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

Inverse Helmholtz

\[
\begin{align*}
t_{ijk} &= \sum_{l,m,n} A_{kn}^{T} \cdot A_{jm}^{T} \cdot A_{il}^{T} \cdot w_{lmn} \\
p_{ijk} &= D_{ijk} \cdot t_{ijk} \\
v_{ijk} &= \sum_{l,m,n} A_{kn} \cdot A_{jm} \cdot A_{il} \cdot p_{lmn}
\end{align*}
\]

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

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

A cross-domain intermediate language for tensor optimizations

Intermediate Language
- Modular constructs
- First-class citizens:
  - Arrays
  - Tensor operators
  - Loop iterators
  - Transformations

Envisioned Tool
- Meta-programming
- Iterative search

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

Inverse Helmholtz by Example

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

Optimizing CFD Kernels with Existing Tools
- Limited expressivity
- Limited optimizations
- Unadapted heuristics
- Unadapted constructs

Goal
- Should we create yet another domain-specific solution?

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

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