Towards Compositional and Generative Tensor Optimizations
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Tensors in Computational Fluid Dynamics (CFD)
- Loop characteristics:
  1. 3 to 4 dimensions nesting
  2. Few iterations per dimension (e.g., 17 or 33 iterations)
- Type of computations:
  1. Tensor contractions
  2. Outer products
  3. Element-wise multiplications
  4. Computations on each element of a structured mesh

Inverse Helmholtz
\[
t_{ijk} = \sum_{l,m,n} A_{kn}^i \cdot A_{jm}^f \cdot A_{il}^r \cdot w_{lmn}
\]
\[
p_{ijk} = D_{ijk} \cdot t_{ijk}
\]
\[
v_{ijk} = \sum_{l,m,n} A_{kn}^i \cdot A_{jm}^f \cdot A_{il}^r \cdot p_{lmn}
\]

Tensor Optimization Frameworks
- Domain-specific expressivity
- Flexible/Adaptive optimization heuristics
- Hidden and/or rigid optimization heuristics
- Generic expressivity

Related Work
- Different levels of expressiveness and control on optimizations
- Flexible/adaptive
- Hidden/rigid

Tensor Optimization Frameworks
- Chill •
- Pluto •
- TensorFlow •
- TVM •
- Tensor Contraction Engine •
- Numpy •
- Tensor Algebra Compiler •

Optimizing CFD Kernels with Existing Tools
- Several limitations
- Few opportunities for adaptations

Goal
A cross-domain intermediate language for tensor optimizations

Intermediate Language
- Modular constructs
- First-class citizens:
  1. Arrays
  2. Tensor operators
  3. Loop iterators
  4. Transformations

Envisioned Tool
- Meta-programming
- Iterative search
- Flexible/Adaptive optimization heuristics

Search Space Exploration
- Evaluation order of tensor contractions
- Fusions
- Permutations
- Vectorization
- Collapsing
- Unrolling

Inverse Helmholtz by Example

Future Work
- Applications to other domains
- Syntax refinement
- Formal semantics

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