Status of the New Backend

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HS'Bi

Hochschule
Bielefeld
University of
Applied Sciences
and Arts
1 Overview

2 Bindings

3 Function Alias

4 Inline

5 Summary
Section 1

Overview
Overview

Backend Modules

Status on Array-Handling

Lowering

Bindings → FunctionAlias → Inline → Simplify → Events → Partitioning → Causalize

DetectStates → Alias

Partitioning

Initialization

Causalize → Categorize → Tearing → Solve → Jacobian → SimCode

DAE-Mode

Finished

Core Finished

Work in Progress
Overview

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Lowering → Bindings → FunctionAlias → Inline → Simplify → Events → Partitioning → Causalize

Initialization → Causalize → Categorize → Tearing → Solve → Jacobian → SimCode

DAE-Mode

Detected States

Alias

Simplify → Events

Solve → Jacobian

SimCode

Finished Core Finished Work in Progress

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DAE-Mode

DetectStates

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Simplify

Events

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DetectionStates → Alias

Initialization → Causalize → Categorize → Tearing → Solve → Jacobian → SimCode

DAE-Mode

Finished  Core Finished  Work in Progress

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Backend Modules
Status on Array-Handling

- Lowering
- Bindings
- FunctionAlias
- Inline
- Simplify
- Events
- Partitioning
- DetectStates
- Causalize
- Initialization
- Causalize
- Categorize
- Tearing
- Solve
- Jacobian
- SimCode
- DAE-Mode

Status of the New Backend
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Section 2

Bindings
Creating Binding Equations

Debugging

Flag: -d=dumpBindings

Outline

1. Create binding equations for simulation (Bindings Module).
2. Create binding equations for initialization (Initialization Module).

Challenges

- Correctly parse bindings of multi dimensional variables.
- Correctly parse record bindings. Some records are bound themselves, for some one needs to create binding equations for the elements.
- Correctly parse external object bindings (e.g. alias).

Motivation

Mandatory to have a balanced model in the first place.
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Section 3

Function Alias
Introducing Function Alias

Debugging
Flag: -d=dumpCSE

Outline
1. Gathering and replacing all function calls in the model.
2. Creating the auxiliary equations for the replaced function calls.

Challenges
- Only create a single alias for identical function calls.
- Wrap the auxiliary equations in the iterators (+when/if conditions) of the function call.
- Do not replace impure functions, inlineable functions and functions in algorithms that do not strictly depend on the inputs.
- Create multiple function alias variables and wrap them in a tuple if the function has multiple outputs.
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Introducing Function Alias

Motivation

- Call identical function calls only once.
  - Function calls in algebraic loops that don’t depend on the iteration variables will be extracted entirely from the strong component to not be evaluated multiple times during the process of solving the algebraic loop.
  - Function calls in algebraic loops that depend on iteration variables can be extracted to be only evaluated as torn inner equations when using proper tearing methods. This results in function calls never being part of a residual equation.
  - If applied before the Inlining module it ensures that it can properly resolve all inlinable operator record functions.
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- If applied before the Inlining module it ensures that it can properly resolve all inlinable operator record functions.
Structures for Function Alias

```plaintext
record CALL_ID
    Expression call;
    Iterator iter;
    // Option<Expression> when_condition
    // Option<Expression> if_condition
end CALL_ID;

record CALL_AUX
    Expression replacer;
    EquationKind kind;
    Boolean parsed;
end CALL_AUX;

UnorderedMap<Call_Id, Call_Aux> map;
```
Structures for Function Alias

record CALL_ID
    Expression call;
    Iterator iter;
    // Option<Expression> when_condition
    // Option<Expression> if_condition
end CALL_ID;

record CALL_AUX
    Expression replacer;
    EquationKind kind;
    Boolean parsed;
end CALL_AUX;

UnorderedMap<Call_Id, Call_Aux> map;
Structures for Function Alias

```java
record CALL_ID
    Expression call;
    Iterator iter;
    // Option<Expression> when_condition
    // Option<Expression> if_condition
end CALL_ID;

record CALL_AUX
    Expression replacer;
    EquationKind kind;
    Boolean parsed;
end CALL_AUX;

UnorderedMap<Call_Id, Call_Aux> map;
```
Inlining Function Calls

Debugging

Flag: -d=dumpBackendInline

Main Outline

1. Collecting all inlineable functions from the function tree (+native functions).
2. Inline inlineable functions in all equations.
3. Inline all record constructors and tuple equations.

Function Inline Outline

1. The input variables of the call have to be mapped to the input variables of the interface.
2. If any input variables are records, the mapping has to be extended to their record elements.
3. The bindings of local variables have to be evaluated using the existing input mapping. Furthermore, the local variables and their evaluated bindings have to be added to the mapping.
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1 Collecting all inlineable functions from the function tree (+native functions).
2 Inline inlineable functions in all equations.
3 Inline all record constructors and tuple equations.
4 Additional functionality: Inline for-equations with iterators of size 1.

Function Inline Outline
1 The input variables of the call have to be mapped to the input variables of the interface.
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Inlining Function Calls

Challenges
- Define what *inlineable* means.

Motivation
- Make the inlined function body susceptible for symbolic manipulation.
- Remove most record equations and remove all tuple equations.
- Correctly handle ignored outputs.
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Example: Inlining operator record functions

Considering following Modelica model record_inlining three record functions will be inlined:

1. The record constructor Complex.'constructor'.fromReal
2. The overloaded operator Complex.'*'. multiply
3. The overloaded operator Complex.'^'

```model record_inlining
  Complex a,b,c,d;
equation
  a = Complex(sin(time), cos(time));
  b = Complex(time, tan(time));
  c = a * b;
  d = a ^ b;
end record_inlining;
```
Example: Inlining operator record functions

Considering following *Modelica* model `record_inlining` three record functions will be inlined:

1. The record constructor `Complex.constructor.fromReal`
2. The overloaded operator `Complex.*.multiply`
3. The overloaded operator `Complex.^`

```model record_inlining
    Complex a,b,c,d;
equation
    a = Complex(sin(time), cos(time));
    b = Complex(time, tan(time));
    c = a * b;
    d = a ^ b;
end record_inlining;
```
Example: Inlining operator record functions
Inlining the multiplication operator for complex numbers

encapsulated operator '*' "Multiplication"
  function multiply "Multiply two complex numbers"
    import Complex;
    input Complex c1 "Complex number 1";
    input Complex c2 "Complex number 2";
    output Complex c3 "= c1*c2";
    algorithm
      c3 := Complex( c1.re*c2.re - c1.im*c2.im, c1.re*c2.im + c1.im*c2.re );
      annotation( Inline=true );
    end multiply;
end '*';
Example: Inlining operator record functions
Inlining the multiplication operator for complex numbers

Inlining: Complex.‘∗’.multiply(a, b)
--- Result: Complex.‘constructor’.fromReal(a.re * b.re - a.im * b.im, a.re * b.im + a.im * b.re)

Inlining: [RECD] (2) c = Complex.‘constructor’.fromReal(a.re * b.re - a.im * b.im, a.re * b.im + a.im * b.re)
--- Result: [SCAL] (1) c.re = a.re * b.re - a.im * b.im
--- Result: [SCAL] (1) c.im = a.re * b.im + a.im * b.re
Example: Inlining operator record functions

Inlining the multiplication operator for complex numbers

**Inlining**: `Complex.‘*‘.multiply(a, b)

--- Result: `Complex.‘constructor’.fromReal(a.re * b.re − a.im * b.im, a.re * b.im + a.im * b.re)

**Inlining**: `[RECD] (2) c = Complex.‘constructor’.fromReal(a.re * b.re − a.im * b.im, a.re * b.im + a.im * b.re)

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--- Result: `[SCAL] (1) c.im = a.re * b.im + a.im * b.re"
Example: Inlining operator record functions

Inlining the power operator for complex numbers

```plaintext
encapsulated operator function '^'
  "Complex power of complex number"
import Complex;
input Complex c1 "Complex number";
input Complex c2 "Complex exponent";
output Complex c3 "= c1^c2";
protected
  Real lnz=0.5*log(c1.re*c1.re + c1.im*c1.im);
  Real phi=atan2(c1.im, c1.re);
  Real re=lnz*c2.re - phi*c2.im;
  Real im=lnz*c2.im + phi*c2.re;
algorithm
  c3 := Complex(exp(re)*cos(im), exp(re)*sin(im));
  annotation (Inline=true);
end '^';
```
Example: Inlining operator record functions

Inlining the power operator for complex numbers

Inlining: Complex.'^'(a, b)

Result: Complex.'constructor'.fromReal(exp(0.5 * log(a.re * a.re + a.im * a.im) * b.re - atan2(a.im, a.re) * b.im) * cos(0.5 * log(a.re * a.re + a.im * a.im) * b.im + atan2(a.im, a.re) * b.re), exp(0.5 * log(a.re * a.re + a.im * a.im) * b.re - atan2(a.im, a.re) * b.im) * sin(0.5 * log(a.re * a.re + a.im * a.im) * b.im + atan2(a.im, a.re) * b.re))
Section 5

Summary
Results

- **Overview**

- **Large TestSuite**
  - NB
  - OB

- **Recent Coverage**
  - Scalable TestSuite
  - PowerGrids
Summary

Recent Development

- Bindings (+Initialization) Module
- FunctionAlias Module
- Inline Module

Current Development

- Adjacency Matrix Improvements (+Tearing)
- Enable Sparse Solvers

Upcoming Plans

- Pseudo-Array Index Reduction
- Resizable Arrays after Compilation
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