1. **(3 points)**

   A movie film digitizer integrates a sensor and image processor with RAM and HD. The system cost 1000 euros. It work in a 4-phase cycle, where (1) the sensor captures each frame and (2) transfers the resulting image to RAM, from where (3) the processor converts it to RGB and (4) writes the result to HD. These phases are strictly sequential, so none of the 4 phases executes in parallel with the rest.

   The system allows the digitization of 10 frames per second (fps). It has been measured that the work carried out by the sensor takes $30\,\%$ of this time, the transfer of the resulting image to the RAM of the processor takes $20\,\%$, the conversion to RGB takes $40\,\%$ and finally, writing the result to the system HD takes $10\,\%$ of the time.

   Compute, for each one of the following alternatives, the system digitization speed (in fps) and determine which is the best option from a performance/cost viewpoint.

   a) Pay 200 euros and change the processor by another one $100\,\%$ faster than the original.

   b) Pay 500 euros and change the processor by another one $100\,\%$ faster than the original and the HD by an SDD unit $400\,\%$ faster than the original HD.

   c) Pay 1000 euros, keep the same HW and change the SW by another one enabling the parallel execution of the different phases: acquisition of image i, transfer of image $i-1$, conversion of image $i-2$ and storage of image $i-3$.

Solución:

a) Changing the processor by another one 100 % faster than the original, means applying an speedup of $S_p = 2$ to the fraction of time $F_p = 0{,}4$. So,

$$S' = \frac{1}{1 - 0{,}4 + 0{,}4/2} = \frac{1}{0{,}8} = 1{,}25$$

So, the resulting speed will be of 12.5 fps.
Concerning the cost/performance relation, this improvement is interesting, since the inversion (of $200/1000 = 0{,}2$) remain below the resulting speed up.

b) Changing the processor by another one 100 % faster than the original and the HD by an SDD unit 400 % faster than the original HD means: i) speeding up by a factor of $S_p = 2$ the fraction of time $F_p = 0{,}4$ and ii) speeding up by a factor of $S_d = 5$ the fraction of time $F_d = 0{,}1$

$$S' = \frac{1}{1 - 0{,}4 + 0{,}4/2 - 0{,}1 + 0{,}1/5} = \frac{1}{0{,}72} \simeq 1{,}39$$

Thus, the resulting speed will be of 13.8 fps.
This improvement is not interesting sin the inversion is of $500/1000 = 0{,}5$, which exceeds the resulting speed up.

c) The applied level of concurrency leads the slowest phase (3) to become the system bottleneck and the only one impacting the resulting system performance. This is equivalent to applying an infinite speedup $S_{1,2,4} = \infty$ to all the other of phases, which in the original configuration took a fraction of time of ($F = 0{,}6$).

$$S' = \frac{1}{1 - 0{,}6 + 0{,}6/\infty} = \frac{1}{0{,}4} = 2{,}5$$

Thus, the resulting speed is of 25 fps.
The result surpasses the inversion, which is of $1000/1000 = 100\,\%$.

From all the options where the performance improvement exceeds the increment of cost, the best one is the one exploiting the concurrency of steps via SW.

□