UNIVERSITY OF EDINBURGH

FACULTY OF SCIENCE AND ENGINEERING

MASTER OF SCIENCE IN COMPUTER SCIENCE

SYSTEM INTEGRATION - 1

Friday 20 April 2001

14:00 to 15:30

Examiners:

I. Watson (External)

R.N. Ibbett (Chairman)

INSTRUCTIONS TO CANDIDATES

Answer any TWO questions.

All questions carry equal weight.

1. (a) Explain the following loop transformations and illustrate your answers with examples:

   i. Loop fusion
   ii. Loop reversal
   iii. Loop peeling
   iv. Loop unrolling
   v. Loop spreading
   vi. Software pipelining

   [*12 marks*]

   (b) Explain the following terms as used in dependence analysis of programs:

   i. True dependence
   ii. Anti dependence
   iii. Output dependence

   [*6 marks*]

   (c) Describe the dependences between statements $S1$, $S2$ and $S3$ and derive the dependence distances and direction vectors in the following loops:

   i.

```
        DO X = 1, N
            DO Y = 2, N
S1:             P(X, Y) = P(X, Y-1) + Q(X, Y)
S2:             R(X, Y) = P(X, Y) + S(X+1, Y)
S3:             S(X, Y) = 5.0
            END DO
        END DO
```

   ii.

```
        DO X = 1, N
            DO Y = 2, N
S1:             P(X, Y) = Q(X, Y) + R(X, Y)
S2:             R(X, Y) = S(X, Y)/3
S3:             T(X, Y) = P(X, Y-1) * 5 + T(X, Y-1)
            END DO
        END DO
```

   [*7 marks*]

2. (a) Discuss how the design of modern processors has been influenced by the greater interaction between the compiler and the Instruction Set Architecture. Illustrate your answer with examples. [*8 marks*]

   (b) Critically appraise the roles of the following techniques in exploiting parallelism in programs:

      i. Control dependence analysis
      ii. Simultaneous execution of multiple flows of control
      iii. Speculative execution

   [*12 marks*]

   (c) Why are systolic arrays suitable candidates for VLSI implementation [*5 marks*]

3. (a) Derive declarations for **neutrality** and **independence** in systolic computation for the inner-product step in the following cases:

   i. The multiplication of two banded matrices A and B, where p_A and q_A, and p_B and q_B are the band widths of the upper and lower triangles of matrices A and B, respectively.

   ii. The solution to the system of equations $Ax = B$, where A is a nxn lower triangular matrix, and $B = (b_1, b_2, \ldots, b_n)$ is a n-vector. [*10 marks*]

   (b) Define the following terms in the context of systolising compilation: the functions **step**, **place**, **flow** and **pattern**. [*4 marks*]

   (c) Recall that the **step** and **place** functions for the inner-product step, $(i : j : k)$, in the multiplication of two banded matrices on a rectangular array of processes is given by:

   $\text{step}((i : j : k)) = i + j + k$; $\text{place}((i : j : k)) = (i, j)$

   Propose a new **place** function such that the array size is now independent of the matrix sizes. Derive an expression for the array size in terms of the band widths, and the **flow** and **pattern** functions. [*11 marks*]