Documentation for repository

EMAM2CPP

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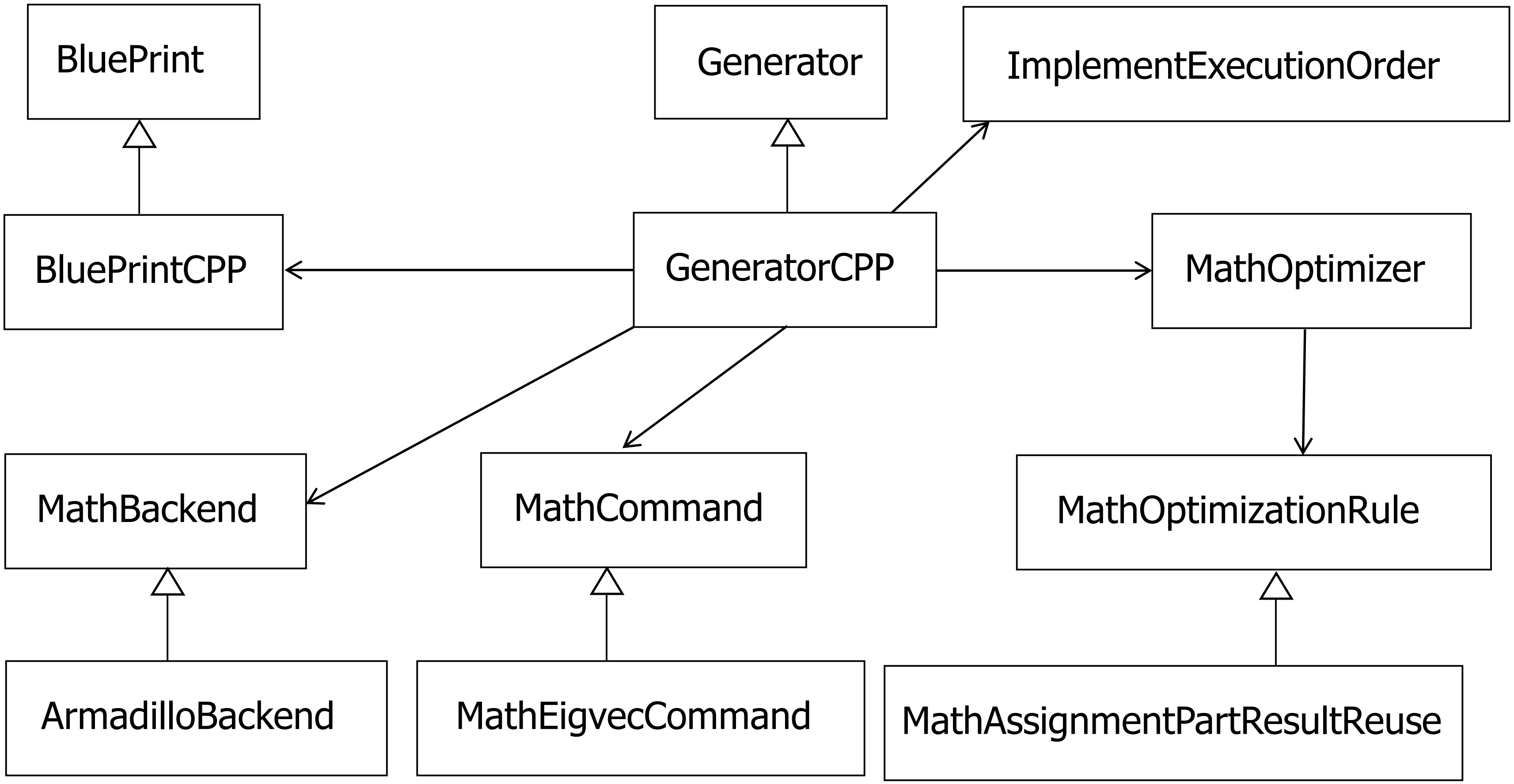
Purpose

- Automatically generate executable C++ code out of EmbeddedMontiArcMath models
- Automatically generate integration code for the MontiSim simulator
- Optimize generated code by utilizing algebraic and threading optimizations

Most Important Classes

- Namely:
  - Generator(GeneratorCPP)
  - BluePrint(BluePrintCPP)
  - MathCommand(MathAbsCommand,MathEigvalCommand)
  - ImplementExecutionOrder
  - MathBackend(ArmadilloBackend)
  - MathOptimizier
  - MathOptimizationRule(MathAssignmentPartResultReuse)

Class Relations



GeneratorCPP

- Represents an instance of the generator
- Can be used to generate the code of a single ExpandedComponentInstanceSymbol
- Can be used to generate all files needed for an ExpandedComponentInstanceSymbol
- Test Coverage: 100%

BlueprintCPP

- Stores all information for one transformed component
- This includes:
  - Variables
  - Methods
  - Includes
- Test Coverage: 74%

MathCommand

- Base class for all math commands
- A math command is a built in function of the generator/EMAM language that is automatically transformed
- This includes functions like ones, atan, eigvec
- Test Coverage: 85%

ImplementExecutionOrder

- Computes the components execution based on the Simulink execution order specification:
  - If a block drives the direct-feedthrough port of another block, the block must appear in the sorted order ahead of the block that it drives.
  - Blocks that do not have direct-feedthrough inputs can appear anywhere in the sorted order as long as they precede any direct-feedthrough blocks that they drive.
- Test Coverage: 93%

MathBackend

- Math library/framework that is used as the backend for matrix and other complex mathematical operations
- Backend classes: ArmadilloBackend, OctaveBackend
- Has methods for retrieving the name of common functions/types in the target language(e.g. matrix type)
- Test Coverage: 100%

MathOptimizer & MathOptimizationRule

- Stores all registered MathOptimizationRules that are applied when the generator uses algebraic optimizations
- Some rules are:
  - MathAssignmentPartResultReuse(a*b+a*b -> c+c with c=a*b)
  - MathDiagonalMatrixOptimizations(matsqrt(D) -> matdiagsqrt(D))
  - MathMatrixMultiplicationOrder(a*b*c -> a*(b*c) if faster)
- Test Coverage:
  - MathOptimizer: 75%
  - MathOptimizationRule: 100%

Software Quality

- Code Quality(according to codeclimate.com): C
- Test Coverage:
  - Whole: 79%
  - Handwritten code: 79%
  - Generated code: (There is no code generated into target folder)

Utilization(Excerpt)

- Used in the following projects:
  - SpectralCluster
  - PacMan
  - MontiSim
  - EMAM2WASM

Threading Optimization

- ImplementExecutionOrder calculates independent subcomponents
- Independent subcomponents can then be executed in different threads
- Can be enabled and disabled depending on input
- Drawback: Too many threads do not provide that much benefit, if not enough cores are available on the target processor due to thread creation overhead
- Future Work: Devise threading algorithm that restructures program execution to only use x threads with (roughly) the same workload

Algebraic Optimizations

- Basic mathematical instruction reordering if amount of operations can be reduced by using the commutative law
- This includes reordering:
  - Multiplications(Matrix and Scalar)
  - Removing unused variable assignments
- Associative law is used to change instructions like AB+AC to A(B+C) if this reduces the amount of operations
- All equations from a component are taken into consideration
- Does also use matrix properties like diagonal to automatically compute fast matrix inverse and fast matrix squareroot

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Algebraic Optimization Example

Original:

EMA

```
component MatrixModifier {
 ports in Q(-oo:oo)^{1000,2} mat1,
       in Q(-oo:oo)^{2,1000} mat2,
       in Q(-oo:oo)^{1000,2} mat3,
       in Q(-oo:oo)^{2,10000} mat4,
       in Q(-oo:oo)^{2,10000} mat5,
       out Q(-oo:oo)^{1000,10000} matOut;

 implementation Math{
    Q^{1000,1000} h1 = mat1 * mat2;
    Q^{1000,1000} h2 = mat3 * mat4;
    Q^{1000,1000} h3 = h1 * h2;
    matOut = h3 * mat5;
 }
}
```

Algebraic Optimization Example

Transformed:

EMA

```
component MatrixModifier {
 ports in Q(-oo:oo)^{1000,2} mat1,
       in Q(-oo:oo)^{2,1000} mat2,
       in Q(-oo:oo)^{1000,2} mat3,
       in Q(-oo:oo)^{2,10000} mat4,
       in Q(-oo:oo)^{2,10000} mat5,
       out Q(-oo:oo)^{1000,10000} matOut;

 implementation Math{
    matOut = (mat1*(mat2*mat3))*(mat4*mat5);
 }
}
```

Future Work

- Refactoring and cleanup(Remove deprecated methods)
- Integrate utilizing projects as tests to improve test coverage and robustness
- Implement additional optimizations