OpenMP* support in Clang/LLVM

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OpenMP* Support in LLVM: A Brief History

Terminology: Typical OpenMP code generation requires "outlining", the conversion of a inline parallel region (or task) to an outlined function.

2H 2012: Several proposals with late outlining

- All of them involve changes to LLVM IR and thus, modifications of LLVM phases
- None of them received enough community support to make it into the trunk

October 2012: OpenMP in Clang project

- Started by AMD*, continued by Intel
- Early outlining
- OpenMP RTL calls generated in Clang

No Changes to LLVM IR

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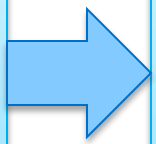
Early vs Late Outlining

Parallel regions are "outlined" into separate routines

- To be executed in separate threads
- This can be done either in the front-end or the back-end

```
float a,x,y,z;
#pragma omp parallel for
for (i = 0; i < N; i++) {
  a[i] = x * y * z;
  ... // rest of loop
}
```



```
omp_parallel_for(0, N,
N/omp_get_num_threads(), forb)
...
void forb(int L, int U, R *r) {
  for (i = L; i < U; i++) {
    r->a[i] = r->x * r->y * r->z;
    ... // rest of loop
  }
}
```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Comparison Early vs Late

	Early	Late
LLVM IR unchanged	Yes	No
Common language independent parallel optimisation	No	Yes
Preserves other optimizations (constant propagation, …)	No	Yes
Affects later compilation phases	No	Yes

Late outlining viewed as too intrusive by LLVM architects
Early outlining (in clang frontend) has been implemented

Tiny Example

```
void vzero(float *a, int n)
{
#pragma omp parallel for
    for (int i = 0; i < n; ++i)
        a[i] = 0;
}
```

$ clang -cc1 -ast-dump -fopenmp test.c

```
|-FunctionDecl 0x7fbdc2026930 <test.c:1:1, line:6:1> vzero 'void (float *, int)'
| |-ParmVarDecl 0x7fbdc20267f0 <line:1:12, col:19> a 'float *'
| |-ParmVarDecl 0x7fbdc2026860 <col:22, col:26> n 'int'
| `-CompoundStmt 0x7fbdc2070c18 <line:2:1, line:6:1>
|   `-OMPParallelDirective 0x7fbdc2070be8 <line:3:9, col:25>
|     `-CapturedStmt 0x7fbdc2070b90 <col:9, col:25>
|       |-Capture byref ParmVar 0x7fbdc2026860 'n' 'int'
|       |-Capture byref ParmVar 0x7fbdc20267f0 'a' 'float *'
|       |-DeclRefExpr 0x7fbdc20702a8 <line:4:25> 'int' lvalue ParmVar 0x7fbdc2026860 'n' 'int'
|       `-DeclRefExpr 0x7fbdc20704b8 <line:5:9> 'float *' lvalue ParmVar 0x7fbdc20267f0 'a' 'float *'
```

OpenMP* Runtime

The OpenMP runtime is responsible for executing the compiler-generated code in parallel

The existing GCC implementation uses libgomp, which is licensed under version(s) of the GPL

Clang / LLVM uses UoI / NCSA* Open Source License

- Permissive (aka BSD-style) free software license

Intel's Runtime now Open Source, with LLVM compatible license

- BSD
- Patent grant

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Additional Advantages of Open Source runtime

Ability for tools providers to instrument the runtime

- E.g. HPCToolkit (John will say more on this next)

Prototyping of new language features

Port to other architectures

Detailed instrumentation to support hardware simulation

Current Status

OpenMP* 3.1 in Clang patch is available

- Hosted on clang-omp.github.com
- Targets Intel OpenMP runtime ABI
- Runs SPEC OMP 2012, passes internal Intel tests

Upstreaming to Clang trunk is under way

- Approved by Chris Lattner and other Clang architects
- Code reviewers throughput is limiting factor

Intel OpenMP RTL available

- Hosted at openmp.llvm.org and openmprtl.org
- LLVM compatible licenses

Other Issues

Intel libiomp5 is interoperable with gcc OpenMP code generation so clang, gcc and icc compiled OpenMP code can be linked into the same image

There is no direct Dragon Egg (gfortran) solution for LLVM because outlining is done in the clang frontend

- Gfortran-generated objects continue to work because of library interoperability.

Intel compiler suite fully interoperable as always

- If libiomp5.so is the OpenMP runtime library

Conclusions

OpenMP support is available in clang now from clang-omp.github.com

Promotion to the clang mainline in process

Runtime available from openmp.llvm.org

- Usable for other purposes

Code is available
Contributions are welcome
Feedback please

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