OpenACC Support in LLVM

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https://csmd.ornl.gov/project/clacc

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What is Clacc?

• Goal
  – OpenACC C/C++ support for Clang and LLVM

• Design
  – Translate OpenACC to OpenMP to build on OpenMP support

• Availability
  – Web page: https://csmd.ornl.gov/project/clacc
  – Source code: https://github.com/llvm-doe-org/llvm-project/wiki

• Funding
  – Exascale Computing Project (ECP)

• Contact
  – Joel E. Denny (dennyje@ornl.gov)
Clacc: Two Compilation Modes

- **Traditional compilation**
  - OpenACC source → executable
    - Similar to NVHPC or GCC
  - OpenMP serves as an internal IR
    - Diagnostics and profiling data expressed in terms of original OpenACC source not OpenMP
    - Maximizes reuse of OpenMP implementation

- **Source-to-source**
  - OpenACC source → OpenMP source
    - Target other OpenMP compilers and tools
    - Port apps or benchmarks
  - Uses Clang’s Rewrite facility
    - Remains human-readable
    - Appropriate for other OpenMP compilers, perhaps targeting other architectures
Clacc: Does OpenMP have what OpenACC needs?

• Unrepresentable individual behaviors. For example:
  – Reference counters for device allocations
    • OpenACC has two: structured and dynamic
    • OpenMP has one: dynamic
  – no_create clause

• Unrepresentable range of behaviors, each of which is individually representable. For example:
  – auto clause
  – kernels construct
Clacc: Solution is OpenMP Extensions†

• Clean design
  – Supports unrepresentable individual behaviors and unrepresentable ranges of behaviors
  – Supports traditional compilation mode and source-to-source mode (with a caveat we'll discuss next)
  – Distinct OpenACC vs. OpenMP representations with full translation in one compiler phase
  – Complex analyses and transformation passes can be implemented on LLVM IR instead of Clang AST

• Improves OpenMP
  – Following OpenACC’s history, leads to contributions to the OpenMP specification
  – Encourages prototyping new OpenMP features (for OpenACC support) before standardizing
Clacc: User Impact of OpenMP Extensions

• Traditional compilation mode
  – OpenMP is just an internal IR
  – Clacc compiler quietly uses OpenMP extensions where needed

• Source-to-source mode
  – Compile-time error diagnostic if translation uses OpenMP extension
  – Option to disable diagnostic
    • Useful if OpenMP compiler supports extension
  – Option to convert error to warning
    • Useful to find all occurrences to manually adjust
  – Option to choose alternative, good enough translation to standard OpenMP
    • User not compiler must verify if it’s good enough per application
    • Can be used in traditional compilation mode to help test the alternative translation
Clacc: OpenACC Runtime Library and Profiling Interface

- Again, build on OpenMP plus extensions
  - Clearly defined relationship between OpenACC and OpenMP representations
  - Provides support for source-to-source and using other OpenMP runtimes
  - Following OpenACC’s history, leads to contributions to the OpenMP specification

- **libacc2omp**: OpenACC runtime
  - Wrapper around OpenMP runtime
  - Currently tested with LLVM’s OpenMP runtime only
  - Carefully defined interfaces to facilitate extending support to other OpenMP runtimes in the future

- **OpenACC Runtime Library Routines**
  - libacc2omp wraps OpenMP runtime library routines plus original extensions

- **OpenACC Profiling interface**
  - libacc2omp wraps OpenMP’s OMPT plus original extensions

- **OpenACC Environment Variables**
  - libacc2omp requires OpenMP runtime to call handler routines provided by libacc2omp

- Clacc’s compiler currently does not translate runtime library routine calls or profiling libraries to OpenMP
Clacc: Development Status

The most noteworthy new efforts from the past year are shown in **bold**

- **Directives**
  - Basic features are supported (e.g., data, parallel, loop directives, `acc routine seq`)
  - Some important features missing (e.g., kernels directive, C++ support, async/wait)

- **Runtime Library Routines, Preprocessor, Environment Variables**
  - Most features supported (e.g., async/wait routines are missing)

- **Profiling interface**
  - All events supported except wait events
  - Some profiling data missing (e.g., kernel_name, num_gangs, num_workers, vector_length)
  - `var_name` support
  - Integrated with TAU

- **Supported Architectures**
  - x86_64, Power 9, NVIDIA GPU
  - AMD CPU and GPU underway

- **Ongoing activities**
  - CI testing on ORNL’s ExCL cluster and Ascent (Summit training system)
  - Issue tracking on LLVM DOE Fork in github
    - Identifies potential external contributions
  - Upstream Clang/LLVM
    - Merging into Clacc
    - **Contributed dual ref count support: OpenMP ompx_hold map type modifier extension**
    - Contributing various other improvements
  - Contributing improvements to OpenACC spec (eventually OpenMP spec)
What is Flacc?

- **Goal**
  - OpenACC Fortran support for upstream LLVM Flang

- **Design**
  - Lowers OpenACC to mix of FIR and OpenACC dialects in MLIR

- **Availability**
  - Upstreamed to LLVM Flang as developed

- **Funding**
  - Exascale Computing Project (ECP)

- **Contact**
  - Valentin Clement
Flacc: Progressive Lowering

- F18 = older name for upstream LLVM Flang
- Mix of FIR and OpenACC dialects
- Optimizations can happen at multiple levels
- Multiple approach possible to lower to LLVM IR
  - Using lower level dialect like the GPU dialect
  - Leveraging the work in the OpenMP IR Builder
Flacc: Progressive Lowering

- **F18** = older name for upstream LLVM Flang
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Clacc and Flacc: Planned Implementation Reuse

- **OpenACC Directive Support in Compiler**
  - Clacc is based on Clang (no MLIR)
  - Flacc is based on Flang (targets MLIR)
  - Little opportunity for reuse

- **OpenACC Directive Support in Runtime**
  - Both use LLVM’s OpenMP runtime
  - Both benefit from Clacc’s OpenMP runtime extensions (e.g., dual ref count)

- **Clang’s OpenMP Directive Extensions**
  - E.g., ompx_hold to select 2nd ref count
  - Clacc directly benefits
  - Flacc benefits indirectly because they are used to test OpenMP runtime extensions

- **OpenACC Runtime Library Routines**
  - libacc2omp’s C routines directly support Clacc
  - Expect that libacc2omp will grow Fortran routines that wrap the C routines

- **OpenACC Profiling Interface**
  - C interface for OpenACC profiling libraries (e.g., TAU) not for OpenACC apps
  - OpenACC app language is irrelevant
  - Expect Flacc to reuse libacc2omp’s support from Clacc w/o modification

- **OpenACC Environment Variables**
  - Expect Flacc to reuse libacc2omp’s support from Clacc w/o modification
Takeaways

• Clacc
  – OpenACC C/C++ support for Clang/LLVM
  – Builds on OpenMP plus extensions
  – Two compilation modes: traditional and source-to-source

• Flacc
  – OpenACC Fortran support for Flang/LLVM
  – Lowers to MLIR dialects
  – Plan to reuse Clacc’s runtime and profiling support

• Join Us
  – Oak Ridge National Laboratory
  – Hiring interns, postdocs, research and technical staff
  – External collaborators welcome

• URLs
  – Web: https://csmd.ornl.gov/project/clacc
  – Source: https://github.com/llvm-doe-org/llvm-project/wiki
  – Email: dennyje@ornl.gov

• Publications
  – Clacc: Translating OpenACC to OpenMP in Clang, Joel E. Denny, Seyong Lee, and Jeffrey S. Vetter, 2018 IEEE/ACM 5th Workshop on the LLVM Compiler Infrastructure in HPC (LLVM-HPC), Dallas, TX, USA, (November 2018).