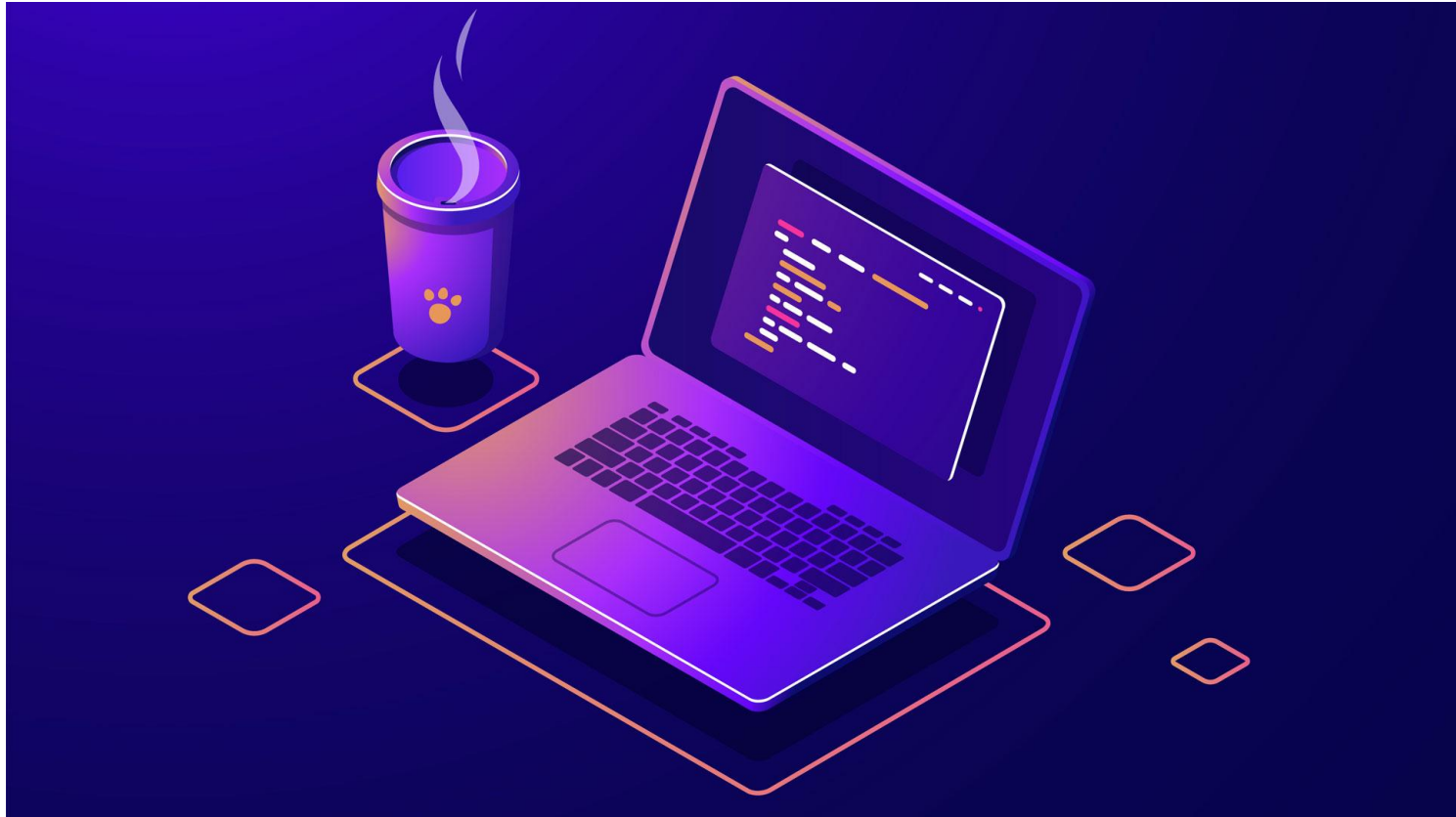


Recursive Task Decomposition in OpenMP



Task Generation Control

- Iterative Task Decompositions
- Recursive Task Decompositions

Task Generation Control

- Iterative Task Decompositions
- Recursive Task Decompositions



Task Generation Control

- Iterative Task Decompositions
- **Recursive Task Decompositions**



Task Generation Control

Recursive task decomposition: divide-and-conquer (1)

Recursively divide the problem into smaller sub-problems

```
#define N 1024
#define MIN_SIZE 64
int result = 0;

void dot_product(int *A, int *B, int n) {
    for (int i=0; i< n; i++)
        result += A[i] * B[i];
}

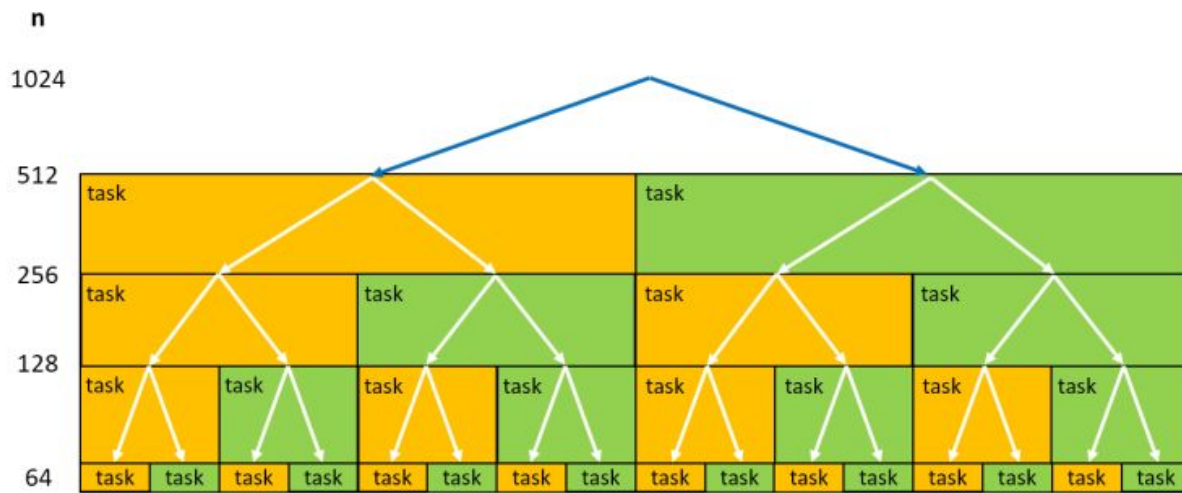
void rec_dot_product(int *A, int *B, int n) {
    if (n>MIN_SIZE) {
        int n2 = n / 2;
        rec_dot_product(A, B, n2);
        rec_dot_product(A+n2, B+n2, n-n2);
    }
    else
        dot_product(A, B, n);
}

void main() {
    rec_dot_product(a, b, N);
}
```

Task Generation Control

Recursive task decomposition: tree strategy (1)

A task corresponds with each invocation of `rec_dot_product`



- ▶ Parallel generation of tasks
- ▶ Granularity: some tasks simply generate new tasks

Task Generation Control

Recursive task decomposition: different sequential code ...

```
int dot_product(int *A, int *B, int n) {
    int tmp = 0;
    for (int i=0; i< n; i++) tmp += A[i] * B[i];
    return(tmp);
}

int rec_dot_product(int *A, int *B, int n) {
    int tmp1, tmp2 = 0;
    if (n>MIN_SIZE) {
        int n2 = n / 2;
        tmp1 = rec_dot_product(A, B, n2);
        tmp2 = rec_dot_product(A+n2, B+n2, n-n2);
    } else tmp1 = dot_product(A, B, n);
    return(tmp1+tmp2);
}

void main() {
    result = rec_dot_product(a, b, N);
}
```

Task Generation Control

Recursive task decomposition: tree strategy (2)

```
int dot_product(int *A, int *B, int n) {
    int tmp = 0;
    for (int i=0; i< n; i++) tmp += A[i] * B[i];
    return(tmp);
}

int rec_dot_product(int *A, int *B, int n) {
    int tmp1, tmp2 = 0;
    if (n>MIN_SIZE) {
        int n2 = n / 2;
        #pragma omp task shared(tmp1) // firstprivate(A, B, n, n2) by default
        tmp1 = rec_dot_product(A, B, n2);
        #pragma omp task shared(tmp2) // firstprivate(A, B, n, n2) by default
        tmp2 = rec_dot_product(A+n2, B+n2, n-n2);
        #pragma omp taskwait
    } else tmp1 = dot_product(A, B, n);
    return(tmp1+tmp2);
}

void main() {
    #pragma omp parallel
    #pragma omp single
    result = rec_dot_product(a, b, N);
}
```


Shared Clause

shared: Specifies that one or more variables should be shared among all threads.

taskwait: Specifies a wait on the completion of child tasks of the current task.

Task Generation Control

Recursive task decomposition: tree strategy (2)

```
int dot_product(int *A, int *B, int n) {
    int tmp = 0;
    for (int i=0; i< n; i++) tmp += A[i] * B[i];
    return(tmp);
}

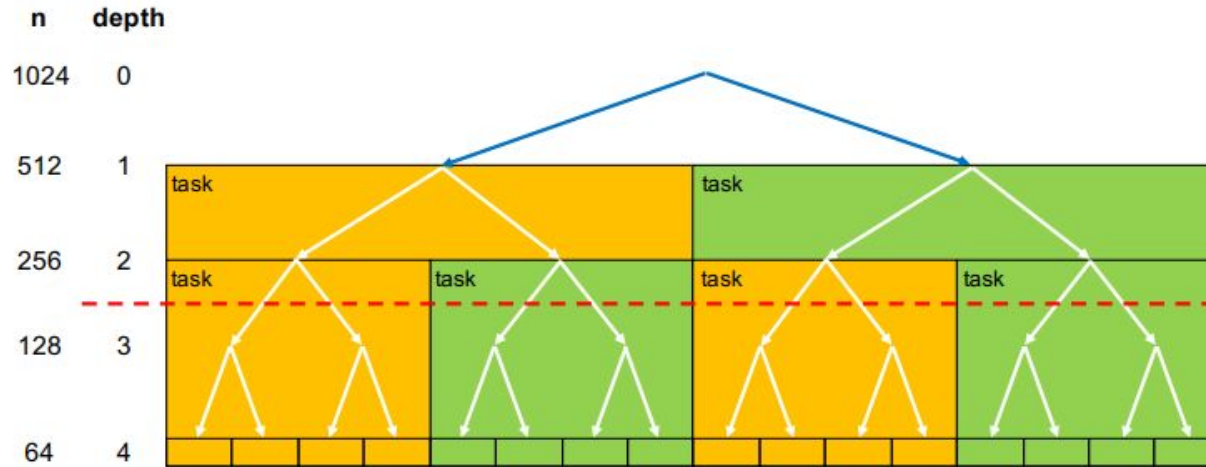
int rec_dot_product(int *A, int *B, int n) {
    int tmp1, tmp2 = 0;
    if (n>MIN_SIZE) {
        int n2 = n / 2;
        #pragma omp task shared(tmp1) // firstprivate(A, B, n, n2) by default
        tmp1 = rec_dot_product(A, B, n2);
        #pragma omp task shared(tmp2) // firstprivate(A, B, n, n2) by default
        tmp2 = rec_dot_product(A+n2, B+n2, n-n2);
        #pragma omp taskwait
    } else tmp1 = dot_product(A, B, n);
    return(tmp1+tmp2);
}

void main() {
    #pragma omp parallel
    #pragma omp single
    result = rec_dot_product(a, b, N);
}
```

Task Generation Control

How to control task granularity in tree strategy (1)

Tree strategy with **depth recursion control**



Task Generation Control

How to control task granularity in tree strategy (2)

Tree strategy with **depth recursion control**

```
#define N 1024
#define MIN_SIZE 64
#define CUTOFF 3

int rec_dot_product(int *A, int *B, int n, int depth) {
    int tmp1, tmp2 = 0;
    if (n > MIN_SIZE) {
        int n2 = n / 2;
        if (depth < CUTOFF) {
            #pragma omp task shared(tmp1)
            tmp1 = rec_dot_product(A, B, n2, depth+1);
            #pragma omp task shared(tmp2)
            tmp2 = rec_dot_product(A+n2, B+n2, n-n2, depth+1);
            #pragma omp taskwait
        } else {
            tmp1 = rec_dot_product(A, B, n2, depth+1);
            tmp2 = rec_dot_product(A+n2, B+n2, n-n2, depth+1);
        }
    }
    else tmp = dot_product(A, B, n);
    return(tmp1+tmp2);
}
```

Task Generation Control

OpenMP support for cut-off

- ▶ `final` clause: If the expression of a `final` clause evaluates to *true* the generated task and **all of its descendent tasks** will be final. The execution of a final task is sequentially **included** in the generating task (but the task is still generated)
- ▶ `omp_in_final()` intrinsic function: it returns true when executed in a final task region; otherwise, it returns false.

Task Generation Control

OpenMP support for cut-off: tree strategy

Making use of `omp_in_final`:

```
#define MIN_SIZE 64
#define CUTOFF 3
...
int rec_dot_product(int *A, int *B, int n, int depth) {
    int tmp1, tmp2 = 0;
    if (n > MIN_SIZE) {
        int n2 = n / 2;
        if (!omp_in_final()) {
            #pragma omp task shared(tmp1) final(depth >= CUTOFF)
            tmp1 = rec_dot_product(A, B, n2, depth+1);
            #pragma omp task shared(tmp2) final(depth >= CUTOFF)
            tmp2 = rec_dot_product(A+n2, B+n2, n-n2, depth+1);
            #pragma omp taskwait
        } else {
            tmp1 = rec_dot_product(A, B, n2, depth+1);
            tmp2 = rec_dot_product(A+n2, B+n2, n-n2, depth+1);
        }
    }
    else tmp1 = dot_product(A, B, n);
    return(tmp1+tmp2);
}
...
```

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