
    if (dist > max) {
      max = dist;
    }
    p = p->next;
  }
  return max;
}
```

Notes: This is one possible solution; there are obviously many others and as long as the code was correct it received full credit. Common variations were using a `for` loop to traverse the list and using a temporary variable to hold the value `p->pt` (although given a reasonable optimizing compiler, the generated code would likely be just as efficient either way).

Question 1. (cont.) (b) (15 points) Complete the definition of function `free_list` below so that it frees (returns to the heap) all of the data belonging to the list that is its argument. After freeing the list nodes and points, the function should set the list pointer supplied as its argument to `NULL`.

Restriction: as with part (a), for full credit your function must use an appropriate loop to traverse the list and may not use recursion or any additional functions besides `free`.

```
#include <stdlib.h>  // for free, NULL

// free list and contents, then set *list to NULL
void free_list(Ptnode ** list) {
  Ptnode * p = *list;
  Ptnode * tmp;
  while (p != NULL) {
    tmp = p;
    p = p->next;
    free(tmp->pt);
    free(tmp);
  }
  *list = NULL;
}
```

Notes: There are also other possible solutions here too, but it's trickier than in the previous problem. It's important to be careful not to reference the value of a pointer after freeing the associated data. In particular, a `for` loop that executes `p=p->next` in the increment step after freeing node `p` is not correct.

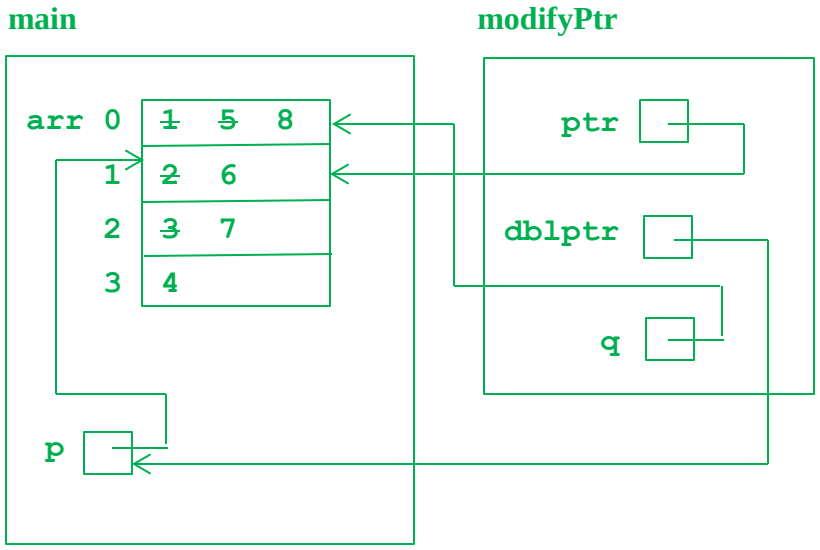
Question 1. (cont.) (14 points) One of the summer interns who has not taken CSE333 was asked to write a function to add the value of a new `Point` to the front of a list. Alas, the code has lots of problems. Indicate on the code below the changes needed so it will work *exactly* as specified. You ***may not*** change the specification of the function, the parameters, or the return type. You may add, remove, rearrange, or alter statements in the body of the function as needed.

```
// Add a new Point to the front of the list lst, with the
// new point's (x,y) values taken from parameter pt.
// Update lst to point to the new node added at the front.
// Return 1 if successful and 0 if not.

int push_front(Point pt, Ptnode ** lst) {

  // Corrections and comments in green bold type.

  // sizeof should be the size of the struct, not a pointer

  Ptnode * node = (Ptnode*)malloc(sizeof(Ptnode~~*~~));

  Point * npt = (Point*)malloc(sizeof(Point~~*~~));

  // need to check malloc failure here before using ptrs

  *npt = pt;              // need to copy pt x,y values

  node->pt = ~~&pt;~~ npt;  // need to use allocated Point

  node->next = *lst;      // need *lst not lst, next 2 lines

  *lst = node;

  if (npt == NULL || node == NULL) {

    return 0;  // probably should also free allocated data
               // if one of the allocations succeeded, but
               // we did not deduct points if that was
               // missed
  }

  return ~~lst;~~ 1;  // wrong return value

}
```

Question 2. (20 points) Yet another ghastly C program. As is traditional, it does compile and execute with no warnings or errors:

```
void modifyPtr(int *ptr, int **dblPtr) {
  int *q = ptr;
  *ptr = 5;
  ptr++;
  *ptr = 6;
  *(q + 2) = 7;
  *((*dblPtr) - 1) = 8;
  // -->HERE<-- //
}

int main(int argc, char **argv) {
  int arr[4] = {1, 2, 3, 4};
  int *p = arr + 1;
  modifyPtr(&(arr[0]), &p);
  printf("%d %d %d %d %d\n",
       arr[0], arr[1], arr[2], arr[3], *p);
  return 0;
}
```

(a) Draw a boxes 'n arrows diagram showing state of memory when control reaches the comment containing `-->HERE<--`, right before executing the `return` statement in function `modifyPtr`. Your diagram should have two boxes showing the stack frames for functions `main` and `modifyPtr`. The stack frames should include values of integer variables and an arrow from each pointer to the location that it references. Then answer part (b) at the bottom of the page.



Note: arr is a local variable in main, not a pointer to an array allocated on the heap

(b) What output does this program produce when it is executed?

8 6 7 4 6

Question 3. (15 points) Make and program building. We have a program that consists of a header file `f.h`, an implementation file `f.c`, and a main program `main.c`. Normally we could use the following `Makefile` to build the program `mumble` from these source files:

```
mumble: main.o f.o
      gcc -o mumble main.o f.o
      ld mumble main.o f.o
main.o: main.c f.h
      gcc -c -o main.o main.c
      cpp main.i main.c
      cc1 main.o main.i
f.o: f.c f.h
      gcc -c -o f.o f.c
      cpp f.i f.c
      cc1 f.o f.i
```

Note: another solution would be to add additional rules to produce the .i files separately and compile them in a different step to produce the .o files.

Unfortunately we need to build this program on a new experimental system that does not yet have a `gcc` command(!). Fortunately, it does have the three programs that `gcc` runs behind the scenes to build a program: the preprocessor `cpp`, the compiler itself `cc1`, and the loader `ld`. These commands work as follows:

`cpp` *outfile infile* – preprocess the program read from *infile* (say `f.c`) and write the preprocessed results to *outfile* (by convention named `f.i` if the input file is `f.c`).

`cc1` *outfile infile* – compile the already-preprocessed file *infile* (say `f.i`) and write the compiled code to the object file *outfile* (a `.o` file, for example `f.o`)

`ld` *outfile infiles…* – read the one or more `.o` files listed as *infiles* and write an executable file named *outfile* (`mumble` in our example above).

For this problem, show the changes that would be needed in the above `Makefile` so it would build the program as before, but using `cpp`, `cc1`, and `ld` instead of `gcc`. You can add or delete `Makefile` rules and Linux commands as needed. The resulting `Makefile` should only recompile/preprocess/load files when necessary, as is the case with the original one. Note that `cpp` and `cc1` only preprocess or compile a single file at a time, so you can't, for instance, preprocess all of the .c files with a single command. Also (if it helps), remember that a single `Makefile` rule can have more than one command on successive lines to bring a file up to date.

Question 4. (20 points) In one of the exercises we implemented a C++ class `Vector` that represented 3-D points and supplied various operations on them. A `Vector` had the following representation:

```
class Vector {
  ...
private:
  double x_, y_, z_; // x, y, and z magnitudes of Vector
};
```

The operations provided included constructors (`Vector()`, `Vector(x,y,z)` and copy constructor); assignment; addition and subtraction, which produced new `Vector` values; scalar and dot-product multiplication; and stream output.

For this problem, give the declaration and implementation of a new `operator+=` for `Vectors`. If `u` is the `Vector` (a,b,c) and `v` is the `Vector` (i,j,k), then `u+=v` should modify vector `u` so it has the value (a+i,b+j,c+k). Note that += is almost the same as regular assignment, except it computes a new value for its left operand instead of copying the right operand without changes. Self-updates like `u+=u`, and chained updates like `u+=v+=w` should also work properly.

(a) (6 points) Give the correct declaration (function prototype) of `operator+=` that should be added to class `Vector` in the header file `Vector.h`. (This is only one line)

```
Vector &operator+=(const Vector &other);
```

(b) (14 points) Give the full implementation of `operator+=` that should be added to file `Vector.cc`.

```
Vector &Vector::operator+=(const Vector &other) {
  x_ += other.x_;
  y_ += other.y_;
  z_ += other.z_;
  return *this;
}
```

Question 5. (1 point) The ***best*** reason to take CSE 333 during the summer is (circle the letter of the best answer; all thoughtful, honest answers get full credit):

(a) A 9:40 class makes me wake up in the morning instead of sleeping till mid-afternoon.

(b) Hacking is much more fun than hiking.

(c) Next year I'll get that Google internship after taking this class!

(d) I'd rather be in an air-conditioned, dark basement room instead of out in the bright, hot sunlight.

(e) Learning C is better than sitting on the shore by the sea.

(f) I get to finally figure out what all the funny symbols mean (`*&::!->`).

(g) gdb is a better video game than anything else I've got.

(h) Gotta get it out of the way eventually, so why not now?

(i) Best reason? Can't think of one, but please give me my free point anyway.

(j) I do have a good reason, but I'd rather not say. Please give me my free point.

(k) You didn't include my reason, it's _____

All answers received 1 point.