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
- Tensor contractions:
  \[ t_{ijk} = \sum_{l,m,n} A^T_{kn} \cdot A^T_{jm} \cdot A^T_{il} \cdot u_{lmn} \]
  \[ p_{ijk} = D_{ijk} \cdot t_{ijk} \]
  \[ v_{ijk} = \sum_{l,m,n} A_{kn} \cdot A_{jm} \cdot A_{il} \cdot p_{lmn} \]

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

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

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

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

Example of assessment: Different heuristics of loop interchanges (+ parallelization)

Baseline: sequential execution (3.32s). Machine: 24-core Intel(R) Xeon(R) CPU E5-2680 v3 @ 2.50GHz (Haswell)

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