Loki v0.1.5: Freely Programmable Source-to-Source Translation for IFS and beyond

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Motivation

- **Perfomance portability** of Numerical Weather Prediction (NWP) codes across a broad range of HPC architectures, including **accelerators** (such as GPUs), from a **single code base**
- **Static code analysis/linting** of source code to aid development

Challenges

- Different **programming paradigms** and environments
- **Hardware-specific** optimisation (loop order, memory layout, ...)
- Handling a **large** and **complex Fortran code base**
- **Compatibility** with operational requirements and scientific changes

Methodology

Source-to-source (S2S) translation tool to inspect/transform code:

- **Static code analysis** using internal representation
- **Build-time transformation** of source code using bespoke recipes

Open development on Github

Source code & bug tracker

/ecmwf-ifs/loki

Documentation

sites.ecmwf.int/docs/loki

Jupyter Notebook Tutorials

/ecmwf-ifs/loki/tree/main/example

Loki: overview and internal representation

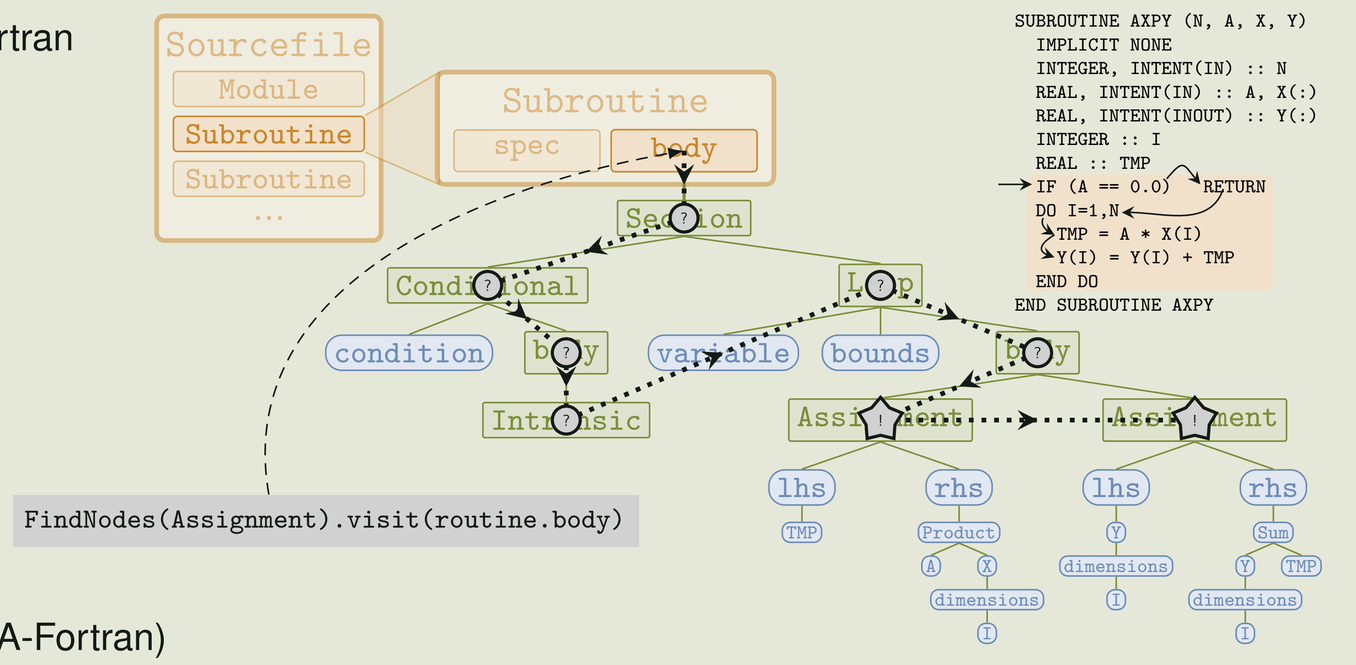
Loki is a **Python package** to encode S2S translation recipes for Fortran

Core library: Internal representation (IR) and API to **encode custom transformations** or **analysis/linting pipelines**

- *Fparser2*[1] is used to generate parse tree of Fortran source
- The parse tree is converted into Loki's **two-level IR**, separating (Fortran-tinted) control-flow from expression tree

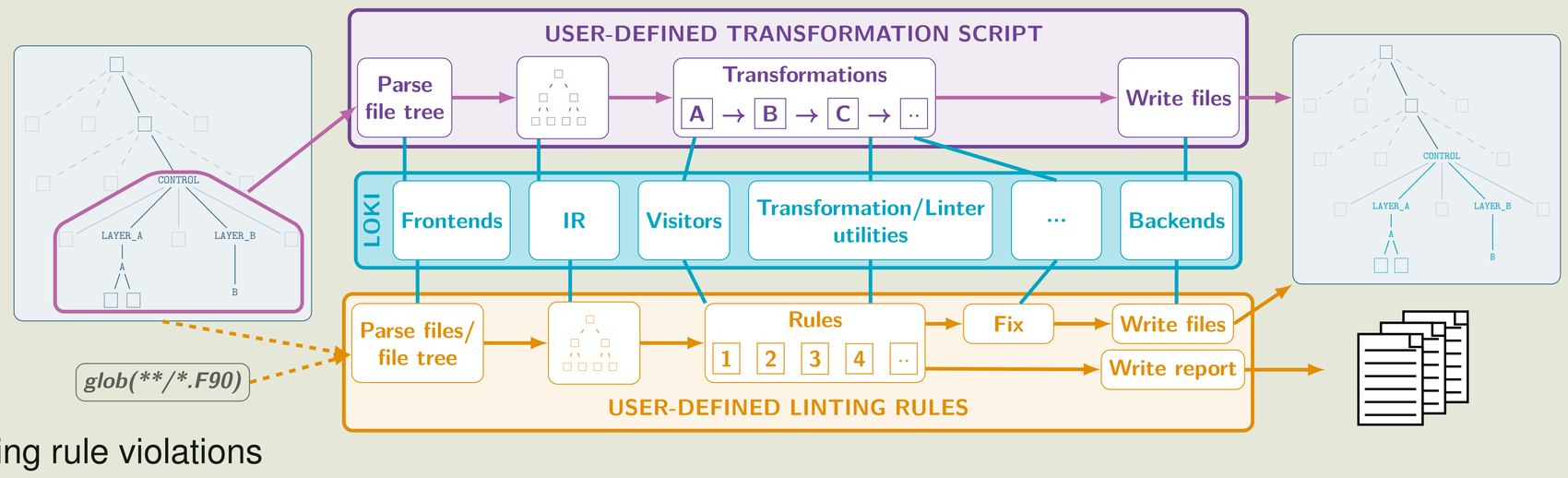
Features:

- **Visitors** are used to traverse and transform the IR
- Scope-aware symbol tables **manage type information**
- **Scheduler** builds a dependency graph for call trees across source files and allows for **inter-procedural analysis**
- **Backends** to generate Fortran (experimental: C, Python, or CUDA-Fortran)



Bulk transformation and analysis of source code

- Typical S2S translation recipes consist of **multiple bespoke transformation steps**
- User-defined pipeline of transformation steps can be built using core library utilities
- **Scheduler** applies transformations in the order of the dependency graph
- **CMake integration** automatically updates dependencies of build system targets
- Same infrastructure unlocks custom static code analysis and experimental fixing of coding rule violations



Loki integration into standalone mini-apps extracted from IFS

CLOUDSC (cloud microphysics) serves as a **proxy for single-column algorithms** to develop transformation recipes for IFS physics

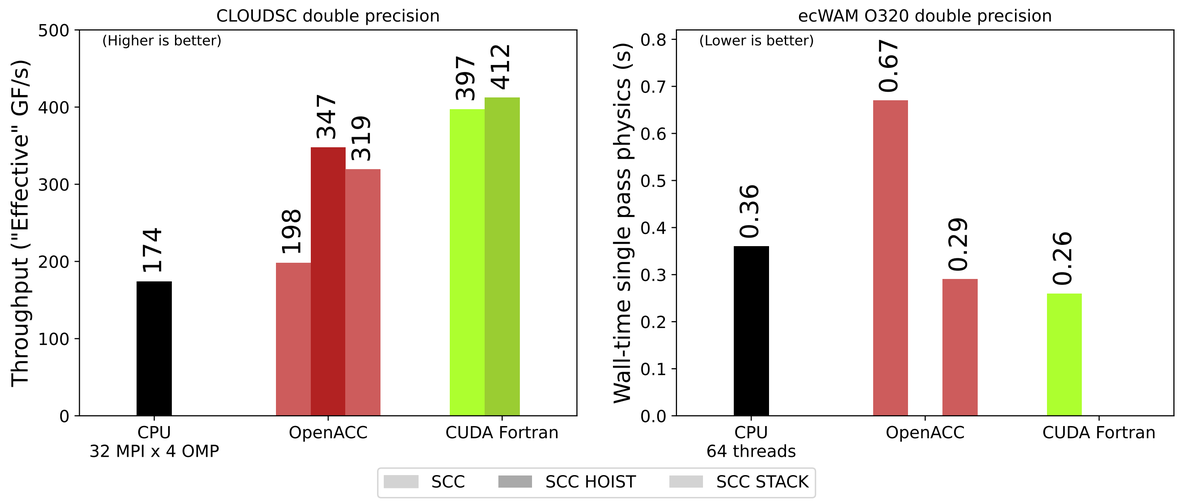
ecWAM is the **operational IFS wave model**, consisting of dynamical core and physics

/ecmwf-ifs/dwarf-p-cloudsc

SCC: Single Column Coalesced GPU transformation

- Swap horizontal/vertical loop, demote arrays
- **HOIST**: pre-allocate temporaries in driver
- **STACK**: pool-allocator for temporaries
- Comparison: AMD EPYC 7742 vs. NVIDIA A100 40GB

/ecmwf-ifs/ecwam



Growing user base

Loki is used for the GPU adaptation of NWP models at **ECMWF**, **Météo-France**, in the **ACCORD** consortium, and as a key component for the digital twins in **Destination Earth**.

stories.ecmwf.int/destination-earth

Outlook and Plans

Core library:

- Add **parallel processing** support in the Scheduler
- Expand **data flow analysis** to unlock advanced transformation steps
- **Fortran-to-C translation** for kernel languages (CUDA, HIP, SYCL)

IFS transformation recipes:

- Automate advanced transformation recipes (e.g., k-caching)
- Expand offload support from OpenACC to OpenMP

Static code analysis:

- Automatic checking and integration into PR review process

1. Science and Technology Facilities Council. *fparser.* https://github.com/stfc/fparser.

The work presented in this poster has been produced in the context of the European Union's Destination Earth Initiative and relates to tasks entrusted by the European Union to the European Centre for Medium-Range Weather Forecasts implementing part of this Initiative with funding by the European Union.