Actividad 2

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Resumen

Este documento presenta los resultados de diferentes intentos de paralelización realizados con base en un algoritmo de *blurring* de imágenes. Usamos primero un programa sin threading en CPU para realizar las corridas, luego, volvimos a correr el programa con threading, y, finalmente, usamos un GPU. Encontramos que el GPU es, sin duda, más eficiente y conveniente para realizar los cálculos.

Configuración

Las corridas se realizaron en un servidor local del Tecnológico de Monterrey, con los siguientes specs:

CPU

```
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3399.601
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 0
cpu cores       : 4
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:
```

```
processor       : 1
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3399.867
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 1
cpu cores       : 4
apicid          : 2
initial apicid  : 2
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:

processor       : 2
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3400.398
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 2
cpu cores       : 4
apicid          : 4
initial apicid  : 4
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
```

```
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:

processor       : 3
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3400.000
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 3
cpu cores       : 4
apicid          : 6
initial apicid  : 6
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:

processor       : 4
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3399.867
```

```
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 0
cpu cores       : 4
apicid          : 1
initial apicid  : 1
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:

processor       : 5
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3399.867
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 1
cpu cores       : 4
apicid          : 3
initial apicid  : 3
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
```

```
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:

processor       : 6
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3402.656
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 2
cpu cores       : 4
apicid          : 5
initial apicid  : 5
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:

processor       : 7
vendor_id       : GenuineIntel
cpu family      : 6
model           : 60
model name      : Intel(R) Core(TM) i7-4770 CPU @ 3.40GHz
stepping        : 3
microcode       : 0x25
cpu MHz         : 3399.867
cache size      : 8192 KB
physical id     : 0
siblings        : 8
core id         : 3
cpu cores       : 4
apicid          : 7
initial apicid  : 7
fpu             : yes
fpu_exception   : yes
```

```
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx
pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology
nonstop_tsc aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2
ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt
tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm epb invpcid_single
ssbd ibrs ibpb stibp kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase
tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln pts
flush_l1d
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf
bogomips        : 6799.22
clflush size    : 64
cache_alignment : 64
address sizes   : 39 bits physical, 48 bits virtual
power management:
```

GPU

```
Device 0: "GeForce GTX 670"
  CUDA Driver Version / Runtime Version          9.0 / 7.5
  CUDA Capability Major/Minor version number:    3.0
  Total amount of global memory:                 1996 MBytes (2093023232
bytes)
  ( 7) Multiprocessors, (192) CUDA Cores/MP:     1344 CUDA Cores
  GPU Max Clock rate:                            980 MHz (0.98 GHz)
  Memory Clock rate:                             3004 Mhz
  Memory Bus Width:                              256-bit
  L2 Cache Size:                                 524288 bytes
  Maximum Texture Dimension Size (x,y,z)         1D=(65536), 2D=(65536,
65536), 3D=(4096, 4096, 4096)
  Maximum Layered 1D Texture Size, (num) layers  1D=(16384), 2048 layers
  Maximum Layered 2D Texture Size, (num) layers  2D=(16384, 16384), 2048
layers
  Total amount of constant memory:               65536 bytes
  Total amount of shared memory per block:       49152 bytes
  Total number of registers available per block: 65536
  Warp size:                                     32
  Maximum number of threads per multiprocessor:  2048
  Maximum number of threads per block:           1024
  Max dimension size of a thread block (x,y,z): (1024, 1024, 64)
  Max dimension size of a grid size    (x,y,z): (2147483647, 65535, 65535)
  Maximum memory pitch:                          2147483647 bytes
  Texture alignment:                             512 bytes
  Concurrent copy and kernel execution:          Yes with 1 copy engine(s)
  Run time limit on kernels:                     Yes
  Integrated GPU sharing Host Memory:            No
  Support host page-locked memory mapping:       Yes
  Alignment requirement for Surfaces:            Yes
  Device has ECC support:                        Disabled
  Device supports Unified Addressing (UVA):      Yes
  Device PCI Domain ID / Bus ID / location ID:   0 / 1 / 0
```

Resultados

CPU, sin threading

Los tiempos corresponden a un promedio realizado a partir de 10 corridas.

Obtenemos un tiempo para hacer *blurring* de 240.68ms.

CPU, con threading usando OpenMP

En cada caso de prueba, los tiempos corresponden a un promedio realizado a partir de 10 corridas.

Caso de prueba	No. de threads	Tiempo para hacer *blurring*	Speedup
1	2	135.543ms	1.78
2	4	72.265ms	3.33
3	8	73.542ms	3.27

GPU con CUDA

Block: (16, 16), grid: (43, 64)

Los tiempos corresponden a un promedio realizado a partir de 10 corridas.

Obtenemos un tiempo para hacer *blurring* de 41.74ms. Esto corresponde a un speedup de 5.77.

Block: (32, 32), grid: (22, 32)

Los tiempos corresponden a un promedio realizado a partir de 10 corridas.

Obtenemos un tiempo para hacer *blurring* de 51.50ms. Esto corresponde a un speedup de 4.67.

Block: (64, 64), grid: (11, 16)

Los tiempos corresponden a un promedio realizado a partir de 10 corridas.

Obtenemos un tiempo para hacer *blurring* de 0.1714ms. Esto corresponde a un speedup de 1,404.

Conclusiones

Con base en lo anterior, podemos afirmar lo siguiente:

- Si bien es significativo, el speedup obtenido con threading en CPU es mínimo comparado al speedup obtenido con uso de GPU.
- A partir de 4 threads en CPU, el speedup no aumenta significativamente.
- Con GPU, el speedup alcanza valores importantes.

- Obtenemos resultados impresionantes de speedup con la configuración en bloques de (64, 64).

Estos resultados reafirman la efectividad de los GPUs ante los CPUs para realizar cálculos intensivos y altamente paralelizables.