Towards Compositional and Generative Tensor Optimations

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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 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
- Hidden and/or rigid optimization heuristics
- Flexible/Adaptive optimization heuristics

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

Goal
A cross-domain intermediate language for tensor optimizations

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

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

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

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

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

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