CSCI-1200 Data Structures
Test 1 — Practice Problem Solutions

1 Opening a New Hair Salon [/32]

In this problem you will implement a simple class named `Customer` to keep track of customers at a hair salon. First, we create 6 `Customer` objects:

```
Customer betty("Betty");     Customer chris("Chris");     Customer danielle("Danielle");
Customer erin("Erin");       Customer fran("Fran");       Customer grace("Grace");
```

Then, we can track customers as they come to the salon for appointments on specific dates with one of the salon's stylists. We use the `Date` class we discussed in Lecture 2. You may assume the appointments are entered chronologically, with increasing dates.

```
betty.hairCut   (Date(1,15,2015), "Stephanie");
chris.hairCut   (Date(1,17,2015), "Audrey"   );
grace.hairCut   (Date(1,20,2015), "Stephanie");
danielle.hairCut(Date(1,28,2015), "Stephanie");
chris.hairCut   (Date(2, 5,2015), "Audrey"   );
betty.hairCut   (Date(2, 9,2015), "Stephanie");
fran.hairCut    (Date(2,12,2015), "Audrey"   );
danielle.hairCut(Date(2,18,2015), "Lynsey"   );
betty.hairCut   (Date(2,20,2015), "Stephanie");
```

In the system, each customer record will store the customer's preferred stylist. The preferred stylist is defined as a customer's most recent stylist. A message is printed to `std::cout` on each customer's first visit to the salon, or if a customer switches to a new stylist. Here is the output from the above commands:

```
Setting Stephanie as Betty's    preferred stylist.
Setting Audrey    as Chris's    preferred stylist.
Setting Stephanie as Grace's    preferred stylist.
Setting Stephanie as Danielle's preferred stylist.
Setting Audrey    as Fran's     preferred stylist.
Setting Lynsey    as Danielle's preferred stylist.
```

Next, we insert the customers into an STL `vector`:

```
std::vector<Customer> customers;
customers.push_back(betty);  customers.push_back(chris);  customers.push_back(danielle);
customers.push_back(erin);   customers.push_back(fran);   customers.push_back(grace);
```

And then sort & print them first alphabetically by stylist, and secondarily by most recent visit to the salon:

```
std::sort(customers.begin(),customers.end(),stylist_then_last_appointment);
for (int i = 0; i < customers.size(); i++) {
   std::cout << customers[i].getName() << " has had "
             << customers[i].numAppointments() << " appointment(s) at the salon";
   if (customers[i].numAppointments() > 0) {
      std::cout << ", most recently with " << customers[i].getStylist()
                << " on " << customers[i].lastAppointment(); }
   std::cout << "." << std::endl;
}
```

Which results in this output to the screen:

```
Erin     has had 0 appointment(s) at the salon.
Chris    has had 2 appointment(s) at the salon, most recently with Audrey    on  2/ 5/2015.
Fran     has had 1 appointment(s) at the salon, most recently with Audrey    on  2/12/2015.
Danielle has had 2 appointment(s) at the salon, most recently with Lynsey    on  2/18/2015.
Grace    has had 1 appointment(s) at the salon, most recently with Stephanie on  1/20/2015.
Betty    has had 3 appointment(s) at the salon, most recently with Stephanie on  2/20/2015.
```

Note: Don't worry about output formatting/spacing. You may assume that the `Date` class has an `operator<` to compare/sort dates chronologically and an `operator<<` to print/output `Date` objects.

1.1 `Customer` Class Declaration [/15]

Using the sample code on the previous page as your guide, write the class declaration for the `Customer` object. That is, write the *header file* (`customer.h`) for this class. You don't need to worry about the `#include` lines or other pre-processor directives. Focus on getting the member variable types and member function prototypes correct. Use `const` and call by reference where appropriate. Make sure you label what parts of the class are `public` and `private`. Include prototypes for any related non-member functions. Save the implementation of all functions for the `customer.cpp` file, which is the next part.

Solution:

```
class Customer {
public:
  // CONSTRUCTOR
  Customer(const std::string& name);
  // ACCESSORS
  const std::string& getName() const;
  const std::string& getStylist() const;
  const Date& lastAppointment() const;
  int numAppointments() const;
  // MODIFIERS
  void hairCut(const Date &d,const std::string &stylist);
private:
  // REPRESENTATION
  std::string customer_name;
  std::string preferred_stylist;
  std::vector<Date> appointments;
};

// helper function for sorting
bool stylist_then_last_appointment(const Customer &c1, const Customer &c2);
```

1.2 `Customer` Class Implementation [/17]

Now implement the member functions and related non-member functions of the class, as they would appear in the corresponding `customer.cpp` file.

Solution:

```
// CONSTRUCTOR
Customer::Customer(const std::string &name) {
  customer_name = name;
}

// ACCESSORS
const std::string& Customer::getName() const {
  return customer_name;
}
const std::string& Customer::getStylist() const {
  return preferred_stylist;
}
const Date& Customer::lastAppointment() const {
  return appointments.back();
}
int Customer::numAppointments() const {
  return appointments.size();
}

// MODIFIER
void Customer::hairCut(const Date &d,const std::string &stylist) {
  if (stylist != preferred_stylist) {
    std::cout << "Setting " << stylist << " as " << customer_name << "'s preferred stylist." << std::endl;
    preferred_stylist = stylist;
  }
  appointments.push_back(d);
}
```

```
// COMPARISON FUNCTION FOR SORTING
bool stylist_then_last_appointment(const Customer &c1, const Customer &c2) {
  return (c1.getStylist() < c2.getStylist() ||
          (c1.getStylist() == c2.getStylist() && c1.lastAppointment() < c2.lastAppointment()));
}
```

2 Color Analysis of HW1 Images [/21]

Write a function named `color_analysis`, that takes three arguments: `image`, an STL `vector` of STL `string`s representing a rectangular ASCII image (similar to HW1); an integer `num_colors`; and a character `most_frequent_color`. The function scans through the image and returns (through the 2nd & 3rd arguments) the number of different colors (characters) in the image & the most frequently appearing color.

Solution:

```
void color_analysis(const std::vector<std::string> &image, int &num_colors, char &most_frequent_color) {
  // local variables to keep track of colors & counts
  std::vector<char> colors;
  std::vector<int> counts;
  // loop over every pixel in the image
  for (int i = 0; i < image.size(); i++) {
    for (int j = 0; j < image[i].size(); j++) {
      // add each pixel to the color counts
      bool found = false;
      for (int k = 0; k < colors.size() && !found; k++) {
        if (image[i][j] == colors[k]) {
          counts[k]++;
          found = true;
        }
      }
      // if we haven't seen this color before...
      if (!found) {
        colors.push_back(image[i][j]);
        counts.push_back(1);
      }
    }
  }
  // loop over all of the colors to find the most frequent
  int max_count = 0;
  for (int k = 0; k < colors.size(); k++) {
    if (max_count < counts[k]) {
      max_count = counts[k];
      most_frequent_color = colors[k];
    }
  }
  // also set the num_colors "return value"
  num_colors = colors.size();
}
```

What is the order notation of your solution in terms of w & h, the width & height of the image, and c, the number of different colors in the image?

Solution: $O(w * h * c)$**. This function is a simple triply-nested loop. Thus, the order notation is a product of the controlling variables for each loop.**

3 Power Matrix Construction [/16]

Write a function named `make_power_matrix` that takes in two arguments, `num_rows` and `num_columns`, and creates and returns a 2D matrix using STL `vectors`. Each element of the matrix $m_{r,c}$ stores the value r^c, that is, the row index raised to the power of the column index. For example, `make_power_matrix(5,7)` should produce this matrix:

```
1        0        0        0        0        0        0
1        1        1        1        1        1        1
1        2        4        8       16       32       64
```

```
1         3          9         27         81        243        729
1         4         16         64        256       1024       4096
```

Try to write this function *without using* the `pow` function.

Solution:

```
std::vector<std::vector<int> > make_power_matrix(int rows, int cols) {
  std::vector<std::vector<int> > answer;
  for (int r = 0; r < rows; r++) {
    std::vector<int> helper;
    int val = 1;
    for (int c = 0; c < cols; c++) {
      helper.push_back(val);
      val *= r;
    }
    answer.push_back(helper);
  }
  return answer;
}
```

What is the order notation of your solution in terms of r, the number of rows, and c, the number of columns?

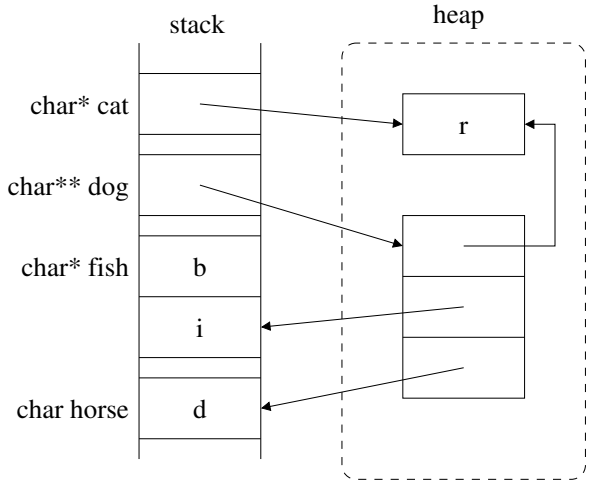
Solution: To create this 2D vector structure, it will cost $O(r * c)$. Note this is true either using the constructor that creates an array of a specific size or with push_back. Keeping a running product (multiplication) means that it is a constant amount of work per element, even without the `pow` function.

4 Diagramming Pointers & Memory [/15]

In this problem you will work with pointers and dynamically allocated memory. The fragment of code below allocates and writes to memory on both *the stack* and *the heap*. Following the conventions from lecture, draw a picture of the memory after the execution of the statements below.

```
char* cat;
char** dog;
char fish[2];
char horse;
dog = new char*[3];
dog[0] = new char;
fish[0] = 'b';
fish[1] = 'i';
dog[1] = &fish[1];
dog[2] = &horse;
cat = dog[0];
*cat = 'r';
horse = 'd';
```

Solution:



Now, write a fragment a C++ code that cleans up all dynamically allocated memory within the above example so that the program will not have a memory leak.

Solution:

```
delete [] dog;
delete cat;
```

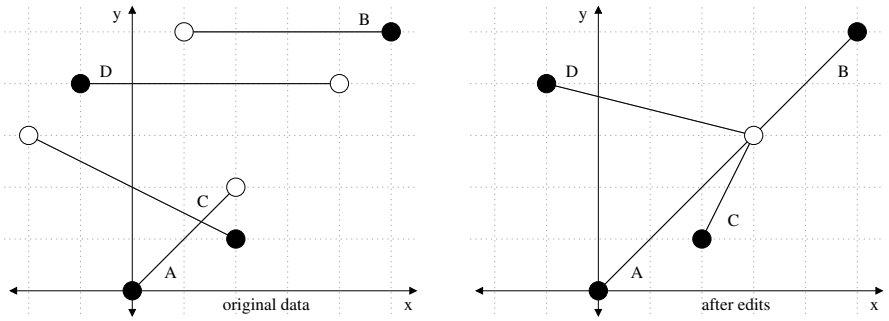
5 Classy Line Slopes [/28]

In this problem you will implement a simple class named `Line` to keep track of two dimensional lines. `Line`s are defined by two endpoints with integer coordinates. We will calculate the slope and y-axis intercept of each of the lines. Remember from algebra/geometry class that the equation for a line is $y = mx + b$, where m is the slope and b is the y-intercept. You may assume that the two endpoints are not the same point, and that the line is not exactly vertical (which would correspond to slope=∞).

In the example below we make four `Line` objects and put them in an STL `vector`. The diagram on the left shows the original position of each of the lines – the black dot is the "first" endpoint and the white dot is the "second" endpoint. The `Line` class allows us to edit the second endpoint of each line, as shown in the diagram on the right, and in the code below.

```
Line a ("A",   0, 0,   2, 2);
Line b ("B",   5, 5,   1, 5);
Line c ("C",   2, 1,  -2, 3);
Line d ("D",  -1, 4,   4, 4);

std::vector<Line> lines;
lines.push_back(a);
lines.push_back(b);
lines.push_back(c);
lines.push_back(d);
```



Here's a helper function that outputs information about each line stored in a `vector`:

```
void printLines(const std::vector<Line> &lines) {
  for (int i = 0; i < lines.size(); i++) {
    std::cout << "Line " << lines[i].getName()
              << std::fixed << std::setprecision(2)
              << " with slope=" << std::setw(5) << lines[i].getSlope()
              << " and y intercept=" << std::setw(5) << lines[i].getYIntercept()
              << std::endl;
  }
}
```

Here's a code fragment that will first sort the line collection by slope and then print the lines:

```
std::cout << "original data, sorted by slope" << std::endl;
sort(lines.begin(),lines.end(),by_slope);
printLines(lines);
```

Now we edit the second endpoint of each line to be the point (3,3) and then sort and print the data again:

```
for (int i = 0; i < lines.size(); i++) {
  lines[i].setNewSecondPoint(3,3);
}
std::cout << "after changing second point to (3,3)" << std::endl;
sort(lines.begin(),lines.end(),by_slope);
printLines(lines);
```

The code above results in this output to the screen:

```
original data, sorted by slope
Line C with slope=-0.50 and y intercept= 2.00
Line D with slope= 0.00 and y intercept= 4.00
Line B with slope= 0.00 and y intercept= 5.00
Line A with slope= 1.00 and y intercept= 0.00
after changing second point to (3,3)
Line D with slope=-0.25 and y intercept= 3.75
Line B with slope= 1.00 and y intercept= 0.00
Line A with slope= 1.00 and y intercept= 0.00
Line C with slope= 2.00 and y intercept=-3.00
```

5.1 `Line` Class Declaration [/13]

Using the sample code on the previous page as your guide, write the class declaration for the `Line` object. That is, write the *header file* (`line.h`) for this class. You don't need to worry about the `#include` lines or other pre-processor directives. Focus on getting the member variable types and member function prototypes correct. Use `const` and call by reference where appropriate. Make sure you label what parts of the class are `public` and `private`. Include prototypes for any related non-member functions. Save the implementation of all functions for the `line.cpp` file, which is the next part.

Solution:

```
class Line {
public:
  // CONSTRUCTOR
  Line(const std::string &name, int x1, int y1, int x2, int y2);
  // ACCESSORS
  float getSlope() const;
  float getYIntercept() const;
  const std::string& getName() const;
  // MODIFIERS
  void setNewSecondPoint(int x2, int y2);
private:
  // REPRESENTATION
  std::string name_;
  int x1_,y1_,x2_,y2_;
};

bool by_slope (const Line &a, const Line &b);
```

5.2 `Line` Class Implementation [/15]

Now implement the member functions and related non-member functions of the class, as they would appear in the corresponding `line.cpp` file.

Solution:

```
Line::Line(const std::string &name, int x1, int y1, int x2, int y2) {
  name_ = name;
  x1_=x1;
  y1_=y1;
  x2_=x2;
  y2_=y2;
  assert (x1_ != x2_);
}

const std::string& Line::getName() const {
  return name_;
}


float Line::getSlope() const {
  int rise = y2_-y1_;
  int run = x2_-x1_;
  return (float)rise/(float)run;
```

```
}

float Line::getYIntercept() const {
  float slope = getSlope();
  return y1_ - slope*x1_;
}

void Line::setNewSecondPoint(int x2, int y2) {
  x2_ = x2;
  y2_ = y2;
  assert (x1_ != x2_);
}

bool by_slope (const Line &a, const Line &b) {
  if (a.getSlope() < b.getSlope())
    return true;
  return false;
}
```

6 Common C++ Programming Errors [/12]

For each code fragment below, choose the letter that best describes the program error. *Hint: Each letter will be used exactly once.*

A) Uninitialized memory
B) Compile error: type mismatch
C) Accessing data beyond the array bounds
D) Infinite loop
E) Math error (incorrect answer)
F) Memory leak
G) Syntax error
H) Does not contain an error

F

```
float* floating_pt_ptr = new float;
*floating_pt_ptr = 5.3;
floating_pt_ptr = NULL;
```

H

```
int* apple;
int banana[5] = {1, 2, 3, 4, 5};
apple = &banana[2];
*apple = 6;
```

A

```
double x;
for (int i = 0; i < 10; i++) {
  x += sqrt(double(i));
}
```

E

```
float a = 2.0;
float b = -11.0;
float c = 12.0;
float pos_root =
  -b + sqrt(b*b - 4*a*c) / 2*a;
float neg_root =
  -b - sqrt(b*b - 4*a*c) / 2*a;
```

D

```
unsigned int x;
for (x = 10; x >= 0; x--) {
  std::cout << x << std::endl;
}
```

B

```
std::vector<std::string> temperature;
temperature.push_back(43.5);
```

G

```
int balance = 100;
int withdrawal;
std::cin >> withdrawal;
if (withdrawal <= balance)
  balance -= withdrawal;
  std::cout << "success\n";
else
  std::cout << "failure\n";
```

C

```
int grades[4] = { 1, 2, 3, 4 };
std::cout << "grades" << grades[1]
          << " " << grades[2]
          << " " << grades[3]
          << " " << grades[4]
          << std::endl;
```

7 Detecting Compound Words [/18]

Write a C++ function that takes in a collection of English words stored as an STL `vector` of STL `strings`. The function should return a `vector` containing all *compound words* from the input collection. We define a compound word as two or three words joined together to make a different word. For example, given the input collection:

```
a back backlog backwoods backwoodsman cat catalog
less log man none nonetheless ship the woods woodsman
```

Your function should return (in any order):

```
backlog backwoods backwoodsman catalog nonetheless woodsman
```

Solution:

```
std::vector<std::string> compound_detector(const std::vector<std::string> &words) {
  std::vector<std::string> answer;
  // loop over each word, testing to see if it is a compound word
  for (int w = 0; w < words.size(); w++) {
    bool found = false;
    for (int x = 0; !found && x < words.size(); x++) {
      for (int y = 0; !found && y < words.size(); y++) {
        // 2 word combinations
        if (words[w] == words[x]+words[y]) {
          answer.push_back(words[w]);
          found = true;
        }
        for (int z = 0; !found && z < words.size(); z++) {
          // 3 word combinations
          if (words[w] == words[x]+words[y]+words[z]) {
            answer.push_back(words[w]);
            found = true;
          }
        }
      }
    }
  }
  return answer;
}
```

If there are n words in the input, what is the order notation of your solution?

Solution: To create compound words built from 3 words, we need a triple-nested loop. To see if combination is in the original list, we need another loop. The code above is $O(n^4)$. Depending on how the code is structured, an additional loop may be necessary to avoid adding duplicates to the output, which may increase the order notation. We will learn other data structures would help improve the running time.

8 Sorting by Vowels [/20]

Write a fragment of C++ code to read all the words stored in a file named "`input.txt`". You should then print the words to `std::cout` sorted by the number of vowels ('`a`', '`e`', '`i`', '`o`', or '`u`') that each contains, fewest first. If 2 words have the same number of vowels, output them in normal alphabetical order ('a' before 'z'). You may assume that all words in the file contain only lowercase letters. For example, if `input.txt` contains:

```
aspire  dog  zoological  cat  meow  grrr  utopia  audio
```

Your program should output:

```
grrr  cat  dog  meow  aspire  audio  utopia  zoological
```

You should write one or more simple helper functions as part of your solution.

Solution:

```
// HELPER FUNCTIONS
int num_vowels(const std::string &a) {
  int answer = 0;
```

```
  for (int i = 0; i < a.size(); i++) {
    if (a[i]=='a'||a[i]=='e'||a[i]=='i'||a[i]=='o'||a[i]=='u') answer++;
  }
  return answer;
}

bool fewest_vowels(const std::string &a, const std::string &b) {
  int num_vowels_a = num_vowels(a);
  int num_vowels_b = num_vowels(b);
  return (num_vowels_a < num_vowels_b) ||
    (num_vowels_a == num_vowels_b && a < b);
}

// FRAGMENT OF CODE
std::ifstream istr("input.txt");
std::string tmp;
std::vector<std::string> words;
while (istr >> tmp) { words.push_back(tmp); }
sort(words.begin(),words.end(),fewest_vowels);
for (int i = 0; i < words.size(); i++) {
  std::cout << words[i] << "  ";
}
```

9 Navigating the City [/23]

Write a function named `give_directions` that takes in three arguments. The first argument is an STL `vector` of STL `vector`s of STL `string`s named `city` that contains the city block layout of stores in downtown. The city is a regular square grid, and each city block has exactly one store. Here is an example of the data stored in a city with 20 blocks (each row & column are labeled with numbers for clarity):

	0	1	2	3
0	bestbuy	lenscrafters	walmart	gap
1	claires	payless	starbucks	oldnavy
2	brookstone	teavana	sears	macys
3	cvs	tmobile	lowes	footlocker
4	dsw	jcrew	apple	zales

The second and third arguments to the function are the names of two stores that may or may not be in the grid. If both stores are in the city grid, your function should print to `std::cout` a set of directions to help someone walk through the city starting at the store named by the second argument and ending at the store named by the third argument. For example:

```
give_directions(city,"cvs","oldnavy");
```

Should result in this output:

```
walk from cvs to brookstone
walk from brookstone to claires
walk from claires to payless
walk from payless to starbucks
walk from starbucks to oldnavy
```

In each step of the directions we walk to one of the 4 adjacent neighboring city blocks. We cannot directly walk to one of the diagonal blocks. Also, there is usually more than one solution. Your program may output any correct shortest-path solution.

9.1 Store Location Helper Function [/6]

First, write a helper function to find the location of a single store in the city grid. You may assume there are no duplicate stores in the city.

Solution:

```
bool location(const std::vector<std::vector<std::string> > &city,
              const std::string &store_name, int &i, int &j) {
  for (i = 0; i < city.size(); i++) {
```

```
    for (j = 0; j < city[i].size(); j++) {
      if (city[i][j] == store_name) return true;
    }
  }
  return false;
}
```

9.2 Providing Step-by-step Directions [/15]

Now, using the helper function you defined in the previous part, implement the `give_directions` function. Make sure your code does simple error checking and outputs a helpful error message to `std::cerr` if either the starting point or ending point does not exist in the city.

Solution:

```
void give_directions(const std::vector<std::vector<std::string> > &city,
                     const std::string &start, const std::string &end) {
  int i,j;
  int end_i,end_j;
  if (!location(city,start,i,j)) {
    std::cerr << "ERROR: cannot find starting point " << start << std::endl;
    return;
  }
  if (!location(city,end,end_i,end_j)) {
    std::cerr << "ERROR: cannot find end point " << end << std::endl;
    return;
  }
  while (i != end_i) {
    std::cout << "walk from " << city[i][j] << " to ";
    if (i < end_i) i++; else i--;
    std::cout << city[i][j] << std::endl;
  }
  while (j != end_j) {
    std::cout << "walk from " << city[i][j] << " to ";
    if (j < end_j) j++; else j--;
    std::cout << city[i][j] << std::endl;
  }
}
```

9.3 Order Notation [/2]

If there are n blocks in the city downtown, what is the order notation of your solution?

Solution: We need to locate each store, which is a linear scan through all n stores. Then we will take at most n steps in walking between the two stores $= O(n+n+n)$. Final simplified answer $= O(n)$.

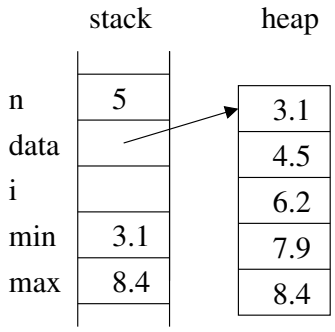
10 Minimum and Maximum Absolute Value [/20]

Finish the program below to read in a positive integer `n` followed by n floating point numbers from the keyboard (`std::cin`). The code prints out the absolute value of each of the input numbers as well as the minimum and maximum absolute values. If the user types:

```
5   3.1  -4.5  6.2  7.9  -8.4
```

The program should produce the memory diagram on the right, and output this to the console (`std::cout`):

```
absolute values: 3.1 4.5 6.2 7.9 8.4
min: 3.1
max: 8.4
```



The main function is responsible for input and output. A helper function will edit and process the data. *Note:* Make sure the finished program does not have any memory leaks.

```
int main() {
```

Solution:

```
   int n;
   std::cin >> n;
   float *data = new float[n];
   int i;
   for (i = 0; i < n; i++) {
      std::cin >> data[i];
   }
   float min;
   float max;

   find_min_and_max(data,n,min,max);
   std::cout << "absolute values: ";
   for (i = 0; i < n; i++) { std::cout << data[i] << " "; }
   std::cout << std::endl;
   std::cout << "min: " << min << std::endl;
   std::cout << "max: " << max << std::endl;
```

Solution:

```
   delete [] data;

   return 0;
}
```

Now implement the helper function `find_min_and_max`:

Solution:

```
void find_min_and_max(float data[], int n, float &min, float &max) {
  for (int i = 0; i < n; i++) {
    if (data[i] < 0)
       data[i] = -data[i];
    if (i == 0 || data[i] < min)
       min = data[i];
    if (i == 0 || data[i] > max)
       max = data[i];
  }
}
```

11 Olympic Medal Statistics [/34]

In this problem you will implement a simple class named `OlympicTeam` to keep track of the athletes on one country's team and the gold, silver, and bronze medals won by that team. Here's an example usage of the class. We create an `OlympicsTeam` object and enter data about the athletes and the medals as they are won.

```
OlympicsTeam US_Winter_2014;

US_Winter_2014.addAthlete("Sage_Kotsenburg");
US_Winter_2014.addAthlete("Hannah_Kearney");
US_Winter_2014.addAthlete("Gracie_Gold");
US_Winter_2014.addAthlete("Lindsey_Van");
US_Winter_2014.addAthlete("Shani_Davis");

US_Winter_2014.addMedal("Sage_Kotsenburg","gold");
US_Winter_2014.addMedal("Hannah_Kearney","bronze");
```

The `OlympicsTeam` object should do simple error checking on the input, making sure we do not add the same athlete multiple times, or try to count medals won by athletes not on this team, or try to add medals that are a color other than "`gold`", "`silver`" or "`bronze`". Each of the cases below results in a descriptive error message printed to `std::cerr`, with the data in the `OlympicsTeam` object unchanged.

```
US_Winter_2014.addAthlete("Gracie_Gold");
US_Winter_2014.addMedal("Michael_Phelps","gold");
US_Winter_2014.addMedal("Lindsey_Van","pewter");
```

We can output information stored in the `OlympicsTeam` object:

```
  std::cout << "The US Winter Olympics team has " << US_Winter_2014.numAthletes()
            << " athletes and has won on average " << US_Winter_2014.averageMedalsPerAthlete()
            << " medals per athlete." << std::endl;

  if (US_Winter_2014.hasWonGoldMedal("Sage_Kotsenburg")) {
    std::cout << "Sage_Kotsenburg has won a gold medal." << std::endl;
  } else {
    std::cout << "Sage_Kotsenburg has not (yet) won a gold medal." << std::endl;
  }
  if (US_Winter_2014.hasWonGoldMedal("Lindsey_Van")) {
    std::cout << "Lindsey_Van has won a gold medal." << std::endl;
  } else {
    std::cout << "Lindsey_Van has not (yet) won a gold medal." << std::endl;
  }
```

The code above results in this output to the screen (`std::cout` and `std::cerr`):

```
ERROR: cannot add duplicate athlete 'Gracie_Gold'
ERROR: athlete 'Michael_Phelps' is not a member of this team
ERROR: unknown medal color 'pewter'
The US Winter Olympics team has 5 athletes and has won on average 0.4 medals per athlete.
Sage_Kotsenburg has won a gold medal.
Lindsey_Van has not (yet) won a gold medal.
```

11.1 `OlympicTeam` Class Declaration [/14]

Using the sample code on the previous page as your guide, write the class declaration for the `OlympicTeam` object. That is, write the *header file* (`olympicteam.h`) for this class. You don't need to worry about the `#include` lines or other pre-processor directives. Focus on getting the member variable types and member function prototypes correct. Use `const` and call by reference where appropriate. Make sure you label what parts of the class are `public` and `private`. Don't include any of the member function implementations in this file: save the implementation of all functions for the next part.

Solution:

```
class OlympicsTeam {
public:
  // ACCESSORS
  int numAthletes() const;
  float averageMedalsPerAthlete() const;
  bool hasWonGoldMedal(const std::string& athlete) const;

  // MODIFIERS
  void addAthlete(const std::string &athlete);
  void addMedal(const std::string &athlete, const std::string &color);

private:
  // REPRESENTATION
  std::vector<std::string> athletes;
  std::vector<std::string> gold;
  std::vector<std::string> silver;
  std::vector<std::string> bronze;
};
```

11.2 `OlympicTeam` Class Implementation [/20]

Now implement the member functions of the class, as they would appear in the corresponding `olympicteam.cpp` file.

Solution:

```
int OlympicsTeam::numAthletes() const {
  return athletes.size();
}
```

```
float OlympicsTeam::averageMedalsPerAthlete() const {
  return (gold.size() +  silver.size() + bronze.size()) / float (athletes.size());
}

bool OlympicsTeam::hasWonGoldMedal(const std::string& athlete) const {
  for (int i = 0; i < gold.size(); i++) {
    if (gold[i] == athlete) return true;
  }
  return false;
}

void OlympicsTeam::addAthlete(const std::string &athlete) {
  for (int i = 0; i < athletes.size(); i++) {
    if (athletes[i] == athlete) {
      std::cerr << "ERROR: cannot add duplicate athlete '" << athlete << "'" << std::endl;
      return;
    }
  }
  athletes.push_back(athlete);
}

void OlympicsTeam::addMedal(const std::string &athlete, const std::string &color) {
  bool found = false;
  for (int i = 0; i < athletes.size(); i++) {
    if (athletes[i] == athlete) { found = true; }
  }
  if (found == false) {
    std::cerr << "ERROR: athlete '" << athlete << "' is not a member of this team" << std::endl;
    return;
  }
  if (color == "gold") {
    gold.push_back(athlete);
  } else if (color == "silver") {
    silver.push_back(athlete);
  } else if (color == "bronze") {
    bronze.push_back(athlete);
  } else {
    std::cerr << "ERROR: unknown medal color '" << color << "'"<< std::endl;
  }
}
```