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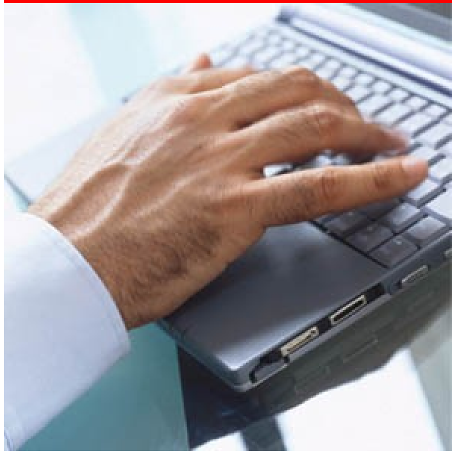
Leveraging OpenMP Infrastructure for Language Level Parallelism

Darryl Gove
Senior Principal Software Engineer

Outline



- Proposal and Motivation
- Overview of OpenMP
- Open Issues and Initial Proposal
- Concluding Remarks and Next Steps

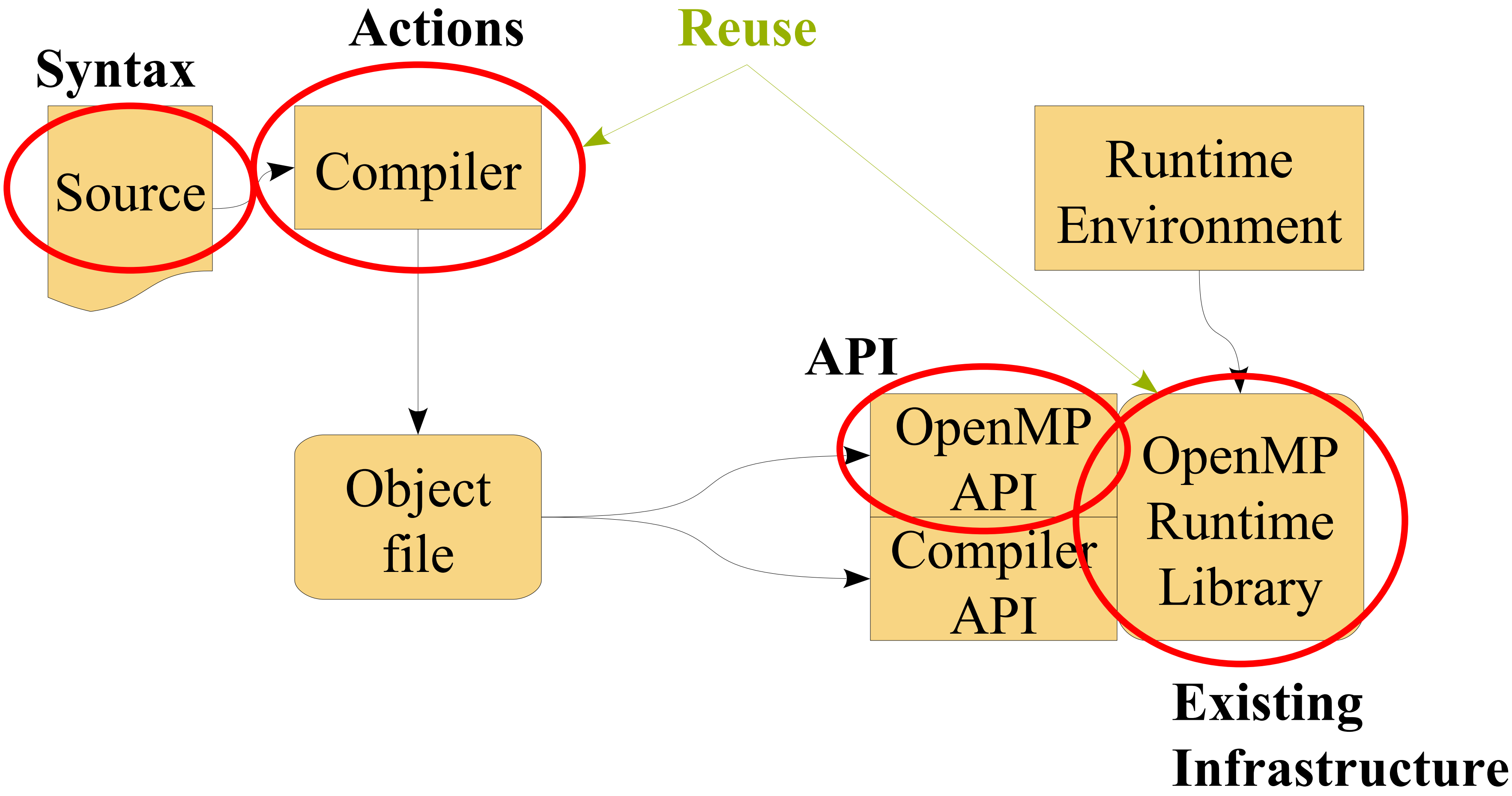
Proposal and Motivation

Why we should do this

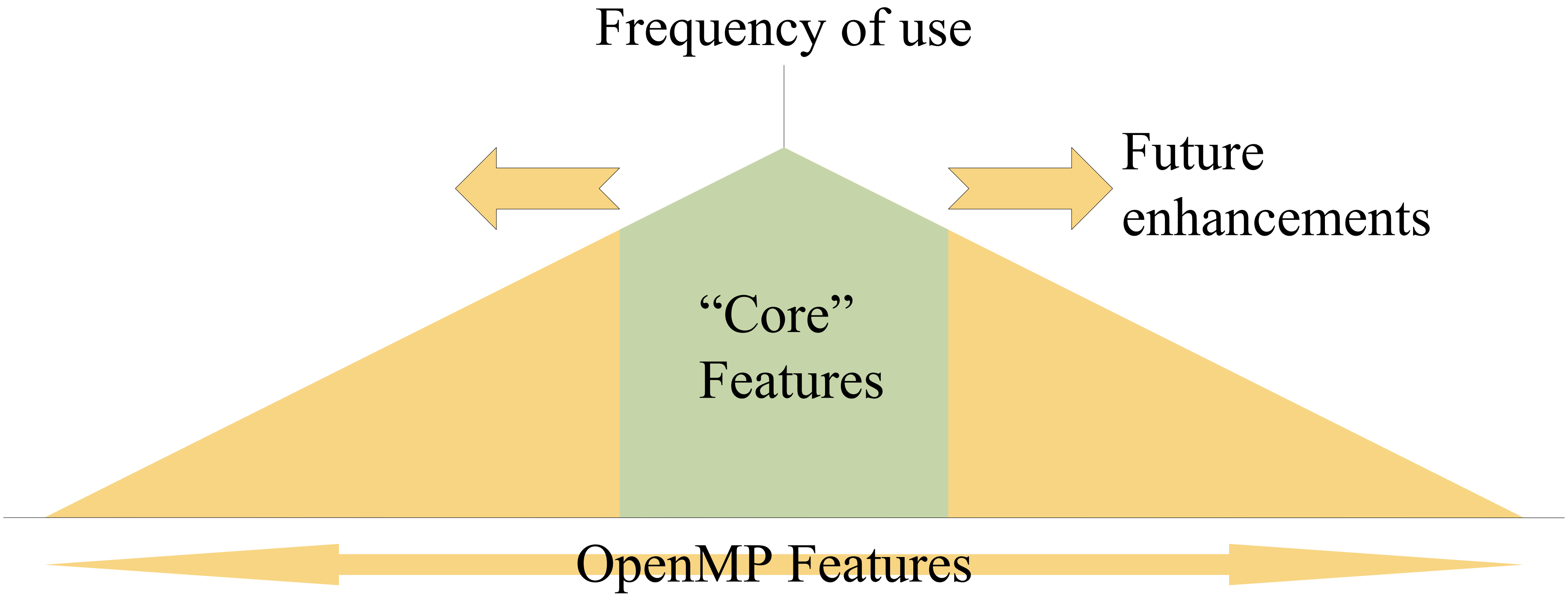
What is OpenMP

- OpenMP “describes” parallelism
  - Parallelism is “added” to the serial code
- Supported by all major compilers
- 1.0 in 1997, version 4.0 this year
- Widely used (even has benchmark suites!)

OpenMP Infrastructure



OpenMP "light"



Leveraging OpenMP

For Developers

- Familiarity for OpenMP developers
  - Easy adoption
- No conflict with OpenMP
  - Can mix parallelisation methods
  - Don’t force a choice on developers
  - Large existing code base using OpenMP
- Gentle transition *both* ways
  - “Standardise” parallel code
  - Utilise “leading edge” OpenMP

Reuse of OpenMP Infrastructure

For compilers

- Widely available on most/all platforms
  - Low development cost
  - Rapid availability
- 15 years of production use
  - Few remaining bugs
  - Already tuned
- Not another library
  - Compatibly leverages existing code
  - Low maintenance costs

Overview of OpenMP

Types of parallelisation

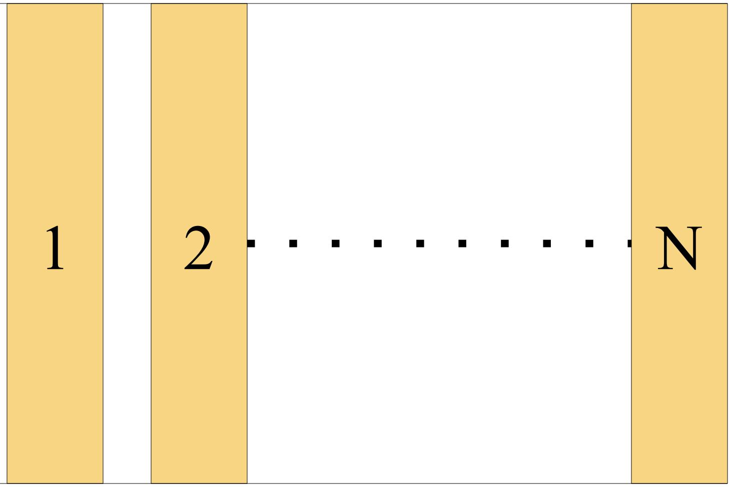
- Parallel region
- Parallel sections
- Parallel for
- Parallel tasks

Parallel Region

```
#pragma omp parallel
{

...

}
```

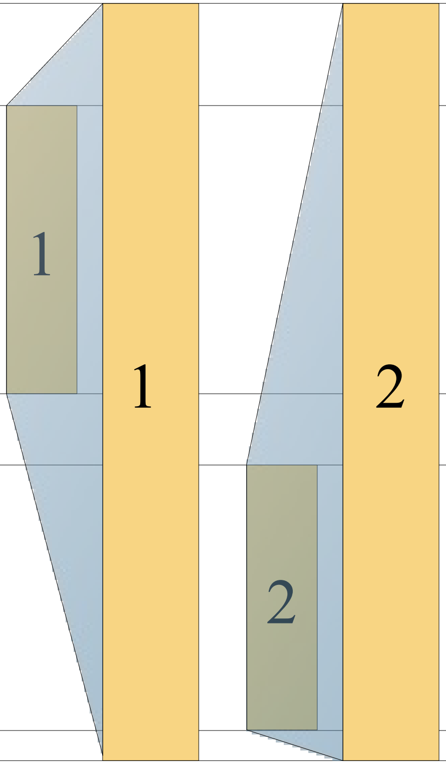


Parallel Region Example

```
#include <stdio.h>
int main()
{
  #pragma omp parallel num_threads(3)
  {
    printf("'Ello\n");
  }
}
$ cc -O -xopenmp copper.c
'Ello
'Ello
'Ello
```

Parallel Sections Example

```
#pragma omp parallel sections
{
#pragma omp section
   {
   ...
   }
#pragma omp section
   {
   ...
   }
}
```

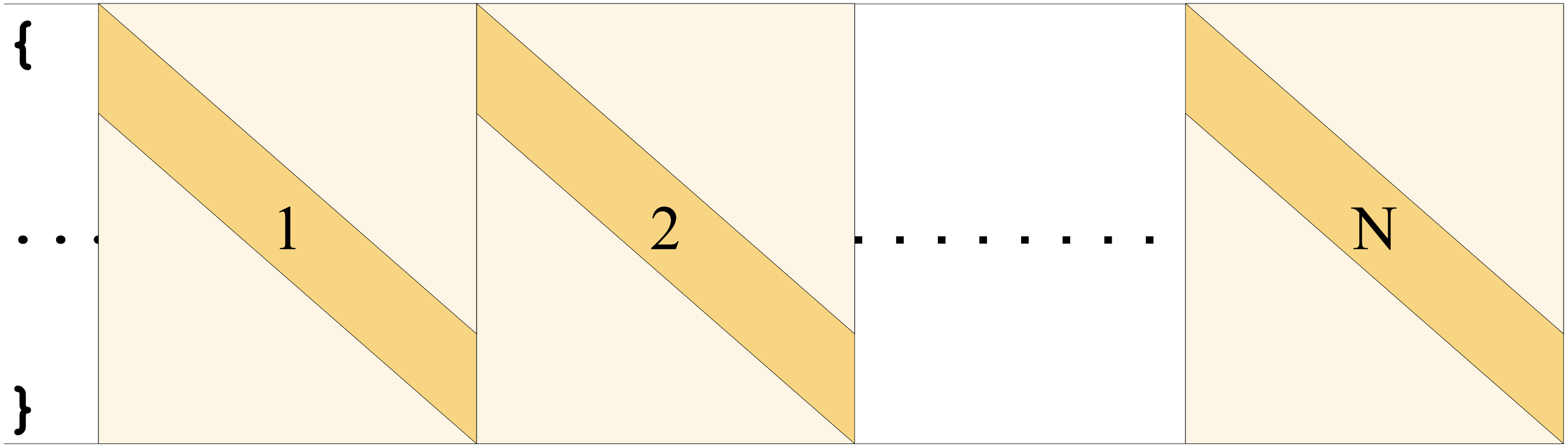


Parallel Sections

```
  #pragma omp parallel sections num_threads(2)
  {
    #pragma omp section
    { printf("Hello\n"); }
    #pragma omp section
    { printf("There\n"); }
  }
...
$ cc -O -xopenmp sections.c
$ ./a.out
There
Hello
```

Parallel For

```
#pragma omp parallel for
for (...)
{
...
}
```

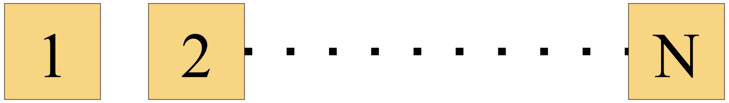


Parallel For Example

```
double sum(double * values, int length)
{
  double total=0.0;
  #pragma omp parallel for reduction(+:total)
  for (int i=0; i<100000; i++)
  {
    total += values[i];
  }
  return total;
}
```

Parallel Tasks

```
#pragma omp parallel
#pragma omp single
while (...)
{
#pragma omp task
    {
    ...
    }
}
```



Parallel Tasks Example

```
int fib(int n) {
  int i, j;
  if (n<2) return n;
  else
  {
    #pragma omp task shared(i) firstprivate(n)
    i=fib(n-1);
    #pragma omp task shared(j) firstprivate(n)
    j=fib(n-2);
    #pragma omp taskwait
    return i+j;
  } }
int main()
{
  #pragma omp parallel
  {
    #pragma omp single
    printf ("fib(%d) = %d\n", 10, fib(10));
  } }
```

Core OpenMP Parallelisation

- `#pragma omp parallel for`
  - Most commonly used
- `#pragma omp task`
  - Most flexible
- Both have “clauses”
  - How parallelisation is performed
  - How variables are scoped

OpenMP Variable scoping

- **`shared`**(var)
  - All threads share original
- **`reduction`**(operation:var)
  - All threads contribute to result
- **`private`**(var)
  - Each thread has private copy
- **`firstprivate`**(var)
  - Private but initialised to value before parallel region
- **`lastprivate`**(var)
  - Private but last value preserved after parallel region

Useful OpenMP Clauses

- **`proc_bind`** – bind threads to processors
- **`if`** – should multiple threads be used
- **`num_threads`** – number of threads used
- **`depend`** – enable ordering of tasks
- **`collapse`** – merge multiple loops

API?

Compile Time?

Core of OpenMP API

Threads

omp_[get|set]_num_threads	Number of threads used for parallel region
omp_get_max_threads	Number of threads available for use
omp_get_thread_limit	Maximum number of threads available
omp_get_thread_num	Get ID of current thread
omp_get_proc_bind	Thread binding pattern

Scheduling

omp_[get|set]_schedule	Scheduling algorithm used
omp_[get|set]_dynamic	Demand based control of number of threads

Hardware

omp_get_num_processors	Number of processors available (next slide)
omp_get_wtime	Wall time in seconds
omp_get_wtick	Precision of wall timer

A Detour into Hardware
How many threads?

- Need to know more about hardware
  - Number of hardware threads?
- Topology important
  - Threads per core?
  - Cores per socket?
  - Sockets per system?
- Performance varies depending on thread location
  - Use many cores
  - Use few sockets

Scattering or Gathering Threads

- Spread (ie scatter)
  - Use fewest threads per core
  - Gives each thread most core resources
- Close (ie co-locate)
  - Use fewest cores for threads
  - Shares core resources
  - Minimises communication costs

Open Issues and Initial Proposal

Open Issues

- Syntax
    - Many options
    - One used as illustration
- Variable scoping
    - Multiple ways to do this
    - Including *not* doing it
- What to include/exclude
    - Aiming to get most benefit
    - From fewest features

_Parallel for

```
_Parallel for (int i=0; i<1000; i++)
{
  // Work divided across all threads
  a[i] = b[i] * c[i];
}
```

_Parallel _Task

```
{
    _Parallel _Task
    { i=fib(n-1); }
    _Parallel _Task
    { j=fib(n-2); }
    waitfortasks();
    return i+j;
  }
```

`_Parallel _Task`

```
while(1)
{
  int stream = accept(s, &client, &size);
  _Parallel _Task
  {
    char buffer[1024];
    while (recv(stream,buffer,sizeof(buffer),0))
    { send(stream,buffer, strlen(buffer)+1,0); }
  }
}
waitfortasks();
```

Variable Scoping Overview

- May not need **`shared`** or **`private`**
  - Data shared by default
  - Private variables declared in parallel region
- Need reductions
  - Important
  - Tricky to emulate
- Private variants sometimes useful
  - **`firstprivate`**
  - **`lastprivate`**

Variable Scoping

- `_Parallel <`*`variable scoping`*`>`
- `For example:`

```
_Parallel _Reduction(+:temp) for (...)
{
   // Work divided across all threads
   temp += ...; // Reduction
}
```

C API

`#include <parallel.h>`

`[get|set]numthreads()`	Number of threads used for parallel region
`getmaxthreads()`	Maximum number of threads available
`getthreadID()`	Get ID of current thread
`[get|set]threadbinding()`	Thread binding pattern
`[get|set]loopschedule()`	Scheduling algorithm used
`[get|set]dynamicthreads()`	Demand based control of number of threads
`getprocessorcount()`	Number of processors available

Conclusion and Next Steps

OpenMP 4.0

- Support for user defined reductions
- Support for SIMD loops
  - simd clause + safelen(length)
- Support for GPU/Accelerators
  - target a particular device
  - map data to/from device
  - array sections
- ….

Concluding Remarks

- Co-exist with OpenMP
    - Gentle integration curve
    - Many existing users
    - Focuses compiler effort
- Leverage existing OpenMP infrastructure
    - Existing code
    - Quick time to market
    - Robust and tuned implementations

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C++ API

```
#include <parallel>
```

`parallel::numthreads`	Number of threads used for parallel region
`parallel::maxthreads`	Maximum number of threads available
`parallel::threadID`	Get ID of current thread
`parallel::threadbinding`	Thread binding pattern
`parallel::loopschedule`	Scheduling algorithm used
`parallel::dynamicthreads`	Demand based control of number of threads
`parallel::processorcount`	Number of processors available

Tasks and `std::async`

- Minimal source change (OpenMP principle)
- Thread pool
- Anonymous tasks