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Gesellschaft für Parallele Anwendungen und Systeme mbH

# OpenMP Tools

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## Introduction: OpenMP is clear and easy ..

- ☺ Easy directive based handling
- ☺ Portable code
- ☺ Single source for sequential/parallel
- ☺ Incremental parallelization
- ☺ Well–defined semantics

So, why tools ?

## Introduction: ... but

- ☹ Performance tuning can be tricky
  Losses are transparent
- ☹ `Easy´ to introduce data conflict bugs
  These are tedious to fix
- ☹ Data mapping
  Will be important for clusters. Heavy inter-thread data dependencies often difficult to detect.
- OpenMP tools must
  - bring out the strengths of OpenMP
  - help to overcome the problems



## Introduction: KAP/Pro Toolset

- Supported Platforms:
  - Compaq alpha (True64 Unix, WinNT4.0)
  - SGI MIPS (IRIX 6.5)
  - Sun SPARC (Solaris 2.5, 2.6, 2.7)
  - Intel IA32 (WinNT4.0, Linux86, Solaris86)
  - HP PA-RISC 2.0 (HP-UX 11)
  - IBM RS/6000 (AIX 4.1.* - 4.3)

## Overview: KAP/Pro Toolset

- Guide: fully OpenMP compliant F77/F90/C/C++ compiler
- GuideView: graphical performance analysis tool

- Assure: fully OpenMP compliant F77/F90/C/C++ compiler for checking semantical code correctness
- AssureView: graphical backend of Assure

- PerView: online performance monitor



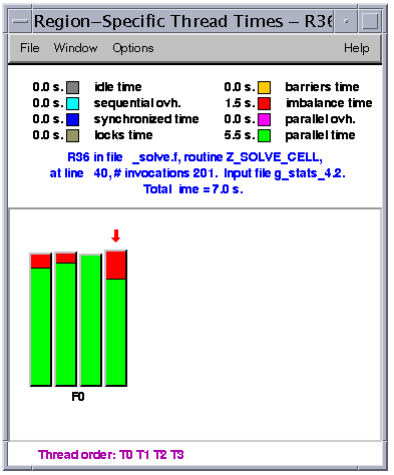
## Overview: Guide and GuideView

- Guide: fully OpenMP compliant C/C++/F77/F90 compiler
- Based on native compiler => native performance, native options are passed to backend compiler

PLUS:

- An additional statistics library on user request, traces OpenMP events at runtime
- After run, visualize tracefile with GuideView

## Overview: Sample with GuideView






## What can be detected?

### Guide (and its alarm colors):

- Loadimbalance
- Too many synchronization points
- Too much `communication´
- Heavy critical sections
- Acquiring locks
- Heavy sequential sections (overhead) (!)
- Idle times

- And the good color is (independent work of thread)

## Performance tuning: invoke Guide -WGstats

- Compile code with Guide compiler:

  **guidef90** [options] **-WGstats** -o myprog myprof.f90

- Execute

  setenv OMP_NUM_THREADS ..
  ./myprog
  => Guide statistics file **guide.gvs** has been produced

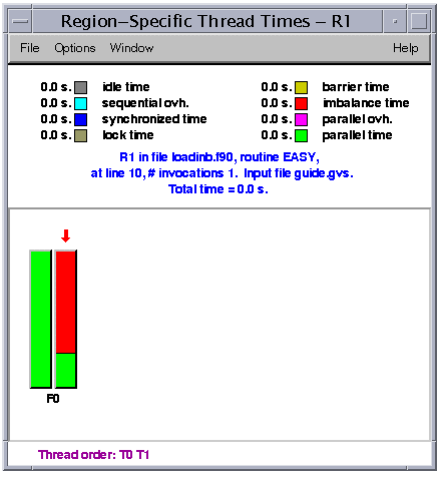
- Visualize

  guideview guide.gvs&

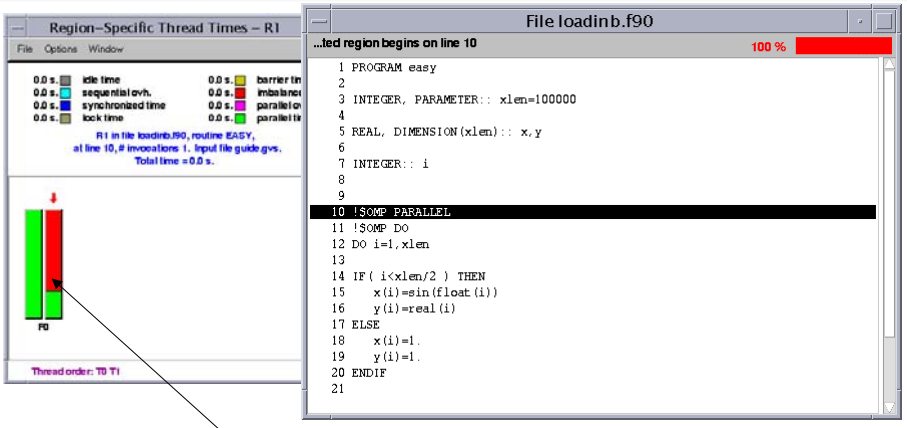


## What can be detected: Loadimbalance

```
!$OMP PARALLEL
!$OMP DO
DO i=1,xlen
IF( i<xlen/2 ) THEN
   x(i)=sin(float(i))
   y(i)=real(i)
ELSE
   x(i)=1.
   y(i)=1.
ENDIF
ENDDO
!$OMP END PARALLEL
```



## Source code view is available!



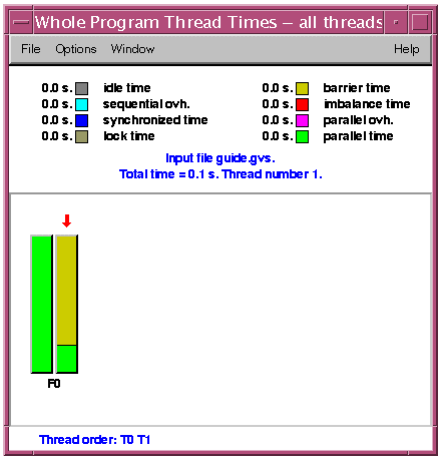

Right mouse click

=> Show code



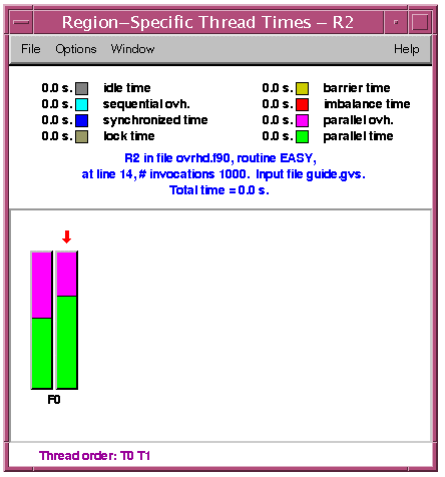
## What can be detected: Barriers

```
!$OMP PARALLEL
!$OMP DO
DO i=1,xlen
<imbalanced as above>
ENDDO

!$OMP DO
DO i=2,xlen
  z(i) = x(i-1)+y(i)
ENDDO

!$OMP END PARALLEL
```



## What can be detected: Overhead

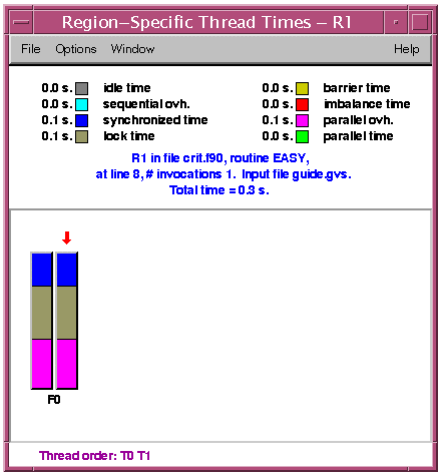
```
Parallelization of
innermost loop:

DO i=1,1000

   !$OMP PARALLEL DO
   DO j=1,100
      temp(j) = &
      temp(j)+1./i
   ENDDO

ENDDO
```



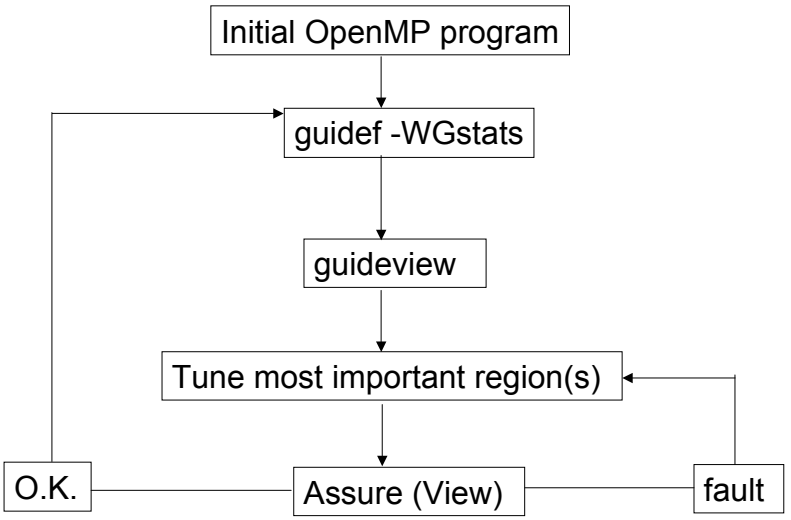



## What can be detected: Critical + Locks

```
!$OMP PARALLEL PRIVATE(temp)
!$OMP DO
DO i=1,100000
! PARALLEL PRVIATE
! CALCULATIONS ..
temp = 1.
! CRITICAL UPDATES
!$OMP CRITICAL
sum = sum+sin(temp)
!$OMP END CRITICAL
ENDDO
!$OMP END PARALLEL
```



## The incremental optimization cycle






## Guide

Output file names can be controlled by environment variables:

KMP_STATSFILE (guide.gvs file)
KDD_OUTPUT (.kdd file of assure, see below)

Three meta characters are available to use in the names:

%P #threads of the run
%I unix process id of the run
%H hostname to run the program

## Guide

e.g.

setenv KMP_STATSFILE gs%P_%I_%H

gives Guide statsfile similar to

gs2_11074_vision.gvs



## GuideView: Displays

Usage:

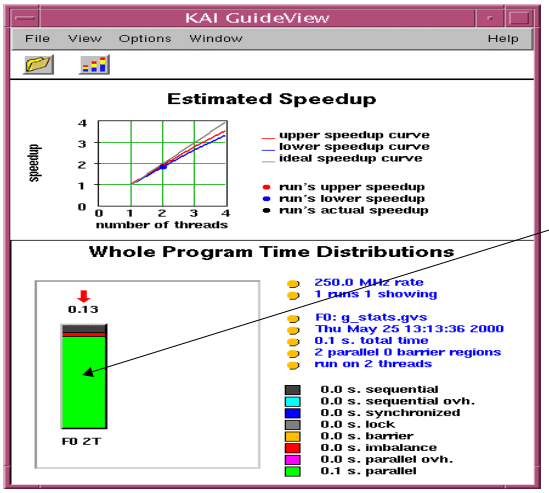
guideview <stats_file>

Main display

- Estimated speedup
- Whole program timing breakdown

# GuideView: Displays

## Whole timing breakdown (averages of threads)




Left button

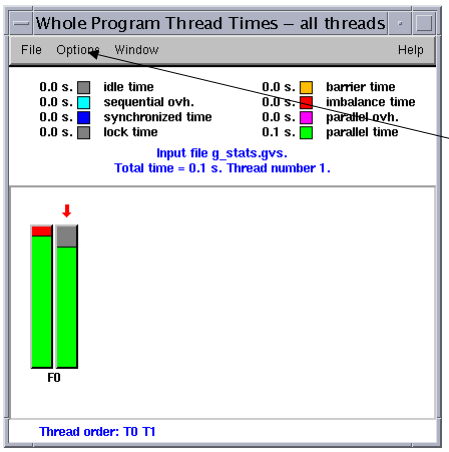
doubleclick

=> ...



# GuideView: Displays

## ... => Thread timing breakdown

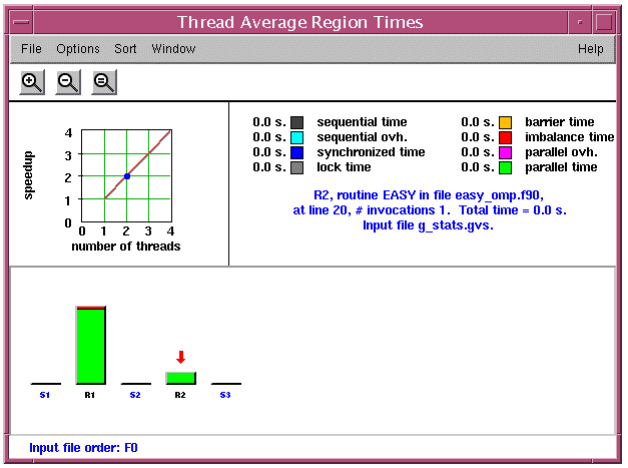



Region View

=> ...

## GuideView: Displays

...=> Region timing breakdown (again average or per thread)






## GuideView: Displays

Region timing breakdown

- Each parallel region (denoted `R1, R2, ...´)
- Each sequential part (denoted `S1, S2, ...´)
- Inside each region (optional):

  Breakdown into sections between barrier points
  (denoted `RxB1, RxB2 ...´).
  Can be unselected in "Options/Show Barrier Regions"

## GuideView: Displays

Always remember:

There is a link between each of the displayed sections and the

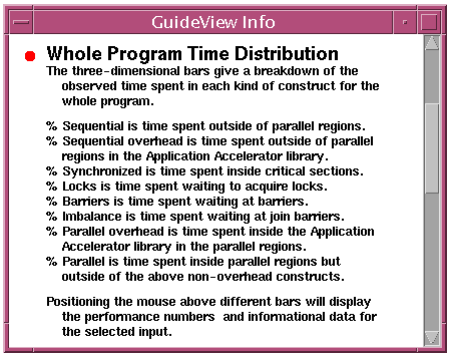
corresponding code

(right mouse button on column => context `show code´)



## GuideView: Displays

- Click "Help/GuideView Info" for explanations



## GuideView: Displays

Sort button

Several sort criteria for the regions, in particular:

sort by time => most important first

sort by overhead => most critical first

Options/Filter button

Filter regions, e.g. only display heavy ones (more than 10% of total)



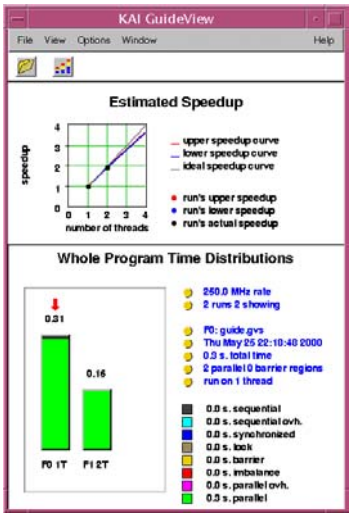
## GuideView: Trace Comparison

Compare different #threads for same program (e.g.)

- guideview <first statsfile>
- Click "File/open new file "
  Menu opened => select second statsfile

All views are then comparative between the two files

## GuideView: Trace Comparison (1 <-> 2 threads)






## Overview: Assure and AssureView

- Assuref77/f90: OpenMP compliant, restriction in usage of OMP library (in particular: OMP_GET_THREAD_NUM)
- Use as normal compiler, but not for getting performance (small input data set)
- Multithreaded run is simulated sequentially, all memory accesses verified
- Run AssureView to visualize error breakdown. When "No Errors" are reported, multithreaded run is assured free of semantical errors as explained below, but only in the branches touched by the simulation run.

## What can be detected: invoke Assure

- Compile code with yet another compiler:

  assuref90 [options] -o myprog myprof.f90

- Execute (but don‘t expect performance!!)

  ./myprog

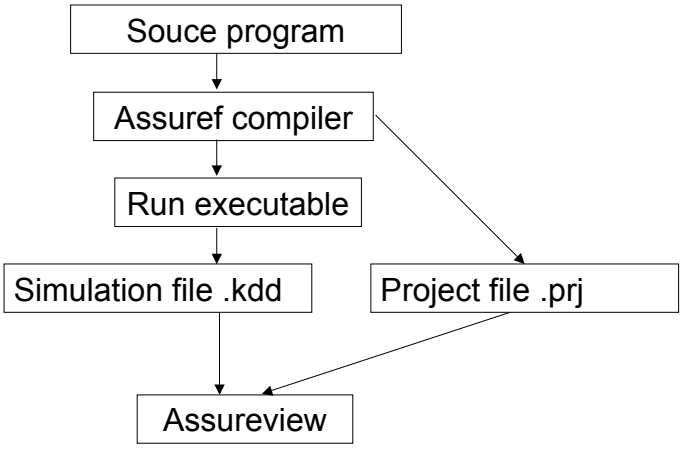
- Visualize

  assureview



## Assure

The Assure process



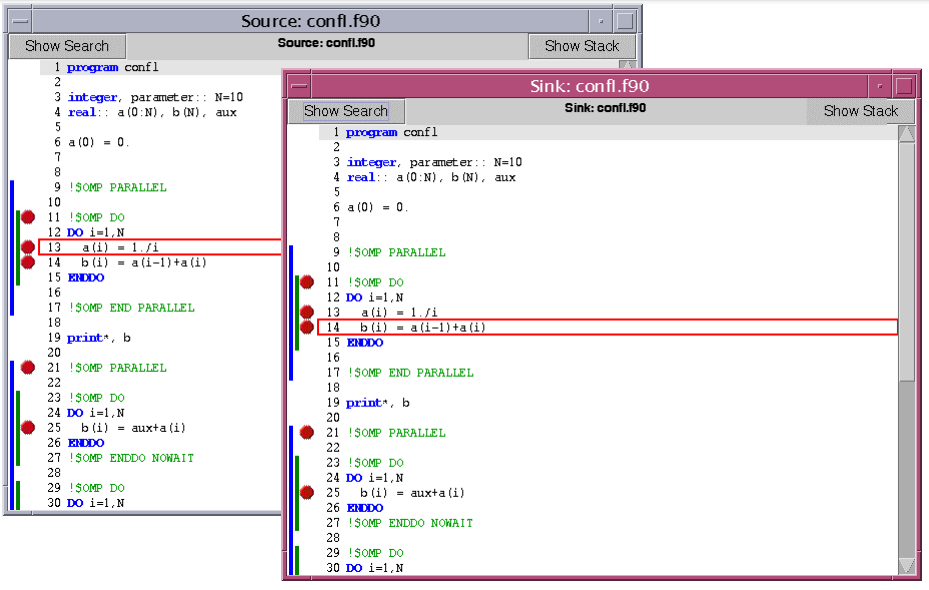
## What can be detected: Conflicts

```
real:: a(0:N), b(N)
a(0) = 0.
!$OMP PARALLEL
!$OMP DO
DO i=1,N
  a(i) = 1./i
  b(i) = a(i-1)+a(i)
ENDDO
```

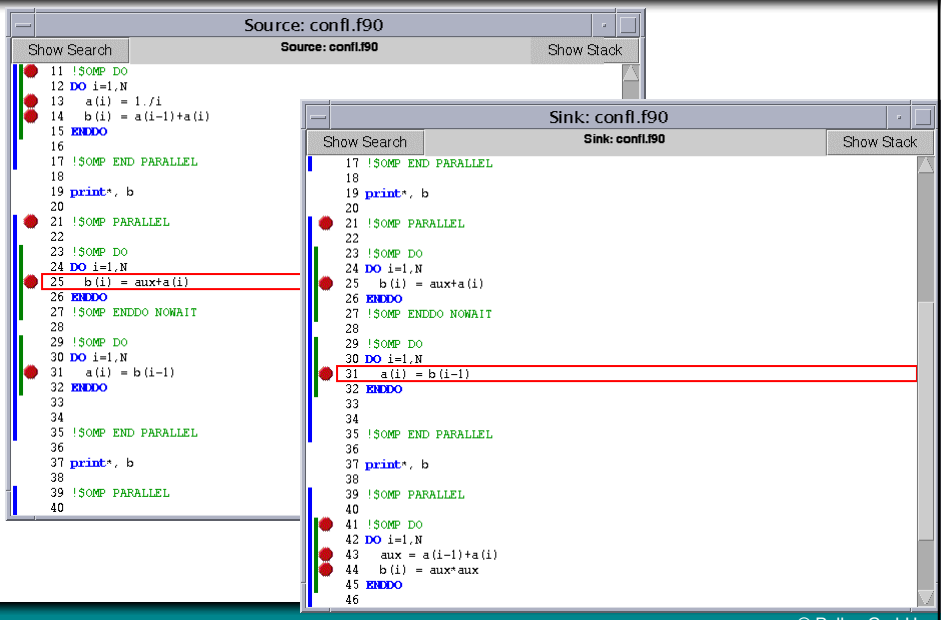
**Whats wrong ??**



## What can be detected: Conflicts



## What can be detected: Conflicts






## Assure: Error Types

Write-Read conflicts

```
!$OMP PARALLEL DO
DO i=1,N
       a = b+c(i)
       d(i) = a+e(i)
```

The 2 statements inside the loop have to be executed in that (Write-Read) order, which is not guaranteed in a multithreaded run (a is shared by default).

Repair: private(a)

## Assure: Error Types

Read-Write conflicts

```
!$OMP PARALLEL DO
DO i=1,N
      d(i) = a+e(i)
      a = b+c(i)
```

Repair: private(a)



## Assure: Error Types

Write-Write conflicts

```
!$OMP PARALLEL DO
DO i=1,N
      a = b+c(i)
```

Repair: private(a)

## Assure: Error Types

Private symbol, used outside loop

```
!$OMP parallel do private(a)
DO i=1,N
      a=c(i)
      d(i) = a*a
ENDDO
PRINT*, a
```

Repair: lastprivate(a)



## Assure: Error Types

Uninitialized private

```
firstiter = .TRUE.

!$OMP parallel do private(firstiter)
DO i=1,N
  IF( firstiter ) THEN ...
ENDDO
```

Repair: firstprivate(firstiter)

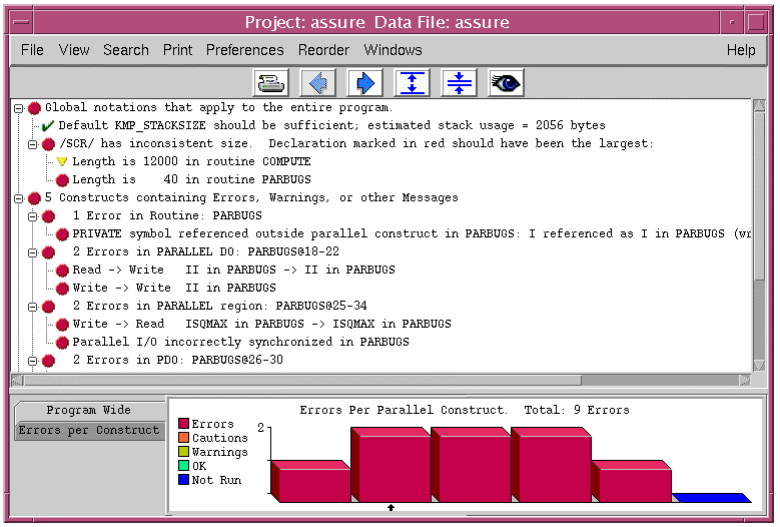
# Assureview: Displays

## Main

- Main error list
  - Clickable button for each error
    Click to get precise diagnostics
  - Overview chart showing statistics of bugs, different severities
- Call Tree



# Assureview: Displays

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## Assureview: Displays

### Reading the diagnostics

Click the "+"  buttons to get into the diagnostics

Finally the code sections are shown containing the error locations, (source and sink), both clearly marked.



## AssureView: Displays

### Inside code windows

- Show Search: normal string search menu
- Show Stack:  show the calling sequence for arriving at the location.

## Assureview: Displays

Other buttons

View

Select display of the error list

Search

Normal search menu, inside error list

Print

Self explaining



## Assureview: Displays

Preferences

Miscellaneous settings. In particular:

source code locations ("finding files")

Reorder

.. error list by different criteria

## Thanks for your attention!


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