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

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

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

Inverse Helmholtz by Example
# Basic array declaration
A = array(2, double, [N, N])
\[ u = array(3, double, [N, N, N]) \]
\[ D = array(3, double, [N, N, N]) \]

# Transposition
At = vtranspose(A, 1, 2)

# Tensor contractions
\[ tmp1 = contract(At, u, [2, 1]) \]
\[ tmp2 = contract(At, tmp1, [2, 2]) \]

# Iterator declaration
i1 = iterator(0, N, 1)

Example of assessment: Different heuristics of loop interchanges (+ parallelization)
- Variant L1: Loop interchanges only.
- Variant L2: Loop interchanges + data transpositions with copying.
- Variant L3: Loop interchanges + data transpositions without copying.

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

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