1 Distributed Systems

A distributed software system follows the client-server model. The microkernel on which it is based supports multi-threaded processes. A remote procedure call (RPC) package is used for client-server interactions. The RPC system runs above an unreliable, datagram-based communications service.

(a) Explain how timers may be used in the RPC protocol to achieve client-server synchronisation. [10 marks]

(b) Discuss how the RPC system may support the location of remote procedures. [7 marks]

(c) Discuss the requirements on the RPC system that follow from the use of multi-threaded processes. [3 marks]
2 Common Lisp

You are asked by your manager to write a Lisp macro, \texttt{itercall}. Evaluating \texttt{(itercall \textit{F} \textit{E})} evaluates \textit{E}, which is expected to yield a non-negative integer \textit{n}. It then executes the function calls \texttt{(\textit{F} \textit{1}), \ldots, (\textit{F} \textit{n})} in succession, and returns \texttt{nil}.

\textbullet{} Your first version of the macro expands to a loop, which uses the symbol \texttt{i} as an index variable and the symbol \texttt{n} to store the initial value of \textit{E}. Present the code for this version. [5 marks]

\textbullet{} Your manager complains that the function

\begin{verbatim}
(defun test1 (i) (itercall (lambda (x) (print (cons x i))) 10))
\end{verbatim}

does not work as expected. Explain the problem and suggest how to fix it by modifying the macro. [4 marks]

\textbullet{} Your manager requests a final modification: \texttt{(itercall \textit{F} \textit{E})} should generate straight-line code instead of a loop provided \textit{E} is an integer constant less than twenty. Present the code for this version. Will it run faster than the previous versions? [11 marks]

Note: \texttt{(integerp \textit{x})} tests whether \textit{x} is an integer. Each time \texttt{(gensym)} is called, it returns a new symbol not previously used in the Lisp system.

3 Software Engineering

Give a brief description of the main constructs used in a VDM specification. [7 marks]

Discuss to what extent the notation used in VDM is significantly different from that used in a conventional programming language. [6 marks]

Use VDM to specify a function that will find the difference between the largest and the smallest values held in an integer array. [7 marks]
4 Prolog

The following Prolog clauses define the procedure named reverse. The goal reverse(X,Y) succeeds for the list X, instantiating Y to the reverse of the list X. For example, evaluating the goal reverse([a,b,c],Q) instantiates Q to [c,b,a].

reverse(X,Y) :- rev(X,[],Y).

rev([],L,L).
rev([H|T],R,Y) :- rev(T,[H|R],Y).

Explain how this procedure works, using a small example. [10 marks]

What is the outcome of the goal reverse(L,[a,b,c])? Explain your answer carefully. [10 marks]

5 Programming Language Compilation

Give a brief description of the main features of Lex and Yacc. [5+5 marks]

Illustrate their use by outlining how you would construct a parser for expressions composed of identifiers, integers, function calls and the operators *, /, + and -. [10 marks]

6 UNIX Case Study

Show how race conditions can arise:

(a) among processes over access to shared data [4 marks]
(b) between processes and interrupt-driven routines [4 marks]

Discuss why the UNIX kernel cannot be run on a shared-memory multiprocessor. [7 marks]

Outline how the UNIX kernel could be modified to run on a shared-memory multiprocessor. [3 marks]

Describe briefly an alternative approach. [2 marks]
7 Operating System Functions

In relation to virtual memory, describe the terms *segment*, *page* and *translation lookaside buffer* (TLB). [6 marks]

The operating system for a microprocessor supports a virtual memory model which implements both segmentation and paging. The only hardware assistance for the virtual memory system in the microprocessor is an on-chip TLB.

Outline the data structures held by the operating system. [5 marks]

Describe the actions of the operating system in response to an address exception due to not matching the address issued by the processor in the TLB. [5 marks]

How can the operating system use access permissions to aid its page replacement policy? [4 marks]

8 Data Structures and Algorithms

Describe

(a) how to determine whether or not a point is inside a simple plane closed polygon, paying proper attention to awkward cases [6 marks]

(b) how, with luck, to exclude large numbers of points from the convex hull of a set of points in the plane, with due consideration of what can go wrong [7 marks]

(c) how to compute economically the convex hull of the points that are left after the measures you have described in (b) above [7 marks]

9 Graphics II

When scan-converting items for display, a Z-buffer is sometimes used to avoid some sorting. Outline its operation and limitations. [12 marks]

The use of an A-buffer will improve matters. Explain why. [8 marks]
10 Numerical Analysis I

What is meant by the term loss of significance? What is the essential difference between the terms condition and stability in numerical analysis? Define the term machine epsilon and explain why it is an important parameter. [6 marks]

Use the recurrence formula

\[ \cos[(k+1)\theta] = 2 \cos \theta \cos[k\theta] - \cos[(k-1)\theta] \]

with starting values \( \cos 0 = 1 \), \( \cos \theta = \frac{1}{\sqrt{2}} + \varepsilon \) to evaluate \( \cos 2\theta \) and show that loss of significance occurs. [4 marks]

Evaluate \( \cos 3\theta \) and \( \cos 4\theta \), ignoring terms \( O(\varepsilon^3) \). On this evidence, comment on the stability of the formula. [8 marks]

Is the computed value of \( \cos 2\theta \) acceptable? Explain your answer. [2 marks]

11 Discrete Mathematics

Let \( A \) be a non-empty set, and \( \prec \) be a relation on \( A \). What is meant by saying that \( (A, \prec) \) is a partially ordered set? [3 marks]

What additional conditions must be satisfied if \( (A, \prec) \) is to form:

(a) a totally ordered set [1 mark]

(b) a well-ordered set [2 marks]

(c) a complete partially ordered set? [3 marks]

Suppose now that \( A \) is a non-empty set, \( R \) a relation on \( A \), and \( B \subseteq A \) a non-empty subset. Write \( R_B = R \cap (B \times B) \) for the relation induced on \( B \) by \( R \). Show that if \( (A, \prec) \) is a partially ordered set, so also is \( (B, \prec_B) \). [1 mark]

On the set \( \mathbb{Z} = \{0, \pm1, \pm2, \ldots\} \) of integers define the following relations:

(i) \( \leq \) as \( S^* \), the reflexive transitive closure of \( S = \{(n, n+1) : n \in \mathbb{Z}\} \)

(ii) \( d = \{(m, n) : \exists q \in \mathbb{Z} \text{ such that } mq = n\} \)

For each of the set \( \mathbb{Z} \) and its subsets \( \mathbb{N} = \{0, 1, 2, 3, \ldots\}, \mathbb{N}^+ = \{1, 2, 3, \ldots\} \) say whether the relations \( \leq \) and \( d \) induce a partial ordering. Identify instances in which any of the cases (a)–(c) arises, giving your reasons briefly. [10 marks]
12 Proving Programs Correct

Explain in detail the method of verification conditions for establishing the truth of
partial correctness specifications. [10 marks]

Outline a proof that the method is correct. [10 marks]