Towards Compositional and Generative Tensor Optimizations
Adilla Susungi, Norman Rink, Jerónimo Castrillón, Immo Huismann, Albert Cohen, Claude Tadonki, Jörg Stiller, Jochen Fröhlich

To cite this version:

HAL Id: hal-01666818
https://hal-mines-paristech.archives-ouvertes.fr/hal-01666818
Submitted on 18 Dec 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Towards Compositional and Generative Tensor Optimizations

Adilla Susungi, Norman A. Rink, Jerónimo Castrillón, Immo Huismann, Albert Cohen, Claude Tadonki, Jörg Stiller and Jochen Fröhlich

adilla.susungi@mines-paristech.fr — norman.rink@tu-dresden.de

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

Related Work

- Different levels of expressiveness and control on optimizations
  - Flexibleadaptive
  - Hiddenrigid

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

```
# 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(A, u, [2, 1])
tmp2 = contract(A, tmp1, [2, 2])
tmp3 = contract(tmp2, [2, 3])

# Iterator declaration
i1 = iterator(0, N, 1)
i2 = iterator(0, N, 1)

# Association of iterators
# to computations
build(D, [td1, td2, td3])
build(v, [k12, k22, k32, k42])

# Transpositions
tmp2t = vtranspose(tmp2, 1, 2)

# Element-wise multiplication
tmp6 = entrywise(D, tmp3)

# Tensor contractions
tmp5 = contract(A, tmp4, [2, 1])
tmp6 = contract(A, tmp5, [2, 2])
v = contract(A, tmp6, [2, 3])

# Loop interchanges
interchange(i1, i3)
interchange(i4, i5)
interchange(j2, j1)
interchange(k3, k2)

# ... other optimizations
```

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)
```

Future Work

- Applications to other domains
- Syntax refinement
- Formal semantics

This work was partially funded by the German Research Council (DFG) through the Cluster of Excellence ‘Center for Advancing Electronics Dresden’ (cfaed) and by PSL Research University through the ACOPAL project.