Programming Assignment #2

Matrix-Matrix Multiplication with SSE
Matrix-Matrix Multiplication

- Building block for Matrix-Matrix Multiplication
  - $M_{nxk} \times V_k = V_n$
Matrix-Matrix Multiplication in C

- Doubly nested loop
  - Loop \( n \) times with inner product

- Inner product: \( x = (x_1, x_2, \ldots, x_k) \) and \( y = (y_1, y_2, \ldots, y_k) \)
  - \( x \cdot y = x_1y_1 + x_2y_2 + \ldots + x_ky_k \)

```c
float x[k], y[k];
float inner_product = 0.0;
for (i = 0; i < k; i++)
    inner_product += x[i] * y[i];
```
Matrix-Vector Multiplication with SSE

typedef float v4sf __attribute__ ((mode(V4SF)));

float x[k], y[k];
float inner_product = 0.0, temp[4];
v4sf acc, X, Y;       // 4x 32-bit float vector registers

acc = __builtin_ia32_xorps(acc, acc);   // zero acc

for (i = 0; i < k-3; i+=4) {
    X = __builtin_ia32_loadups(&x[i]);
    Y = __builtin_ia32_loadups(&y[i]);
    acc = __builtin_ia32_addps(acc, __builtin_ia32_mulps(X, Y));
}
__builtin_ia32_storeups(temp, acc);

for (; i < k; i++) {
    inner_product += x[i] * y[i];
}
Programming Assignment

- Matrix-Matrix Multiplication (single-precision float)
  - C version without SSE intrinsic
  - SSE version (no assembly lang. or embedded asm, but SSE intrinsics)
  - Timing routines – using `gettimeofday()`

- Command line arguments
  - Two input files: matrix1 and matrix2
  - First line specifies the size of matrix
    - E.g. 10 4 (#rows, #columns for matrix)
  - The rest of the lines specify the contents line by line

- Insert timing routine for core computation and report time
SSE builtins

Useful intrinsics

```c
v4sf __builtin_ia32_loadups(float *)
void __builtin_ia32_storeups(float *, v4sf)
v4sf __builtin_ia32_addps(v4sf, v4sf) // parallel arithmetic ops
v4sf __builtin_ia32_subps(v4sf, v4sf)
v4sf __builtin_ia32_mulps(v4sf, v4sf)
v4sf __builtin_ia32_divps(v4sf, v4sf)
v4sf __builtin_ia32_xorps(v4sf, v4sf) // 128-bit XOR
```

// Can be used to quickly generate 0s

- Consider FMA for combination of add and multiply
- Compile with GNU Compiler (example)
  - `gcc -Wall -o mvm.exe -mmmx -msse -msse2 -msse3 mvm.c`
- Reference - GNU Compiler Manual
  - 5. Extensions to the C Language Family
    - Specifying attributes of variables, attributes of types
    - Built-in functions Specific to Particular Target Machines
      - X86 Built-in Functions
Submission

- **Due date**
  - Posted on class web page
  - Delayed submission: 10% per day, up to 50% of your score

- `<student-id>.tar`
  - C-only source code,
  - C with SSE source code
  - Makefile
  - Test input files
  - Readme.docx (instruction for make and run, description of functions)

- icampus - http://www.icampus.ac.kr