# Introduction to OpenMP

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# Data Scoping

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# Scoping Rules

- Managing the Data Environment is the challenge of OpenMP.
- *Scoping* in OpenMP: Dividing variables in *shared* and *private*:
  - *private*-list and *shared*-list on Parallel Region
  - *private*-list and *shared*-list on Worksharing constructs
  - General default is *shared* for Parallel Region, *firstprivate* for Tasks.
  - Loop control variables on *for*-constructs are *private*
  - Non-static variables local to Parallel Regions are *private*
  - *private*: A new uninitialized instance is created for the task or each thread executing the construct
    - *firstprivate*: Initialization with the value before encountering the construct
    - *lastprivate*: Value of last loop iteration is written back to Master
  - Static variables are *shared*

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Tasks are introduced later

# Privatization of Global/Static Variables

HPC.NRW

- Global / static variables can be privatized with the *threadprivate* directive
  - One instance is created for each thread
    - Before the first parallel region is encountered
    - Instance exists until the program ends
    - Does not work (well) with nested Parallel Region
  - Based on thread-local storage (TLS)
    - TlsAlloc (Win32-Threads), pthread_key_create (Posix-Threads), keyword `__thread` (GNU extension)

C/C++

```
static int i;
#pragma omp threadprivate(i)
```

Fortran

```
SAVE INTEGER :: i
!$omp threadprivate(i)
```

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**Really: try to avoid the use of threadprivate and static variables!**

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```

Fortran

```
SAVE INTEGER :: i
!$omp threadprivate(i)
```

# Back to our bad scaling example

HPC.NRW

C/C++

```
int i, s = 0;
#pragma omp parallel for
for (i = 0; i < 100; i++)
{
#pragma omp critical
    {  s = s + a[i];  }
}
```

# It‘s your turn: Make It Scale!



```
#pragma omp parallel

{



#pragma omp for
  for (i = 0; i < 99; i++)
  {
          s  = s   + a[i];
  }



} // end parallel
```

```
do i = 0, 99
   s = s + a(i)
end do
```

```
do i = 0, 24
   s = s + a(i)
end do
```

```
do i = 25, 49
   s = s + a(i)
end do
```

```
do i = 50, 74
   s = s + a(i)
end do
```

```
do i = 75, 99
   s = s + a(i)
end do
```

# The Reduction Clause

HPC.NRW

- In a *reduction*-operation the operator is applied to all variables in the list. The variables have to be *shared*.
  - `reduction(operator:list)`
  - The result is provided in the associated reduction variable

C/C++

```
int i, s = 0;

#pragma omp parallel for reduction(+:s)
for(i = 0; i < 99; i++)
{
   s = s + a[i];
}
```

  - Possible reduction operators with initialization value:
    `+ (0), * (1), - (0), & (~0), | (0), && (1), || (0), ^ (0), min (largest number), max (least number)`

# Reduction Operations

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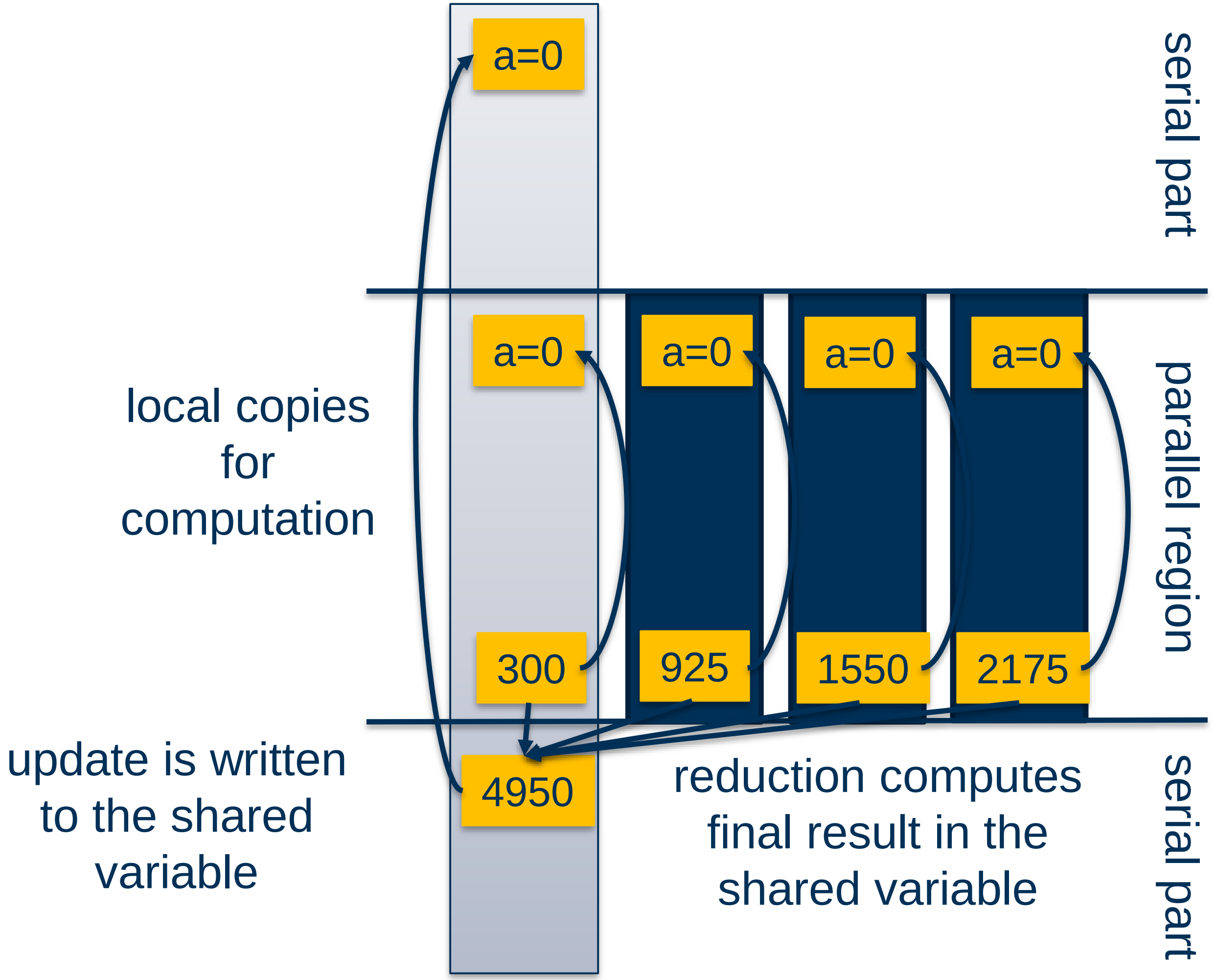
```
int a=0;
.
.
#pragma omp parallel
#pragma omp for reduction(+:a)
for (int i=0; i<100; i++)
{
      a+=i;
}
.
.
.
```



# Questions?