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| **Architetture dei Sistemi di Elaborazione 02GOLOV [A-L]** | Delivery date:  Wednesday, October 30, 2019 |
| **Laboratory**  **2** | Expected delivery of lab\_02.zip must include:   * program\_2.s and program\_3.s * This file, filled with information and possibly compiled in a pdf format. |

Please, configure the winMIPS64 simulator with the *Base Configuration* provided in the following:

* Code address bus: 12
* Data address bus: 12
* Pipelined FP arithmetic unit (latency): 6 stages
* Pipelined multiplier unit (latency): 8 stages
* divider unit (latency): not pipelined unit,

24 clock cycles

* Forwarding is enabled
* Branch prediction is disabled
* Branch delay slot is disabled
* *Integer ALU: 1 clock cycle*
* *Data memory: 1 clock cycle*
* *Branch delay slot: 1 clock cycle*.

1. Write an assembly program (**program\_2.s**) for the *winMIPS64* architecture described before able to implement the following piece of code described at high-level:

for (i = 0; i < 30; i++){

v5[i] = (v1[i]\*v2[i]) + v3[i];

v6[i] =(v3[i]\*v4[i])/v5[i]:

}

Assume that the vectors v1[], v2[], v3[], and v4[] are allocated previously in memory and contains 30 double precision floating point values; **assume that v5[] will not contain 0 values**. Additionally, the vectors v5[], v6[] are empty vectors also allocated in memory.

* + 1. Using the simulator and the *Base Configuration*, compute how many clock cycles take the program to execute.

1. Using the WinMIPS64 simulator, validate experimentally the Amdahl’s law, defined as follows:



1. Using the program developed before: **program\_2.s**
2. Modify the processor architectural parameters related with multicycle instructions (Menu🡪Configure🡪Architecture) in the following way:
   * + - 1. Configuration 1

Starting from the *Base Configuration*, change only the FP addition latency to 3

* + - * 1. Configuration 2

Starting from the *Base Configuration*, change only the Multiplier latency to 4

* + - * 1. Configuration 1

Starting from the *Base Configuration*, change only the division latency to 12

Compute by hand (using the Amdahl’s Law) and using the simulator the speed-up for any one of the previous processor configurations. Compare the obtained results and complete the following table.

Table 1: **program\_2.s speed-up computed by hand and by simulation**

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| **Proc. Config.**    **Speed-up comp.** | Base config.  [c.c.] | Config. 1 | Config. 2 | Config. 3 |
| **By hand** | 1386 | 1.069 | 1.095 | 1.351 |
| **By simulation** | 1386 | 1.045 | 1.095 | 1.351 |

1. Write an assembly program (**program\_3.s**) for the winMIPS64 architecture able to compute the hamming distance between two consecutive elements of a data array X[] previously allocated in memory (the array X contains 30 8-bit elements). Given two consecutive elements X[i] and X[i+1], the Hamming distance is defined as the number of bits set to 1 in (X[i] ^ X[i+1]).

If the Hamming distance is:

* even, the variable even\_counter must be incremented
* odd, the variable odd\_counter must be incremented

These two variables are allocated in memory and initially empty.

1. Considering the following *winMIPS64* architecture:

* Code address bus: 12
* Data address bus: 12
* Pipelined FP arithmetic unit (latency): 4 stages
* Pipelined multiplier unit (latency): 8 stages
* divider unit (latency): not pipelined unit, 12 clock cycles
* Forwarding is enabled
* Branch prediction is disabled
* Branch delay slot is disabled
* *Integer ALU: 1 clock cycle*
* *Data memory: 1 clock cycle*
* *Branch delay slot: 1 clock cycle*.

1. calculate by hand, how many clock cycles take the program to execute?

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| Number of clock cycles: | 1484 |

1. compute the same calculation using the *winMIPS64* simulator.

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| Number of clock cycles: | 510 |

Compare the results obtained in the points 4.a and 4.b., and provide some explanation in the case the results are different.

Eventual explanation:

La differenza del numero dei c.c. è dovuta ai salti condizionati: in alcuni cicli vengono eseguite meno istruzioni rispetto ad altri mentre nel calcolo a mano si è sempre considerato il “caso peggiore” (in cui vengono eseguite tutte le istruzioni, e quindi il numero di c.c. risulta più grande).

In particolare il numero di c.c. calcolati dalla simulazione dipende fortemente dall’input dato al programma.