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COE 308 – Computer Architecture (T032)

Homework # 01 Solution

Suppose that a program is being run on a processor consists of the following instruction mix:

Operation	Frequency	Clock cycle count per instruction
ALU operations	30%	3
Loads	20%	2
Stores	25%	2
Branches	25%	3

With the current processor, only **45%** of all ALU operations **read** operands directly from memory, the remaining ALU operations **read** operands from registers. A designer decides to investigate a modified architecture for the processor by forcing all ALU operations **not** to read operands from registers (i.e. all ALU operations are forced to read operands directly from memory). Thus, total **loads** in the program will be reduced. The modified architecture causes the "Loads" operations' clock cycle to increase by 50%. By what **percentage** the modified processor's clock cycle should be faster/slower than the current processor's clock cycle so that both processors have the same execution time?

Solution:

CPI_{old} = (30% * 3) + (20% * 2) + (25% * 2) + (25% * 3) = 2.55

$CPU\ time_{old}$ = CPI_{old} * $Instruction\ Count_{old}$ * $Clock\ Cycle_{old}$
= 2.55 * $Instruction\ Count_{old}$ * $Clock\ Cycle_{old}$

With new architecture:
Note that 45% of ALU operations already read operands directly from memory. That is, 100% - 45% = 55% of ALU operations do **NOT** read operands directly from memory, and, thus, will be replaced.

ALU operations: (30% * 55%) operations use the new ALU operations with 3 clock cycles per instruction, and 30% - (30% * 55%) operations use the original ALU operations with 3 clock cycles per instruction
Load operations: 20% - (30% * 55%) operations with 3 clock cycles per instruction
Store operations: No change
Branches: No change

Overall program reduces to 100% - (30% * 55%) = 83.5%

CPI_{new} = [(30% * 55%) * 3 + (30% - (30% * 55%)) * 3 + (20% - (30% * 55%) * 3 + 25% * 2 + 25% * 3] / 83.5%
= 2.255 / 0.835 = 2.70

$CPU\ time_{new}$ = CPI_{new} * $Instruction\ Count_{new}$ * $Clock\ Cycle_{new}$
= 2.70 * (83.5% * $Instruction\ Count_{old}$) * $Clock\ Cycle_{new}$
= 2.255 * $Instruction\ Count_{old}$ * $Clock\ Cycle_{new}$

Since execution time must be the same for both processors, then

$CPU\ time_{old}$ = $CPU\ time_{new}$

$\Rightarrow$ 2.55 * $Instruction\ Count_{old}$ * $Clock\ Cycle_{old}$ = 2.255 * $Instruction\ Count_{old}$ * $Clock\ Cycle_{new}$
$\Rightarrow$ $Clock\ Cycle_{new}$ = 1.13 * $Clock\ Cycle_{old}$

Thus, $Clock\ Cycle_{new}$ must be **13% slower** than $Clock\ Cycle_{old}$