Custom Computing: Assessed Course Work

Issued date: 8 February 2023
Submission date: 23 February 2023 (submission through CATE)

Include Ruby programs, simulation commands and their results in your written submission for questions 1 and 2, which should also contain appropriate explanations and illustrations. The submission should contain TWO files: (a) one zipfile containing all your Ruby designs and simulation results; (b) one SINGLE PDF file which contains your written submission, including the diagrams and other explanation not in the comments. Both should be submitted via CATE.

1. A design $P1$ can be expressed in the Ruby language as:
$$\begin{aligned} P1 &= Q1^n; \mathit{fork}^{-1} \\ Q1 &= \mathsf{snd}\,\mathit{fork}; rsh; [add, D^{-1}] \end{aligned}$$
where $Q1 : \langle in, out \rangle \sim \langle out, in \rangle$.
   (a) Given that add describes a 2-input adder and D^{-1} describes a D register, define the wiring component rsh, and provide a diagram of $P1$ when $n = 4$. Include symbolic simulation for $P1$ when $n = 4$. (10%)
   (b) Use the transformation (no need to include its proof)
$$(A; B)^n = A^n; B^n \qquad \text{provided } A; B = B; A,$$
to derive a design $P2$ by inserting registers between the adders. Express $P2$ in the form $Q2^n; \mathit{fork}^{-1}$ and find a suitable definition for $Q2$. Provide a diagram of $P2$ when $n = 4$. Include symbolic simulation for $P2$ when $n = 4$. (15%)
   (c) Using slowdown and the transformation in Part (b), derive a fully-pipelined design $P3$ based on $P1$. Express $P3$ in the form $Q3^n; \mathit{fork}^{-1}$ and find a suitable definition for $Q3$. Provide a diagram of $P3$ when $n = 4$. Include symbolic simulation for $P3$ when $n = 4$. (15%)

   Note: in Parts (b) and (c), you may put balancing antidelays on the range of the fork^{-1}.

2. (a) Given that $[P, Q]; R = R; Q$, show by induction that $[P, Q]^n; R = R; Q^n$. (20%)
   (b) For $n > 0$, provide inductive definitions for $\mathsf{rdr}_n\, R$ and $\triangle_n\, R$. (2%)
   (c) Horner's Rule is given by:
   if $[P, Q]; R = R; Q$ then $[\triangle_n\, P, Q^n]; \mathsf{rdr}_n\, R = \mathsf{rdr}_n\, (\mathsf{snd}\, Q; R)$.
   Provide diagrams for the circuit described on the left-hand side and the circuit described on the right-hand side of this equation when n=3. (6%)
   (d) What are P, Q and R when Horner's Rule is applied to optimise polynomial evaluation? Check your answer by symbolic simulation of a polynomial evaluation design with the coefficients *a0, a1, a2, a3*. (12%)

3. Write a Maxeler MaxJ kernel to calculate N-dimensional vector dot product (inner product), given $2N$ inputs `a1, a2, ..., aN` and `b1, b2, ..., bN`. Your design should output one dot product per cycle. Omit the class declaration and import statements. Assume that `N` is available as a parameter. (20 %)