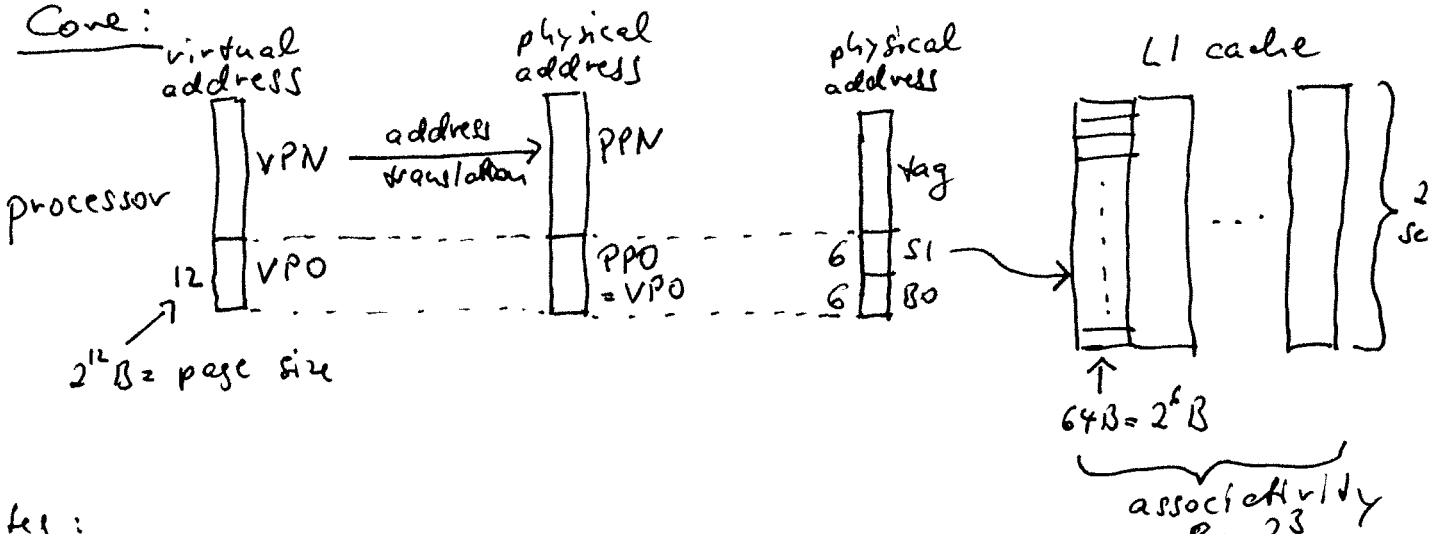
Optimizations related to the Virtual Memory System

Background: (Core)
- the processor works with virtual addresses
- all caches work with physical addresses
- both address spaces are organized in pages
  typical page size: 4KB
- so the address translation translates virtual page numbers into physical page numbers

Core:



Notes:
VPN = virtual page number
VPO = " " offset
PPN = physical page number
PPO = " " offset
SI = set index
BO = block offset

address translation: VPN → PPN
VPO = PPO = SI ∪ BO ⟹ cache lookup can start before VPN → PPN translation is finished!

address translation
- uses a cache called translation lookaside buffer (TLB)
- Core 2: two levels of caches for loads
  DTLB0: 16 entries
  DTLB1: 256 entries

  Pentium 4:
  - one TLB
  - 64 entries

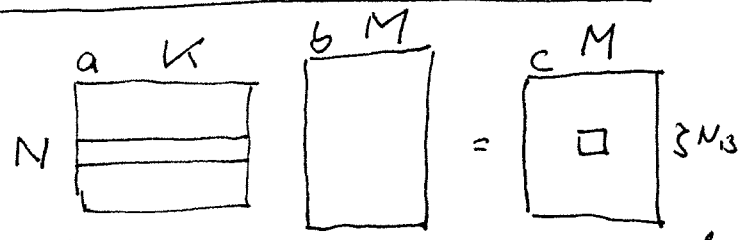
  Case 1: DTLB0 hit: no penalty
  DTLB1 hit: 2 cycle penalty
  miss: possibly very expensive

Consequence: Repeatedly accessing a working set that is spread over >256 pages leads to TLB misses → possible severe slowdown

Solution 1: use larger pages
may require different kernel (OS) and C std library

Solution 2 (if possible): copy working set into contiguous memory
⇒ less pages are used

How does this affect MMM?



ijk loop order, blocked into mini-MMM

which memory regions are repeatedly accessed?
- block row of a: is contiguous
- all of b: is contiguous
- tile of c: can be spread over N_S pages
  if $M > 512$ (512 doubles = 4 KiB = page size)

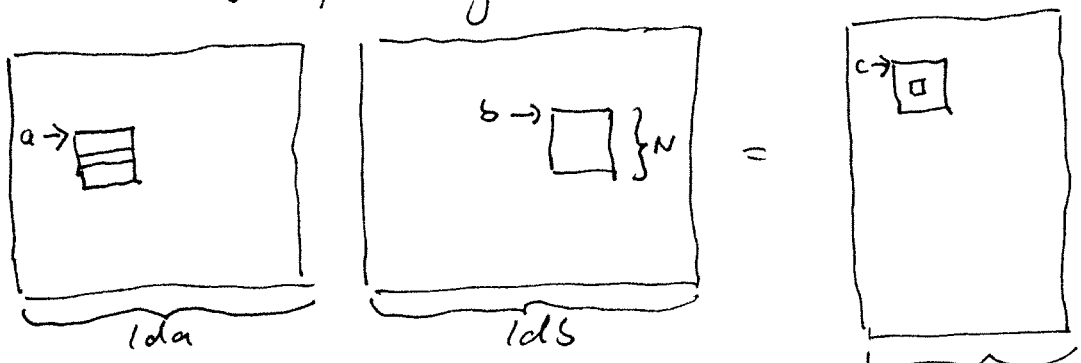
Sol: typically $N_S < 100 <$ size (DTLB1)
so at most 2 cycles penalty per row
⇒ not worth to copy (on Core)

But: the BLAS 3 function dgemm has this interface:

dgemm(a, b, c, N, K, M, lda, ldb, ldc)

matrix pointers — matrix dimensions — ~~leading~~ "leading" dimensions

The leading dimensions enable dgemm to be called on submatrices of larger matrices:



which memory regions are repeatedly accessed?
- block row of a: spread over ≤ N_S pages
- all of b: spread over ≤ N pages
- tile of c: spread over ≤ N_S pages

here copy may pay off for large enough N and lda > N

Code :

```
// all of B reused : possibly copy
for i = 0 : N_B : N-1
    // block row of A reused : possibly copy
    for j = 0 : N_B : M-1
        // tile of C reused : possibly copy
        for k = 0 : N_B : K-1
            ..... .....
```