Architecture Recovery from Fortran Code with Kieker

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KIEL MARINE SCIENCE
CONNECTED RESEARCH

OceanDSL

Why do we do this

Digital Twins

Digital Twin

- a model of the object
- an evolving set of data relating to the object
- a means of dynamically updating or adjusting the model in accordance with the data

[Wright and Davidson 2020]

Models we analyzed so far (1/2)

UVic (University of Victoria, ESM) [Weaver et al. 2001]

- Models the complete earth
- Includes atmosphere, oceans, ice, land, bio-geo-chemical processes in the ocean
- Written in Fortran 77 and Fortran 90
- No VCS, no centralized infrastructure
- Self-made configuration and build system

MITgcm (MIT General Circulation Model, ESM) [Adcroft et al. 2022]

- Versatile model, can model the complete earth system
- Provides wide range on example models also used for testing
- Written in Fortran 77 and 90
- Uses git
- Feature model
- Self-made configuration and build system

Models we analyzed so far (2/2)

Shallow-Water-Model [Claus 2016]

- Written in Fortran 95 with modules
- Uses git
- Standard Makefile, uses autoconf, automake

Upcoming Models

ICON (Icosahedral Nonhydrostatic Model)

- Global weather model
- Deutscher Wetter Dienst (DWD)

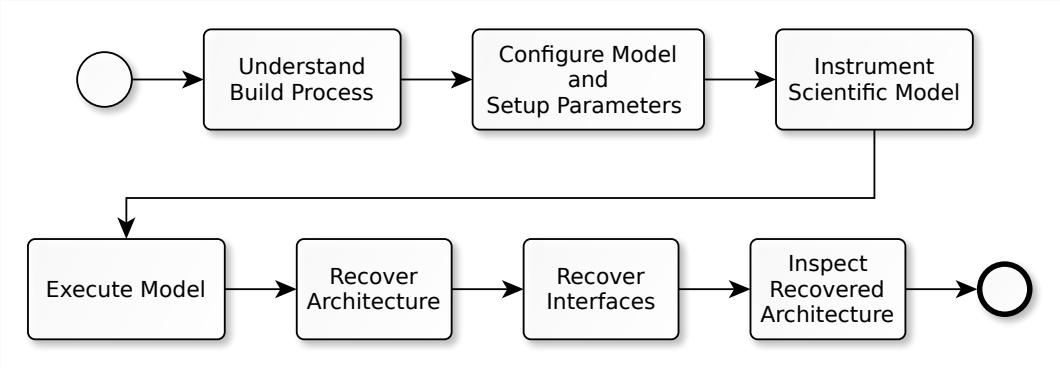
ECHAM5

- Atmospheric general circulation model
- MPI for meteorology

Metos3D

- Marine/Ocean ecosystem model toolkit
- Partly in Python and Fortran

Overview Process



Execute Model

Log events

- Kieker collector
- Netcat & Split `nc -l 5678 | split -b 102400000 - log-`

What is logged?

- Subroutine calls
- Function calls
- Procedure calls

Recover Architecture

Reconstruction

- Resolve operation and file names with `addr2line`
- Construct operation uses and calls from Kieker events
- Create **type**, **assembly** and **deployment** model based on operations
- Add and aggregate call information to the Kieker **execution** model

Component Identification

1. Names of the files
2. Directory names of files
3. Fully qualified operation signatures in **o-files**, e.g., `_module_MOD_operation_`

$\Rightarrow$ We can apply all methods in combination

Interface Discovery Strategies

Approaches

1. Large interface per component to component connection
   - few interfaces
   - different provided interfaces may share operations
2. One provided interface per component, multiple required interfaces
   - fewest interfaces
   - each component has only one provided interface
   - can lead to wide interfaces
3. Provided interfaces have operations that are required by the same requiring components
   - May create too many interfaces when different subsets of operations are used

Current Discovery Strategy

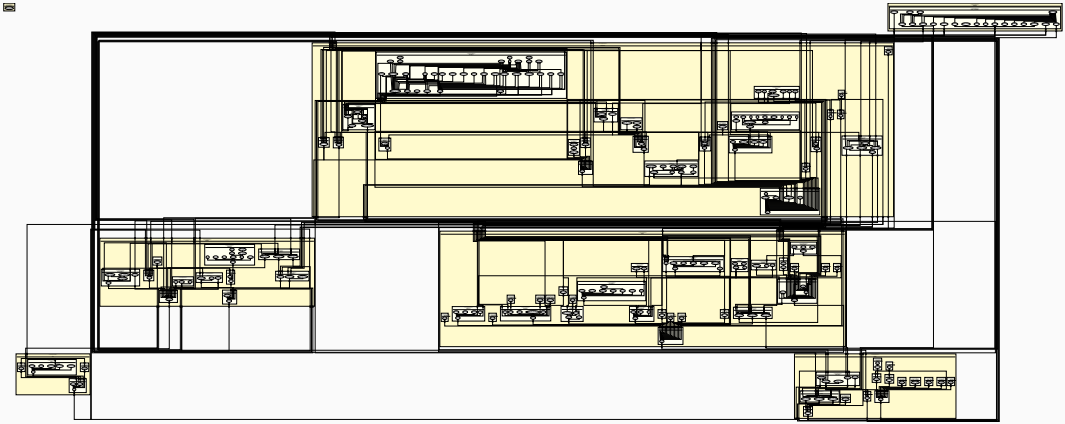
Provided Interfaces

- Identify for each operation all caller components
- Group all callees that have the same set of caller component
- Create a provided interface for each callee group

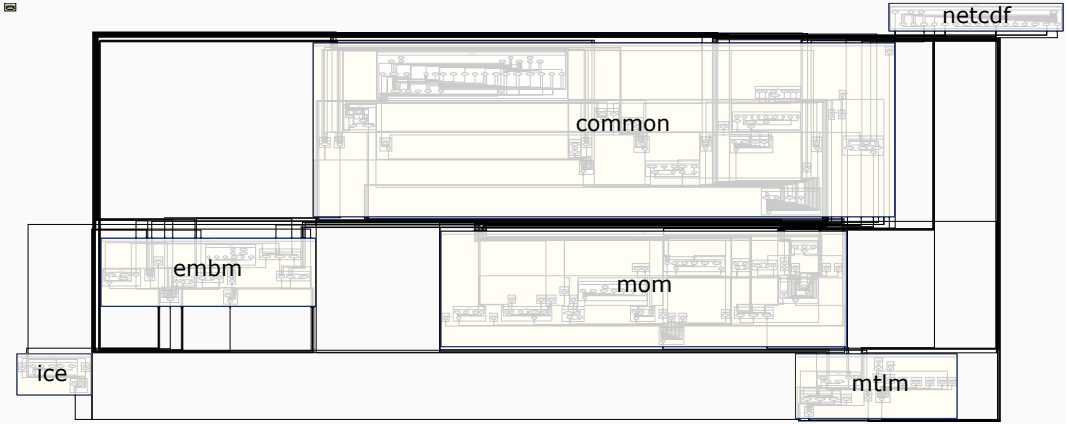
Required Interfaces

- Create one for each used provided interface by a component
- Link all caller that call callees of a provided interface to the corresponding required interface

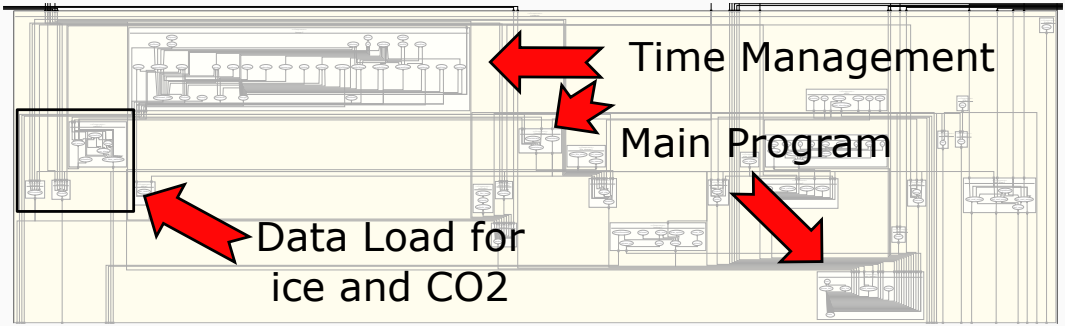
UVic Architecture



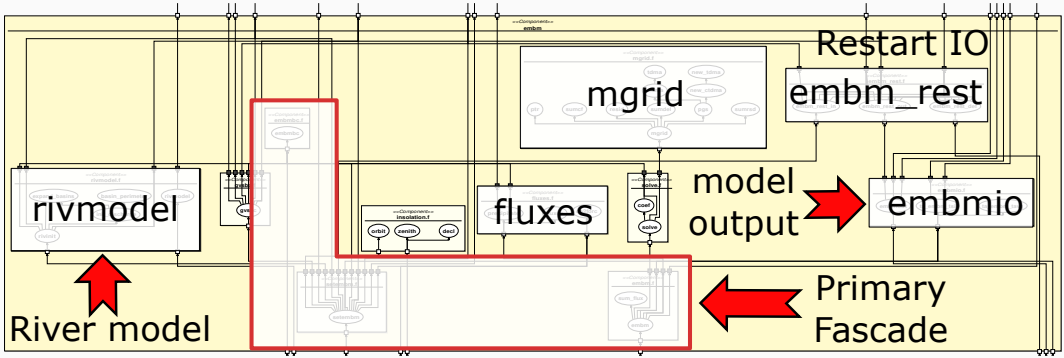
UVic Architecture



Common Component



Energy-Moisture Balance Model (EMBM)



Lessons Learned

Fortran

- F77 uses global symbols, no name spaces
- F95 can use modules, **o-file symbols** use FQN `_module_MOD_operation_`
- Names are **case insensitive**, **o-file symbols** are lower case with `'_'` as prefix

Scientific Models

- Every scientific model has its own build system or use of build tools
- High degree of interconnection between components

Conclusions

Advantages of dynamic recovery

- Object files are sufficient
- Debugging symbols are helpful
- Understanding code assembly and build procedure not necessary
- Can show the number of calls in an interface to rank functions
- Not limited to Fortran
- Fast setup

Disadvantages

- Requires a running executable
- Can result in a lot of monitoring data
- Cannot cover dataflow (but our static recovery does)

Bibliography i

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