Where there is life, there is hope

原 openMP学习笔记

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本次学习课程来自Intel 高级研究员Tim Mattson

课程视频下载地址(全英文且无字幕):

链接：https://pan.baidu.com/s/1nw6pcRv 密码：aolo

虽然最近量子计算和Nvidia CUDA技术越来越热，但是工业上都采用arm架构的嵌入式设备，负担不起nvidia的成本，所以学enMP、SIMD之类的还是比较重要的。

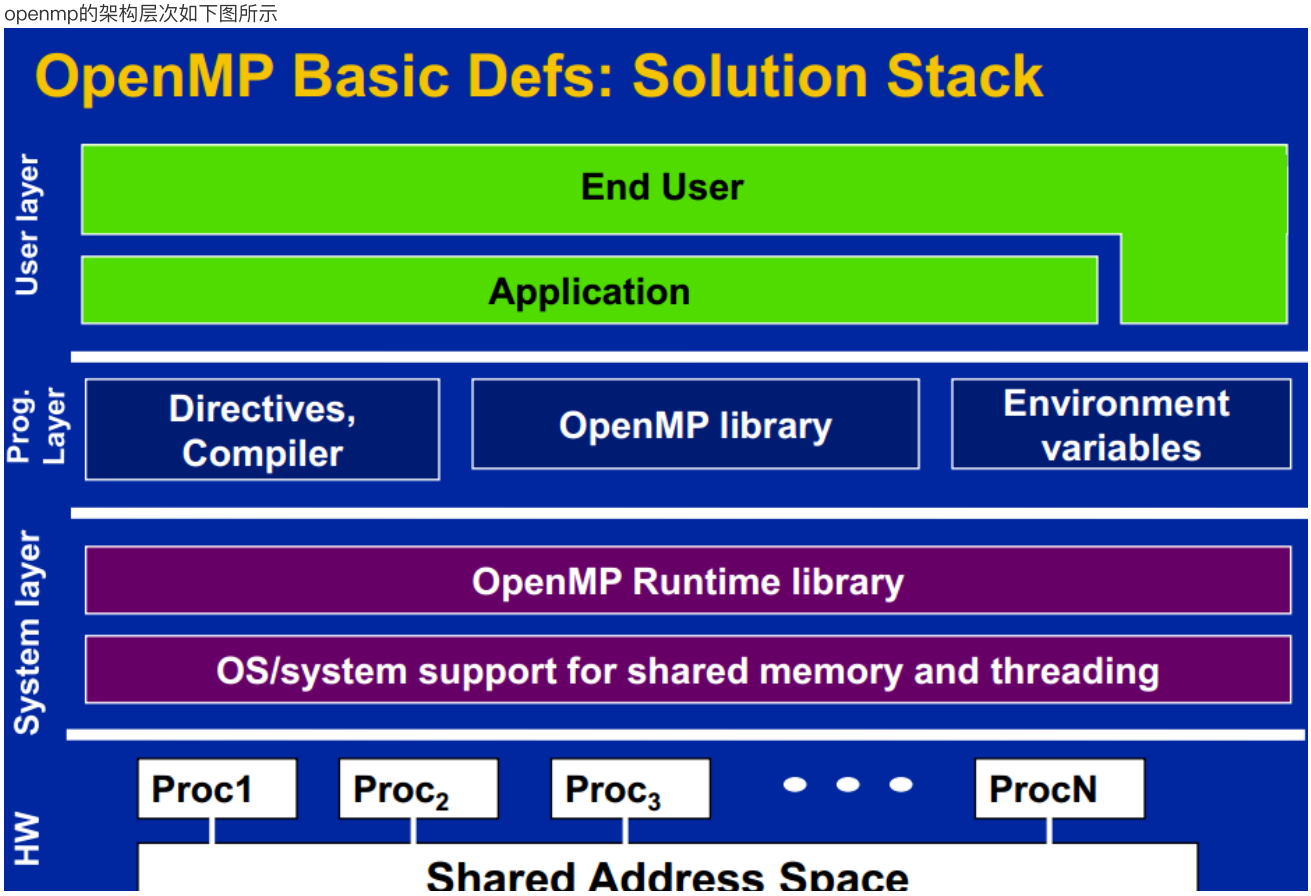
1.openmp是干什么的

openmp是一个跨平台的、较常用的基于共享内存(地址空间)的并行编程模型，它提供一组编译指令集和库例程给并行应用开发者，openmp只支持fortran,c和c++。Linux下的gcc天然支持openmp（注意版本）。

```
[plain]
1. echo |cpp -fopenmp -dM |grep -i open
```

```
jst@jst-pc:~$ echo |cpp -fopenmp -dM |grep -i open
#define _OPENMP 201307
jst@jst-pc:~$
```


openmp的架构层次如下图所示



openmp内线程是如何交互的?

openmp是一个多线程、共享地址模型，不同线程通过共享变量交互信息。但是随意的数据共享将会导致竞争问题，即每次程序运行的结果都会因OS不同的线程调度执行次序而改变。为了控制竞争问题，openmp采用同步策略来保护数据冲突。但是，同步策略是非常昂贵的，消耗performance的。因此，合格的openmp程序员，将以最小的同步代价来制定数据的访问规则。

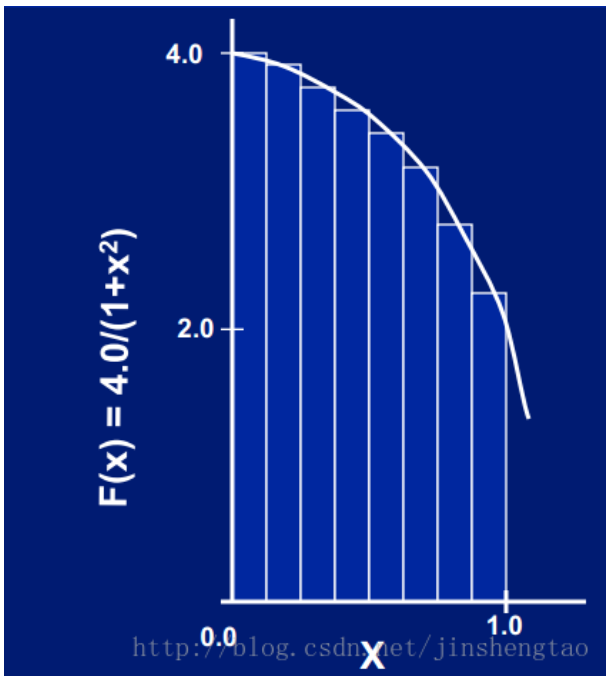
2.一则求PI的例子

我们不来搞hello world这种入门例子了，直接通过对求PI程序的三种优化方法，来感悟下openmp的魅力

$$\int_0^1 \frac{4}{1+x^2} dx = \pi$$

计算机没法求解连续问题，就用数学插值法来离散化求解

$$\sum_{i=0}^{N} F(x_i)\Delta x \approx \pi$$



原来的串行代码:

```cpp
#include <stdio.h>
#include <omp.h>
static long num_steps = 100000000;
double step;
int main ()
{
      int i;
      double x, pi, sum = 0.0;
      double start_time, run_time;

      step = 1.0/(double) num_steps;


      start_time = omp_get_wtime();

      for (i=1;i<= num_steps; i++){
          x = (i-0.5)*step;
          sum = sum + 4.0/(1.0+x*x);
      }

      pi = step * sum;
      run_time = omp_get_wtime() - start_time;
```

SPMD(singleprogram multiple data)优化，每个线程做各自的统计，最后通过atomic同步机制汇总

```cpp
#include <stdio.h>
#include <omp.h>

#define MAX_THREADS 4

static long num_steps = 100000000;
double step;
int main ()
{
      int i,j;
      double pi, full_sum = 0.0;
      double start_time, run_time;
      double sum[MAX_THREADS];

      step = 1.0/(double) num_steps;


for(j=1;j<=MAX_THREADS ;j++){
   omp_set_num_threads(j);
   full_sum = 0.0;
      start_time = omp_get_wtime();
#pragma omp parallel private(i)
{
      int id = omp_get_thread_num();
      int numthreads = omp_get_num_threads();
      double x;

      double partial_sum = 0;

#pragma omp single
      printf(" num_threads = %d",numthreads);

      for (i=id;i< num_steps; i+=numthreads){
          x = (i+0.5)*step;
          partial_sum += + 4.0/(1.0+x*x);
      }
#pragma omp critical
          full_sum += partial_sum;
}

      pi = step * full_sum;
      run_time = omp_get_wtime() - start_time;
      printf("\n pi is %f in %f seconds %d threds \n ",pi,run_time,j);
}
}
```

openMP Loop Parallelism 优化，注意openmp for loop 语法，另外注意reduction归约操作

```cpp
#include <stdio.h>
#include <omp.h>
static long num_steps = 100000000;
double step;
int main ()
{
      int i;
      double x, pi, sum = 0.0;
      double start_time, run_time;

      step = 1.0/(double) num_steps;
     for (i=1;i<=4;i++){
          sum = 0.0;
          omp_set_num_threads(i);
      start_time = omp_get_wtime();
#pragma omp parallel
{
#pragma omp single
      printf(" num_threads = %d",omp_get_num_threads());

#pragma omp for reduction(+:sum)
      for (i=1;i<= num_steps; i++){
```

```
}
      pi = step * sum;
      run_time = omp_get_wtime() - start_time;
      printf("\n pi is %f in %f seconds and %d threads\n",pi,run_time,i);
}
}
```

分治法(Divide and Conquer Pattern)优化，openmp task是高级特性，从openmp3.1后开始支持

Program: OpenMP tasks (divide and conquer pattern)

```
#include <omp.h>
static long num_steps = 100000000;
#define MIN_BLK  10000000
double pi_comp(int Nstart,int Nfinish,double step)
{  int i,iblk;
  double x, sum = 0.0,sum1, sum2;
  if (Nfinish-Nstart < MIN_BLK){
    for (i=Nstart;i< Nfinish; i++){
      x = (i+0.5)*step;
      sum = sum + 4.0/(1.0+x*x);
    }
  }
  else{
    iblk = Nfinish-Nstart;
    #pragma omp task shared(sum1)
       sum1 = pi_comp(Nstart,        Nfinish-iblk/2,step);
    #pragma omp task shared(sum2)
       sum2 = pi_comp(Nfinish-iblk/2, Nfinish,      step);
    #pragma omp taskwait
      sum = sum1 + sum2;
  }return sum;
}
```

```
int main ()
{
  int i;
  double step, pi, sum;
   step = 1.0/(double) num_steps;
   #pragma omp parallel
   {
      #pragma omp single
         sum = pi_comp(0,num_steps,step);
    }
     pi = step * sum;
}
```


3.其他例子

生产者与消费者问题优化

原始的串行代码：

```
[cpp]
#include <omp.h>
#ifdef APPLE
#include <stdlib.h>
#else
#include <malloc.h>
#endif
#include <stdio.h>

#define N        10000

/* Some random number constants from numerical recipies */
#define SEED       2531
#define RAND_MULT  1366
#define RAND_ADD   150889
#define RAND_MOD   714025
int randy = SEED;

/* function to fill an array with random numbers */
void fill_rand(int length, double *a)
{
   int i;
   for (i=0;i<length;i++) {
     randy = (RAND_MULT * randy + RAND_ADD) % RAND_MOD;
     *(a+i) = ((double) randy)/((double) RAND_MOD);
   }
}
```

```
{
   int i;  double sum = 0.0;
   for (i=0;i<length;i++)  sum += *(a+i);
   return sum;
}

int main()
{
  double *A, sum, runtime;
  int flag = 0;

  A = (double *)malloc(N*sizeof(double));

  runtime = omp_get_wtime();

  fill_rand(N, A);        // Producer: fill an array of data

  sum = Sum_array(N, A);  // Consumer: sum the array

  runtime = omp_get_wtime() - runtime;

  printf(" In %f seconds, The sum is %f \n",runtime,sum);
}
```

并行优化代码，用标记符号通知消费者生产者是否完成

```
[cpp]
#include "omp.h"
#ifndef APPLE
#include <malloc.h>
#endif
#include <stdio.h>
#include <stdlib.h>

#define N        10000
#define Nthreads 2

/* Some random number constants from numerical recipies */
#define SEED       2531
#define RAND_MULT  1366
#define RAND_ADD   150889
#define RAND_MOD   714025
int randy = SEED;

/* function to fill an array with random numbers */
void fill_rand(int length, double *a)
{
   int i;
   for (i=0;i<length;i++) {
     randy = (RAND_MULT * randy + RAND_ADD) % RAND_MOD;
     *(a+i) = ((double) randy)/((double) RAND_MOD);
   }
}

/* function to sum the elements of an array */
double Sum_array(int length, double *a)
{
   int i;  double sum = 0.0;
   for (i=0;i<length;i++)  sum += *(a+i);
   return sum;
}

int main()
{
  double *A, sum, runtime;
  int numthreads, flag = 0,flg_tmp=0;

  omp_set_num_threads(Nthreads);

  A = (double *)malloc(N*sizeof(double));

  #pragma omp parallel
  {
     #pragma omp master
     {
        numthreads = omp_get_num_threads();
```

```
            exit(-1);
         }
         runtime = omp_get_wtime();
      }
      #pragma omp barrier

      #pragma omp sections
      {
         #pragma omp section
         {
            fill_rand(N, A);
            #pragma omp flush
            flag = 1;
            #pragma omp flush (flag)
         }
         #pragma omp section
         {
            while (1){
               #pragma omp flush (flag)
               #pragma omp atomic read
                 flg_tmp = flag;
               if(flg_tmp == 1) break;
            }

            #pragma omp flush
            sum = Sum_array(N, A);
         }
       }
       #pragma omp master
          runtime = omp_get_wtime() - runtime;
   }

   printf(" with %d threads and %lf seconds, The sum is %lf \n",numthreads,runtime,sum);
}
```

链表遍历、斐波那契递归问题的优化：

原始串行代码：

```
[cpp]
#include <stdlib.h>
#include <stdio.h>
#include <omp.h>

#ifndef N
#define N 5
#endif
#ifndef FS
#define FS 38
#endif

struct node {
   int data;
   int fibdata;
   struct node* next;
};

int fib(int n) {
   int x, y;
   if (n < 2) {
      return (n);
   } else {
      x = fib(n - 1);
      y = fib(n - 2);
      return (x + y);
   }
}

void processwork(struct node* p)
{
   int n;
   n = p->data;
   p->fibdata = fib(n);
}
```

```
    struct node* head = NULL;
    struct node* temp = NULL;

    head = malloc(sizeof(struct node));
    p = head;
    p->data = FS;
    p->fibdata = 0;
    for (i=0; i< N; i++) {
       temp  =  malloc(sizeof(struct node));
       p->next = temp;
       p = temp;
       p->data = FS + i + 1;
       p->fibdata = i+1;
    }
    p->next = NULL;
    return head;
}

int main(int argc, char *argv[]) {
     double start, end;
     struct node *p=NULL;
     struct node *temp=NULL;
     struct node *head=NULL;

     printf("Process linked list\n");
     printf("  Each linked list node will be processed by function 'processwork()'\n");
     printf("  Each ll node will compute %d fibonacci numbers beginning with %d\n",N,FS);

     p = init_list(p);
     head = p;

     start = omp_get_wtime();
     {
        while (p != NULL) {
           processwork(p);
           p = p->next;
        }
     }

     end = omp_get_wtime();
     p = head;
     while (p != NULL) {
        printf("%d : %d\n",p->data, p->fibdata);
        temp = p->next;
        free (p);
        p = temp;
     }
     free (p);

     printf("Compute Time: %f seconds\n", end - start);

     return 0;
}
```

并行优化代码

看了openmp论坛，递归那边前20个不用并行优化，否则性能反而降低了

```
[cpp]
#include <omp.h>
#include <stdlib.h>
#include <stdio.h>


#ifndef N
#define N 5
#endif
#ifndef FS
#define FS 38
#endif

typedef struct node {
   int data;
   int fibdata;
   struct node* next;
```

```
void processwork(node* p);
int fib(int n);

int fib(int n)
{
   int x, y;
   if (n < 2) {
      return (n);
   } else {
    if(n<20)
       return fib(n-1)+fib(n-2);
#pragma omp task shared(x)
      x = fib(n - 1);
#pragma omp task shared(y)
      y = fib(n - 2);
#pragma omp taskwait
      return (x + y);
   }
}

void processwork(node* p)
{
   int n, temp;
   n = p->data;
   temp = fib(n);

   p->fibdata = temp;

}

node* init_list(node* p)
{
    int i;
    node* head = NULL;
    node* temp = NULL;

    head = (node*)malloc(sizeof(node));
    p = head;
    p->data = FS;
    p->fibdata = 0;
    for (i=0; i< N; i++) {
       temp  = (node*)malloc(sizeof(node));
       p->next = temp;
       p = temp;
       p->data = FS + i + 1;
       p->fibdata = i+1;
    }
    p->next = NULL;
    return head;
}

int main()
{
     double start, end;
     struct node *p=NULL;
     struct node *temp=NULL;
     struct node *head=NULL;

     printf("Process linked list\n");
     printf("  Each linked list node will be processed by function 'processwork()'\n");
     printf("  Each ll node will compute %d fibonacci numbers beginning with %d\n",N,FS);

     p = init_list(p);
     head = p;

     start = omp_get_wtime();

    #pragma omp parallel
    {
            #pragma omp master
                  printf("Threads:      %d\n", omp_get_num_threads());

        #pragma omp single
        {
            p=head;
            while (p) {
                #pragma omp task firstprivate(p) //first private is required
                {
```

```
            }
        }
    }

    end = omp_get_wtime();
    p = head;
    while (p != NULL) {
       printf("%d : %d\n",p->data, p->fibdata);
       temp = p->next;
       free (p);
       p = temp;
    }
    free (p);

    printf("Compute Time: %f seconds\n", end - start);

    return 0;
}
```


文章标签： openMP