Prefetching

Prefetching is used to place a cache line in memory before it is to be used, thus hiding the latency of fetching from off-chip memory.

There are two key issues here:
1. Issuing the prefetch at the right time
2. Issuing the prefetch at the right distance

The right time:
If the prefetch is issued too late, then the memory values won’t be back when the program wants to use them, and the processor has to wait anyway.
If the prefetch is issued too early, then there is a chance that the prefetched values could be evicted from cache by another need before they can be used.

The right distance:
The `prefetch distance` is how far ahead the prefetch memory is than the memory we are using right now.
Too far, and the values sit in cache for too long, and possibly get evicted.
Too near, and the program is ready for the values before they have arrived.

Prefetching in g++

```c
#define WILL_READ_ONLY 0
#define WILL_READ_AND_WRITE 1
#define LOCALITY_NONE 0
#define LOCALITY_LOW 1
#define LOCALITY_MED 2
#define LOCALITY_HIGH 3
#define PD 32 // prefetch distance (fp words)
for( int i = 0; i < ArraySize; i++ )
{
    if( (i%16) == 0 )
    {
        __builtin_prefetch ( &a[ i+PD ],   WILL_READ_AND_WRITE,  LOCALITY_LOW );
        __builtin_prefetch ( &b[ i+PD ],   WILL_READ_ONLY ,              LOCALITY_LOW );
    }
    a[ i ] = a[ i ] + b[ i ];
}
```

Prefetching in icc and icpc

```c
#pragma prefetch a:0:8
#pragma prefetch a:1:32
#pragma prefetch b:1:32
for( int i = 0; i < ArraySize; i++ )
{
    if( (i%16) == 0 )
    {
        __builtin_prefetch ( &a[ i+PD ],   WILL_READ_AND_WRITE,  LOCALITY_LOW );
        __builtin_prefetch ( &b[ i+PD ],   WILL_READ_ONLY ,              LOCALITY_LOW );
    }
    a[ i ] = a[ i ] + b[ i ];
}
#pragma prefetch var:which-prefetch:#vector-iterations
```

Overall, icc and icpc seem to do a good job of prefetching without you doing anything extra, but if you want to be sure:

```c
vprefetch0
vprefetch1
```

There can be two memory prefetches inside a loop.

Prefetching in Visual Studio

```c
void _m_prefetch( void *);
```

Loads a cache line into cache and sets the cache line state to `exclusive`.

```c
#define PD 32 // prefetch distance (fp words)
for( int i = 0; i < ArraySize; i++ )
{
    if( (i%16) == 0 )
    {
        _m_prefetch( &a[ i+PD ]);
        _m_prefetch( &b[ i+PD ]);
    }
    a[ i ] = a[ i ] + b[ i ];
}
```

The Effects of Prefetching on SIMD Computations

```c
for( int i = 0; i < NUM; i += SIMDSIZE)
{
    __builtin_prefetch ( &A[ i+PD ],  WILL_READ_ONLY ,              LOCALITY_LOW);
    __builtin_prefetch ( &B[ i+PD ],  WILL_READ_ONLY ,              LOCALITY_LOW);
    __builtin_prefetch ( &C[ i+PD ],  WILL_READ_AND_WRITE,  LOCALITY_LOW);
    SimdMul( &A[ i ], &B[ iI ], &C[ i ], SIMDSIZE);
}
```

Array Multiplication Example

- Length of Arrays (NUM): 1,000,000
- Number of pairs of floats processed per SIMD call (SIMDSIZE): 4
- Prefetch Distance (PD): 32
The Effects of Prefetching on SIMD Computations

The diagram shows the speed of SIMD computations in MegaMults per second as a function of array size (M). The graph compares different prefetching techniques, with lines indicating various levels of prefetching and their impact on performance. The axes are labeled as follows:

- X-axis: Array Size (M)
- Y-axis: Speed (MegaMults/Second)