Advanced Stencil-Code Engineering
(ExaStencils)

Christian Lengauer

ExaStencils 2014, Dresden
Two alternative approaches in SPPEXA

- *The conservative approach:*

\[
\begin{align*}
\text{Fortran} & \quad + \quad \text{MPI} \\
C & \quad \text{OpenMP} \\
\text{Java} & \quad \text{Threads}
\end{align*}
\]
Two alternative approaches in SPPEXA

- **The conservative approach:**
  
  $$( \text{Fortran} + \text{C} + \text{Java} )^{++}$$

- **The Radical Approach:**
  
  linear transformations
  
  linear algebra
  
  stencil codes
  
  $\Rightarrow$

  domain-specific refinement and optimization

  $\Rightarrow$

  HPC cluster
  
  Manycores
  
  GPGPUs
  
  FPGAs
In the past: all power to the compiler!
In the future: toolboxes and intelligent run-time systems
Our project in the radical tier of SPPEXA

ExaStencils
http://www.exastencils.org/

A new, tool-assisted, domain-specific codesign approach for stencil codes

Jürgen Teich, Frank Hannig
Ulrich Rüde, Harald Köstler
Matthias Bolten
Christian Lengauer, Armin Größlinger
Sven Apel
Work areas of ExaStencils

A: Algorithm design
B: Domain-specific representation and modeling
C: Domain-specific optimization and generation
D: Polyhedral optimization and code generation
E: Platform-specific code optimization and generation
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Numerical Considerations in the Optimization of Stencils Codes Using the Example of Multigrid Methods

Hannah Rittich, Matthias Bolten
Multigrid

Smooth

Finest Grid

The Multigrid V-cycle

Prolongation

Restriction

Fewer Dofs

First Coarse Grid

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A Multi-Layered Domain-Specific Language for Stencil Codes

Christian Schmitt, Frank Hannig, Jürgen Teich
DSL with four levels of abstraction

1. Continuous domains
   - Continuous variables
   - Continuous equations

2. Discrete domains
   - Discrete fields
   - Discrete equations

3. MG parameters

4. MG components

“discretized to”

“influences”
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*Optimizing the Performance of Customizable Stencil Codes with Feature-Interaction Detection*

Alexander Grebhahn, Norbert Siegmund, Sven Apel, Sebastian Kuckuk, Christian Schmitt, Harald Köstler
Partial feature selection and prediction

Partial feature selection

Objective function: $\max(\text{performance})$

Prediction

Optimal configuration
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Automatic Polyhedral Optimization of Stencil Codes

Stefan Kronawitter, Armin Größlinger, Christian Lengauer
Restrictions in the polyhedron model

- **Legal source code**

  ```c
  for (i = 0; i < n; ++i)
      for (j = 0; j < 2*i+n; ++j)
  ```

- **Problematic source code**

  ```c
  A[i] = B[i+3]  // are A and B aliases?
  A[i][j]        // float **A
  A[stride*i]    // uninstantiated stride
  A[B[i]]        // works if B is monotone
  P = P->next     // pointer structures
  ```
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A Common Automatic Code Generator for a Wide Range of Stencil Codes

Harald Köstler, Christian Schmitt, Sebastian Kuckuk
Have a good workshop!