Shoal: self-tuning for memory allocation and access

Stefan Kaestle, Reto Achermann
4th year PhD student
Advisor: Timothy Roscoe

Systems Group @ ETH Zurich

inf | Informatik
Computer Science

Stefan Kaestle
stefan.kaestle@inf.ethz.ch

Observation: HW complex

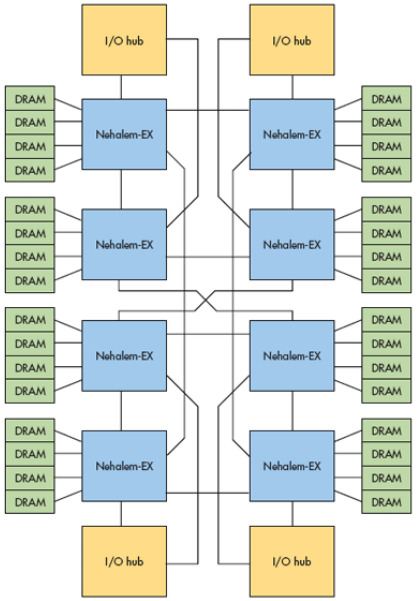
Systems@ETH Zürich

- Multicores: complex memory subsystem
  - non-uniform memory access (NUMA)
  - complex interconnect network
  - hardware features
    - different page sizes (4KB, 2/4MB, 2GB)
    - DMA engines

now

future

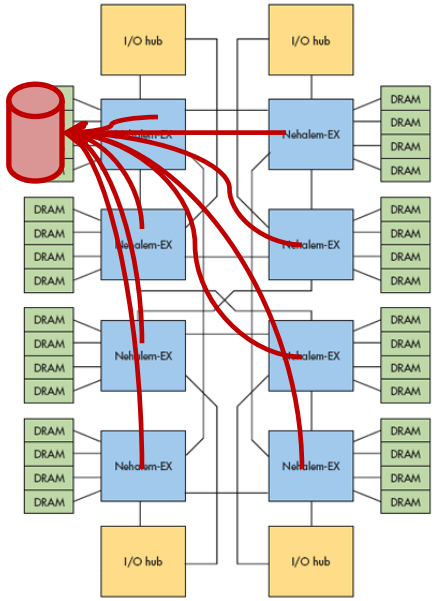
  - no single global address space
  - no cache-coherence



worse:
diversity, constant changes

Implications / Problem

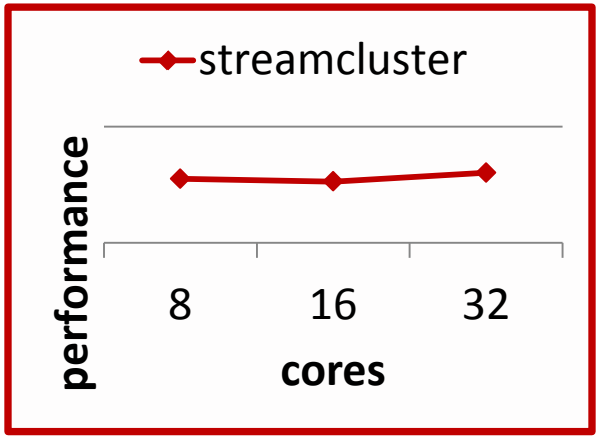
→ programmers **struggle**



- where to allocate memory?
- how to access this memory?

if wrong → no scalability & bad performance:

- interconnect contention
- saturation of memory controllers



Stefan Kaestle <stefan.kaestle@inf.ethz.ch>

Goal

Systems@ETH Zürich

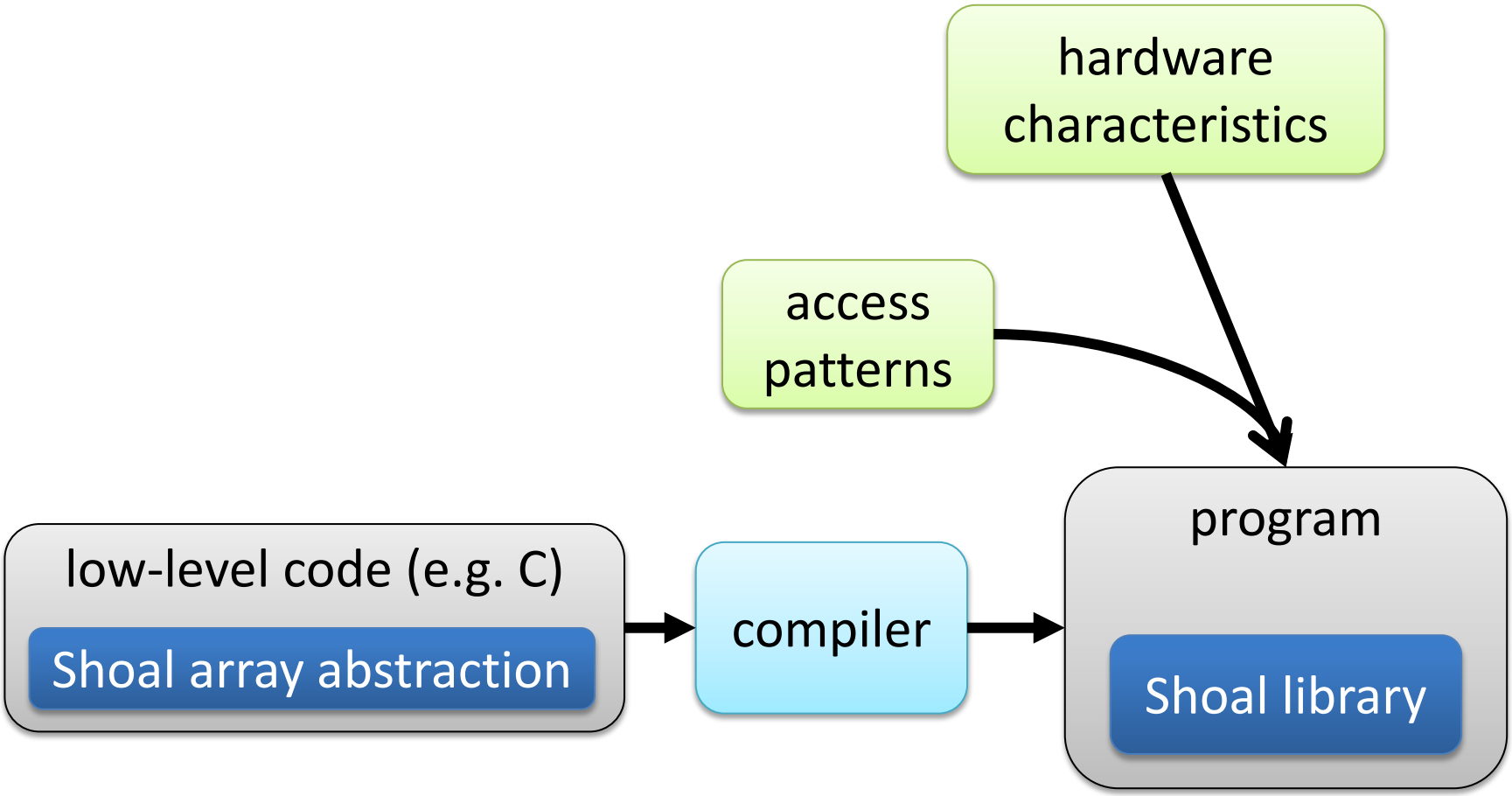
- **simplify** the life of programmers
- **hardware-aware** memory allocation & access
- automatic tuning, **without**:
  - ✗ constantly fine-tune applications
  - ✗ understand the hardware
- support for wide range of current/future HW

Our System: **Shoal**

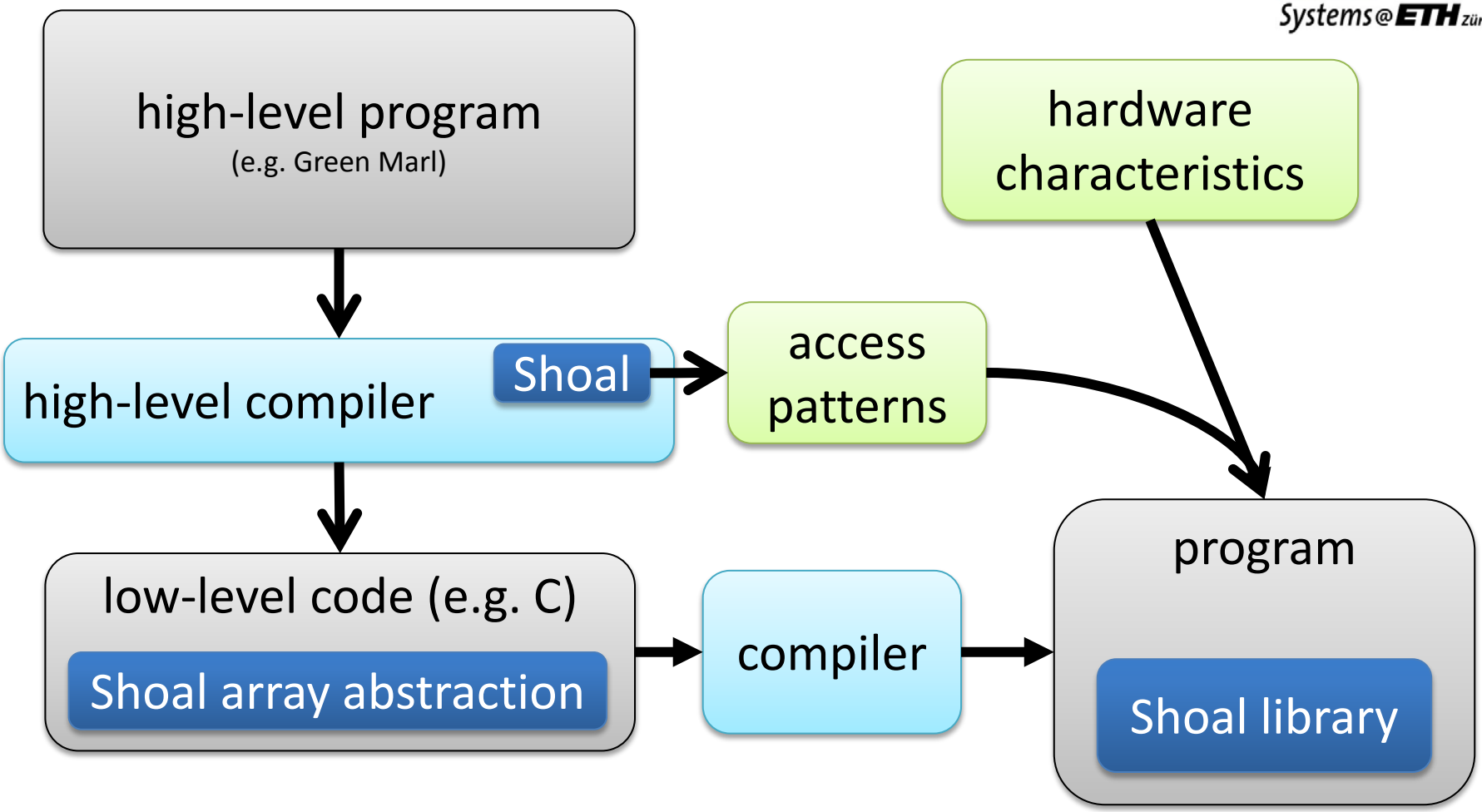
- **array** abstraction
- rich `alloc` call: **access patterns** as arguments
  - manually or automatic from high-level description
- various implementations
  - e.g. replicated, distributed, partitioned
- **selection automatically** based on *a)* access patterns and *b)* HW characteristics

Stefan Kaestle <stefan.kaestle@inf.ethz.ch>

Overview


hardware characteristics
access patterns
program
low-level code (e.g. C)
Shoal array abstraction
compiler
Shoal library

Overview


high-level program
(e.g. Green Marl)
hardware characteristics
high-level compiler
Shoal
access patterns
low-level code (e.g. C)
Shoal array abstraction
compiler
program
Shoal library

Overview

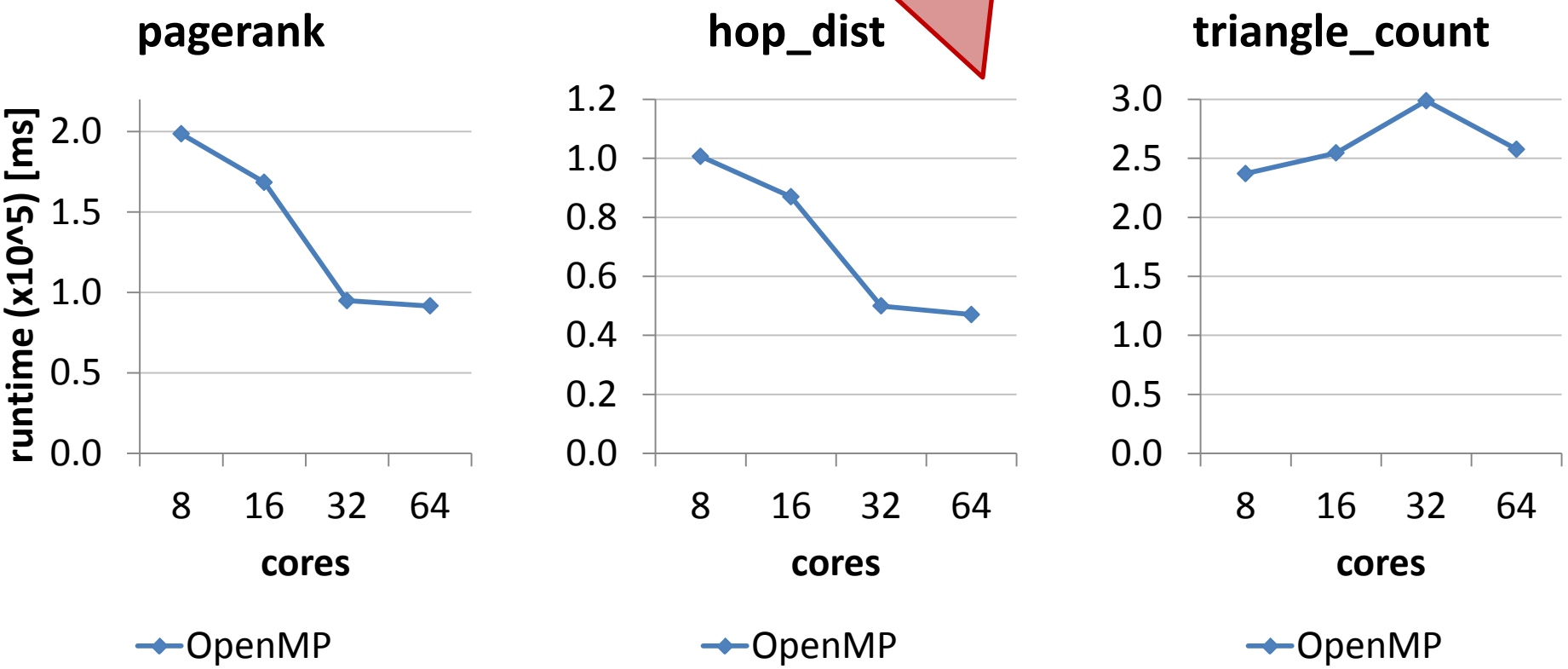
```
Procedure pagerank(G: Graph, e,d: Double,
    max: Int; pg_rank: Node_Prop<Double>)
{
    Double diff;
    Int cnt = 0;
    Double N = G.NumNodes();
    G.pg_rank = 1 / N;
    Do {
        diff = 0.0;
        Foreach (t: G.Nodes) {
            Double val = (1-d) / N + d* Sum(w: t.InNbrs){
                w.pg_rank / w.OutDegree()} ;
            diff += | val - t.pg_rank |;
            t.pg_rank <= val @ t;
        }
        cnt++;
    } While ((diff > e) && (cnt < max));
}
```

No changes to Green Marl input program

Evaluation: Scalability

Green Marl

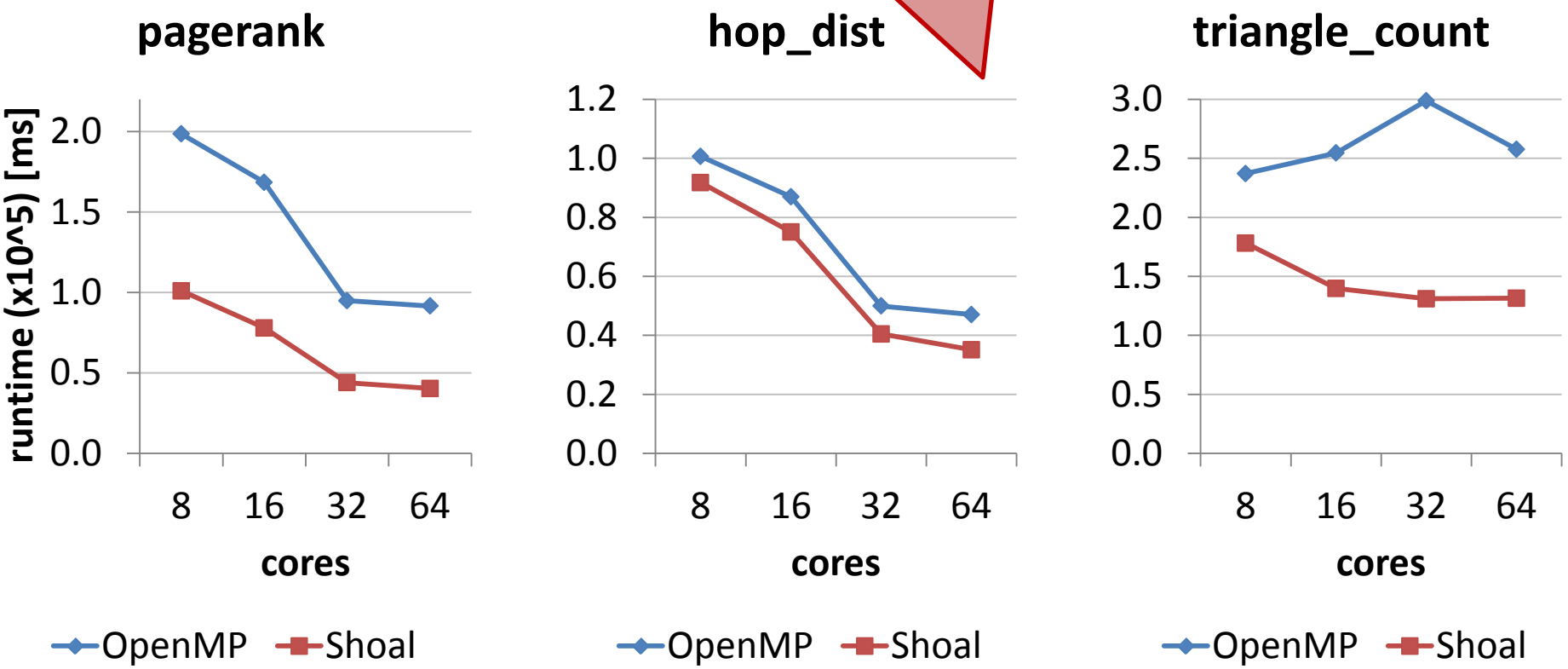
scales fairly well



Evaluation: Scalability

Green Marl

up to 2x improvement



Conclusion / Future work

Systems@ETH Zürich

- library to **auto-tune** memory allocation & access
  - based on: **access patterns & hardware**
- 2x improvement for Green Marl graph algorithms
  - **no modifications** to input program

- Next:
  - scheduling
  - synchronization
  - heterogeneous machines

→ long term: maybe multikernel programming model