



HAL
open science

Towards Compositional and Generative Tensor Optimizations

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

► **To cite this version:**

Adilla Susungi, Norman A Rink, Jerónimo Castrillón, Immo Huisman, Albert Cohen, et al.. Towards Compositional and Generative Tensor Optimizations. ACM SIGPLAN conference on Systems, Programming, Languages and Applications: Software for Humanity (SPLASH), Oct 2017, Vancouver, Canada. 2017. hal-01666818

HAL Id: hal-01666818

<https://minesparis-psl.hal.science/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 Huisman, 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

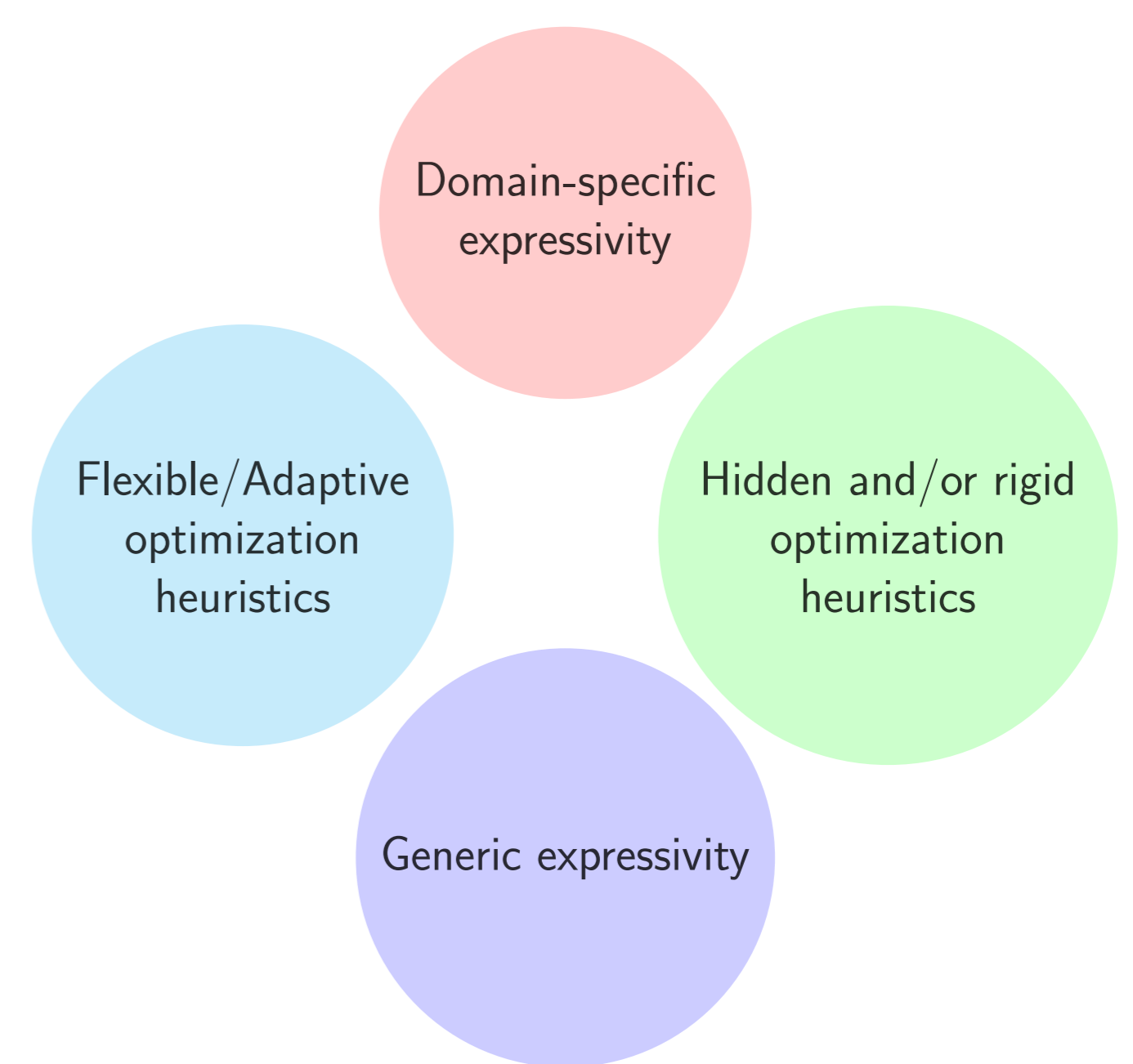
Inverse Helmholtz

$$t_{ijk} = \sum_{l,m,n} A_{kn}^T \cdot A_{jm}^T \cdot A_{il}^T \cdot u_{lmn}$$

$$p_{ijk} = D_{ijk} \cdot t_{ijk}$$

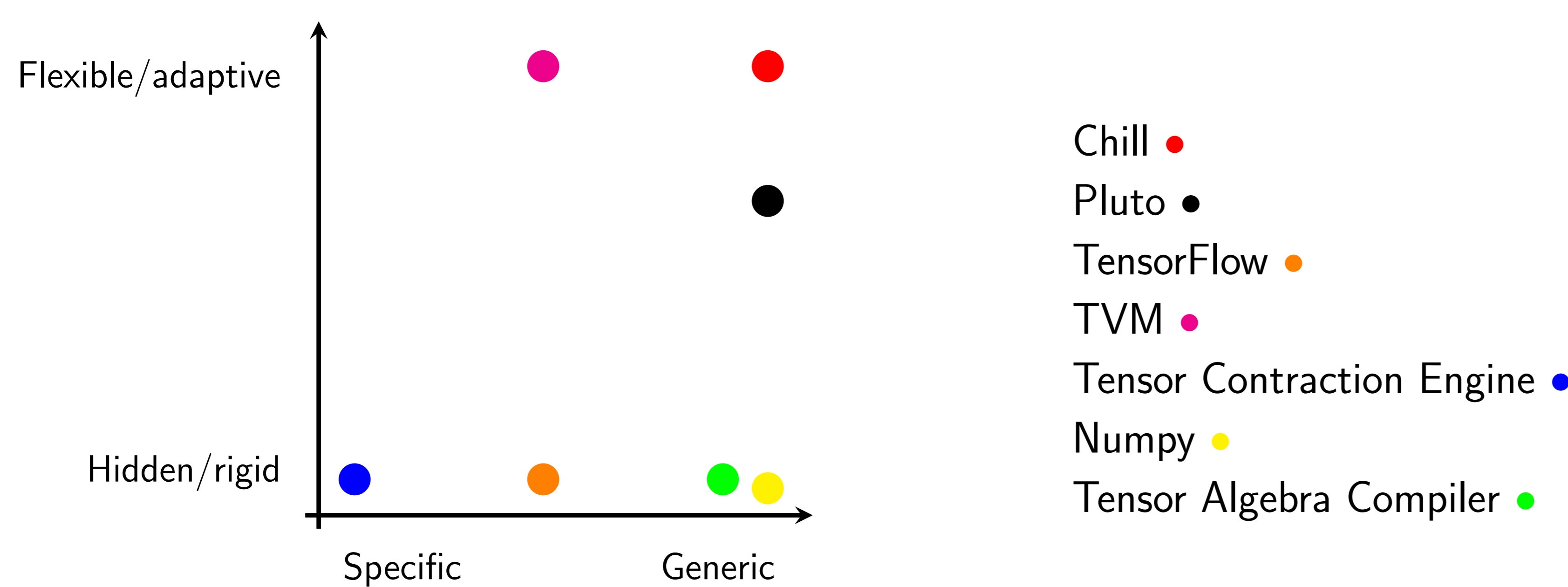
$$v_{ijk} = \sum_{l,m,n} A_{kn} \cdot A_{jm} \cdot A_{il} \cdot p_{lmn}$$

Tensor Optimization Frameworks



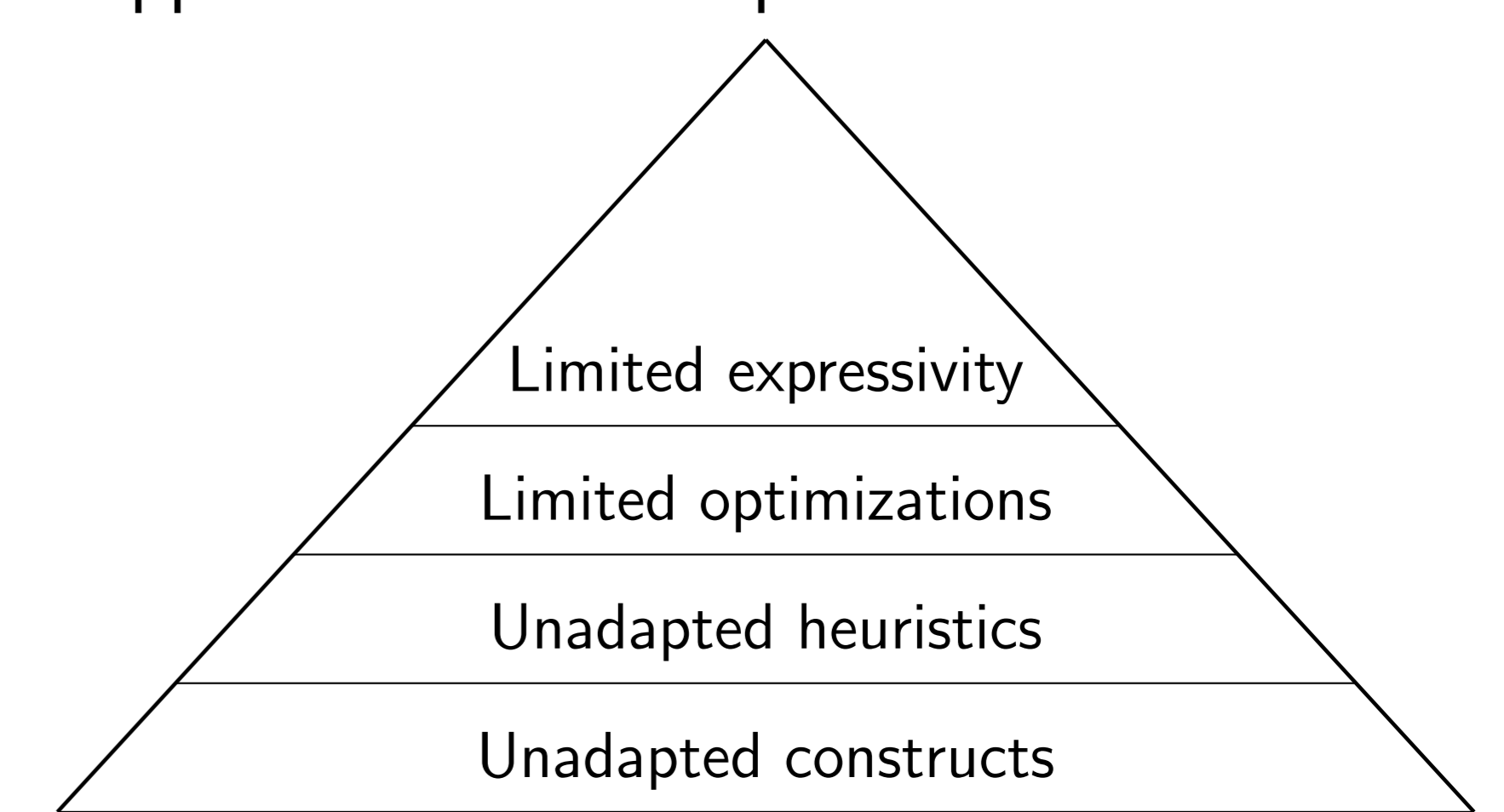
Related Work

- Different levels of expressiveness and control on optimizations



Optimizing CFD Kernels with Existing Tools

- Several limitations
- Few opportunities for adaptations



Should we create yet another domain-specific solution?

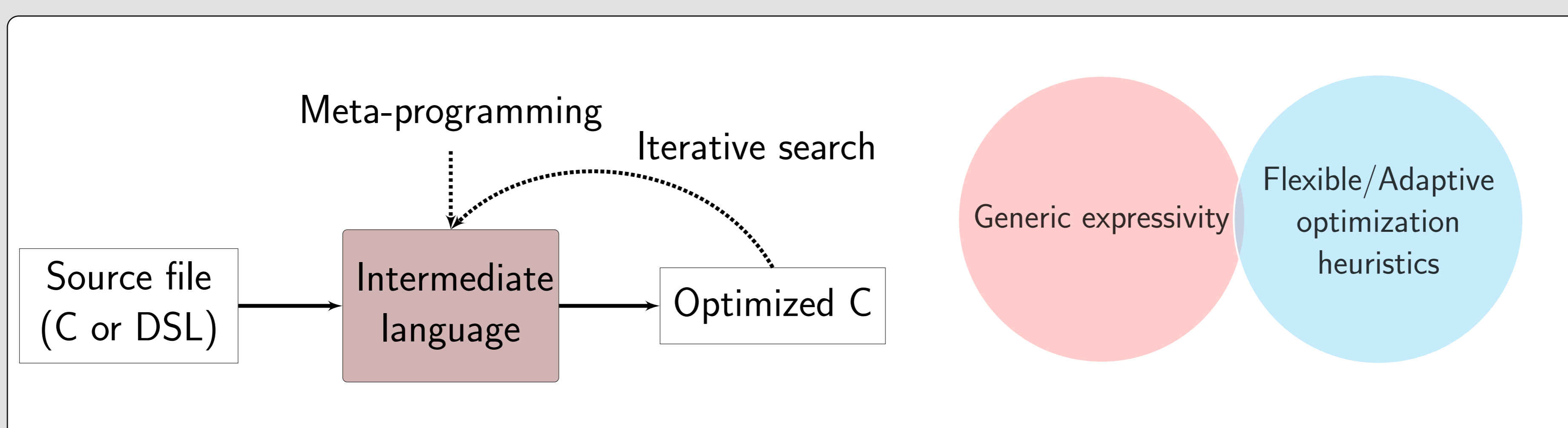
Goal

A cross-domain intermediate language for tensor optimizations

Intermediate Language

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

Envisioned Tool



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(At, u, [2, 1])
tmp2 = contract(At, tmp1, [2, 2])
tmp3 = contract(At, tmp2, [2, 3])

# Element-wise multiplication
tmp4 = entrywise(D, tmp3)

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

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

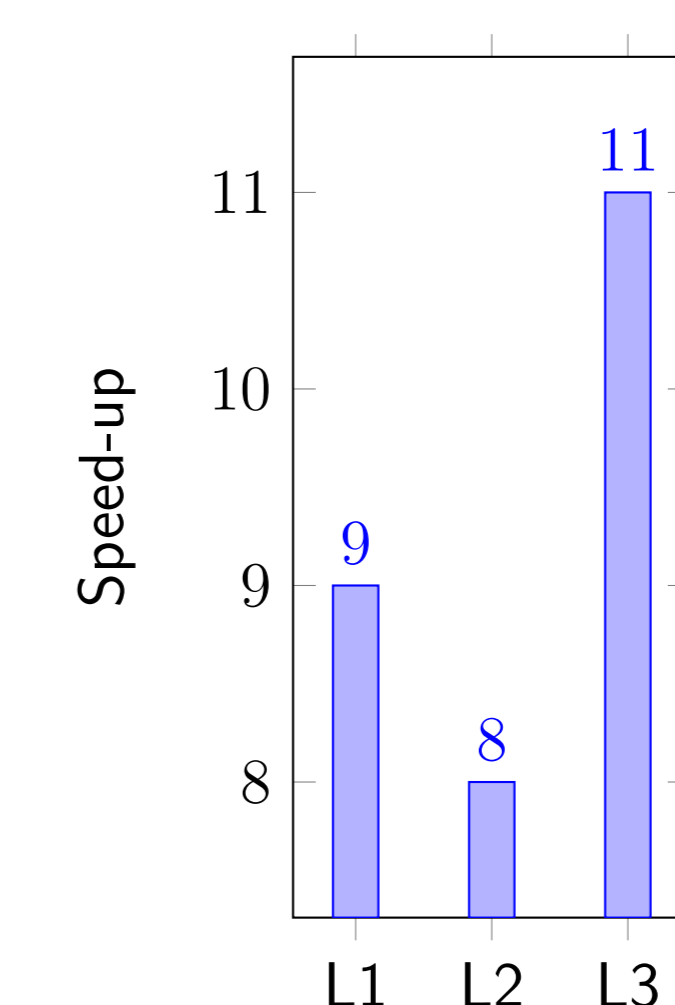
# Association of iterators
# to computations
build(D, [td1, td2, td3])
build(tmp1, [i1, i2, i3, i4])
# Also applies to tmp2, ..., tmp6
build(v, [k12, k22, k32, k42])

# Loop interchanges
interchange(i4, i3)
interchange(i4, i2)
interchange(j2, j1)
interchange(j1, j4)

# Transpositions
tmp2t = vtranspose(tmp2, 1, 2)
replace_array(j3, tmp2, tmp2t)
replace_array(k4, tmp2, tmp2t)
tmp3t = vtranspose(tmp3, 1, 3)
replace_array(k4, tmp3, tmp3t)
interchange(k3, k2)

# ... other optimizations
```

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.

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

