King's College London

UNIVERSITY OF LONDON

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the Authority of the Academic Board.

M.Sci. EXAMINATION

CP/4731 The C and C++ Programming Languages

Summer 2002

Time allowed: THREE Hours

Candidates must answer any THREE questions. No credit will be given for attempting a further question.

The approximate mark for each part of a question is indicated in square brackets.

Good answers to questions will include plans and explanations in addition to sections of C or C++ code.

Some questions specify C or C++. Marks will be lost if you use C++ syntax in the solutions to questions that specify C.

You must not use your own calculator for this paper.
Where necessary, a College calculator will have been supplied.

TURN OVER WHEN INSTRUCTED

Answer THREE questions

1) The correlation coefficient, r, of two sets of data x_i and y_i for $i = 1$ to N is given by:

$$r = \frac{N\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{N\sum x_i^2 - \left(\sum x_i\right)^2}\sqrt{N\sum y_i^2 - \left(\sum y_i\right)^2}}$$

Two sets of experimental data, each containing the same number (at present unknown) of floating point numbers, are stored in files called `data-x.d` and `data-y.d` (You may assume that the data files contain the numbers in ASCII format, separated by spaces.)

Write a program in C which reads both files, and calculates and prints the correlation coefficient between the sets of data. Note that you should not store the data at this stage.

[12 marks]

Modify the program to carry out the following additional tasks:
Test whether the correlation coefficient shows that there is a reasonable linear relationship between the two sets of data, that is if $r > 0.9$. If so, allocate space for the two sets of data and read the values in from the files again. Then use library graphical functions (which you do not have to write or even understand) to plot out the data. Prototypes of the relevant functions in the graphical library are:

```
void axes(double xmin, double xmax, double ymin, double ymax);
void plot(int N, double *x, double *y);
```

where `xmin, xmax, ymin, ymax` define the ranges on the x- and y-axes, and the x and y co-ordinates of the N points are stored in the arrays `x` and `y`.

[8 marks]

2) The "selection sort" method to order the values in an array in ascending order works in the following way. The smallest number in the array is swapped with the first element, then the same procedure is repeated for the remainder of the array, until all the numbers are in order.

Write a function in C or C++ which implements this method for a list of integers. (The list is of an initially unknown length, but you may assume that it contains less than 1000 integers). In the main function you should read the numbers in from a file `list.d`, and the sorted list should be printed into another file `sorted.d`. (You may assume that `list.d` contains the integers in ASCII format, separated by spaces.)

[20 marks]

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3) The incomplete Gamma function, $P(a, x)$, can be approximated by the following series, for integer values of $a > 0$:

$$P(a,x) = e^{-x}x^a \sum_{n=0}^{\infty} \frac{x^n}{(a+n)!}$$

This series converges very slowly for $x > a+1$. In this case, it is preferable to use the truncated "continued fraction" given by:

$$P(a,x) = \frac{e^{-x}x^a}{(a-1)!} \times \cfrac{1}{x + \cfrac{(1-a)}{1 + \cfrac{1}{x + \cfrac{(2-a)}{1 + \cfrac{2}{x + \cfrac{(3-a)}{1 + \cfrac{3}{x}}}}}}}$$

Write a function in C, with the prototype:

```
double P(int a, double x)
```

which calculates $P(a, x)$ using the most appropriate method. Take into account in your program the fact that factorials ($n!$) become very large for quite modest values of n. Your series should include enough terms for the accuracy of the result to be within 10^{-6}.
(Hint: Evaluate the continued fraction from the bottom up.)

[20 marks]

4) A sparse 2-D matrix is one in which most of the elements have values of zero. Design a class, in C++, of sparse, square 2-D matrices, which economises on the memory required to store the values of the elements by exploiting the sparsity. You may assume that no more than 10% of the elements in each matrix are non-zero.

Your class should provide a standard and a default constructor, which use dynamic allocation of memory, a destructor, and functions to access and set individual elements. (You need not include a copy constructor or overloaded assignment operator for this question.)

[15 marks]

Write an additional function to overload the addition operator, +, to add two sparse matrices, after first checking that they are the same size.

[5 marks]

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5) The definition of a certain template function in C++ may be written as:

```
template <class T>
void printArray(const T *array, const int size)
{
for (int i=0;i<size; i++)cout<<array[i]<<"  ";
cout<<endl;
}
```

Explain what a template function is and why it is useful, with reference to the features of this code.

[4 marks]

Write a main function to illustrate the use of this function to print out arrays of type int, float and char.

[4 marks]

The definition of a certain template class in C++ may be written as:

```
template <class T>
class list
{
public:
      list(int s=10);       //constructs empty list of s items
      ~list() { delete []ptr;}
      void add(const T &);
      //add new value to the end of the list
      T& take();
      //remove value from the end of list and return it
private:
      int size, top;    //size of list, location of last item
      T *ptr;
      bool empty(){return (top == 0);} //logical: is it empty?
      bool full() {return (top == size-1);}// logical: full?
};
```

Write the code for the three functions that are declared but not defined within this class definition. Ensure that your code will check that the list is not empty when attempting to take items from it, and whether the list is full when adding items to it.

[6 marks]

Write a short main function that illustrates the use of your functions in this class with lists of type int and float.

[6 marks]

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