Towards Efficient Computing

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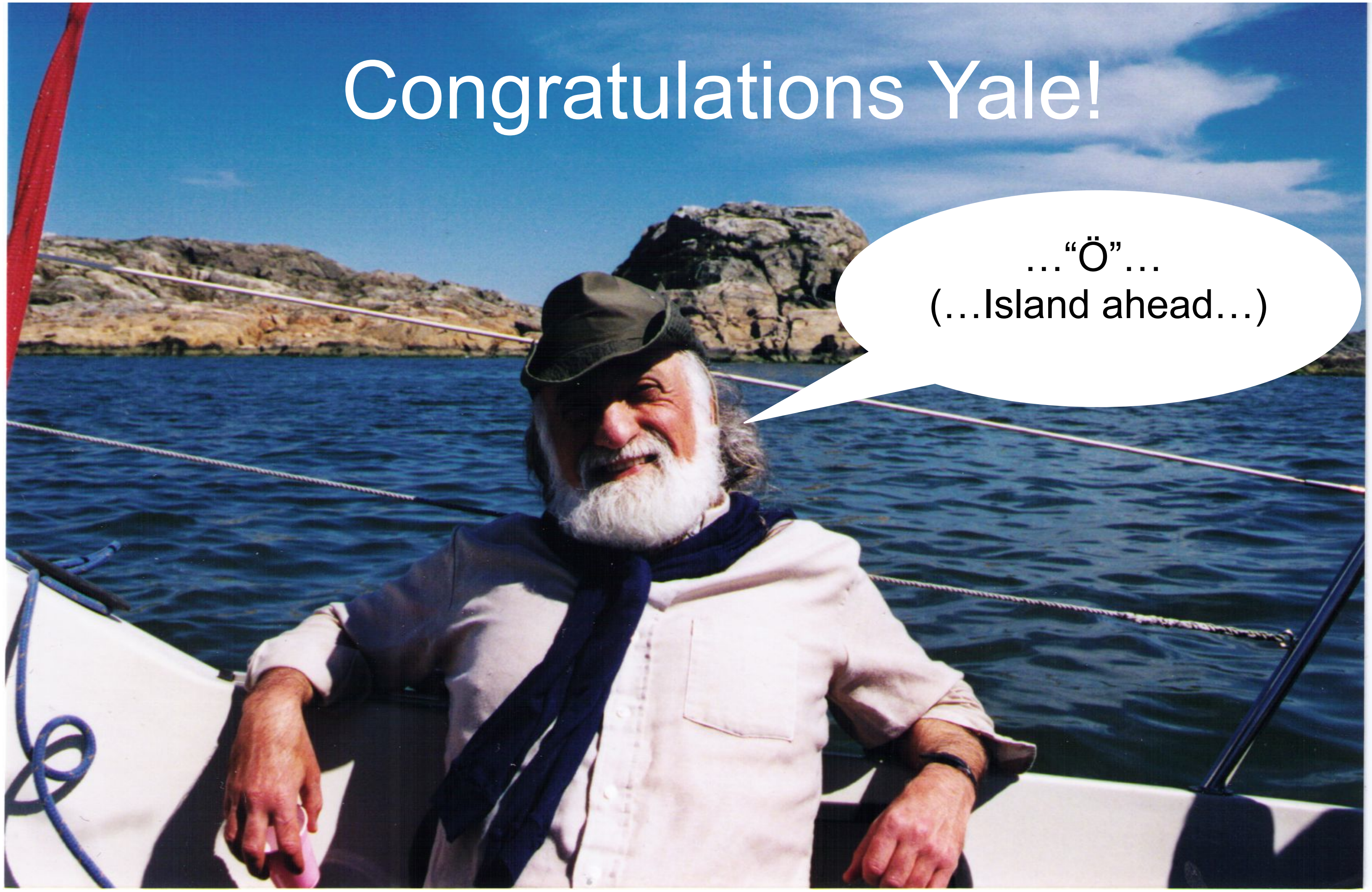
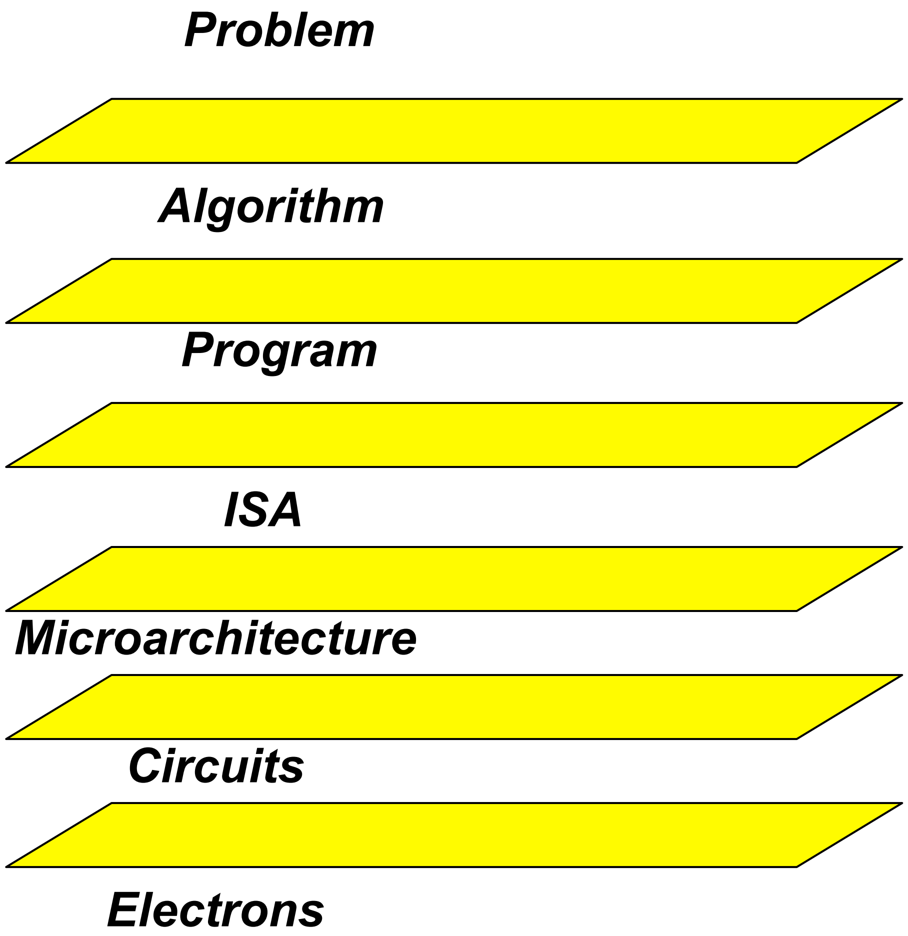

Congratulations Yale!
…"Ö"…
(…Island ahead…)

Threats and Opportunities

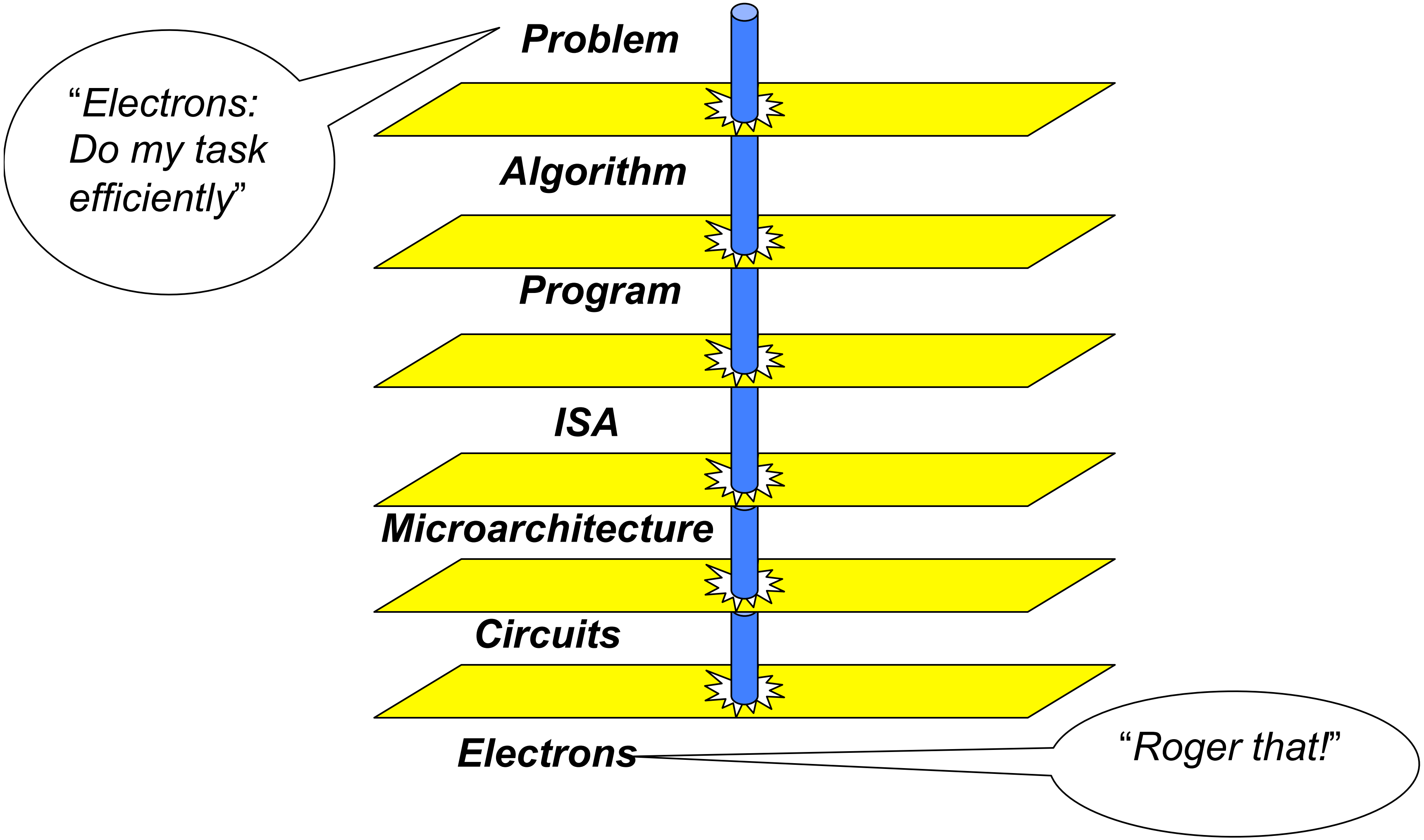
- Parallelism is ubiquitous but hard to deal with
- Power is heavily constraining performance growth
- Moore's Law is running out of steam

A radical new way of thinking of compute efficiency is needed

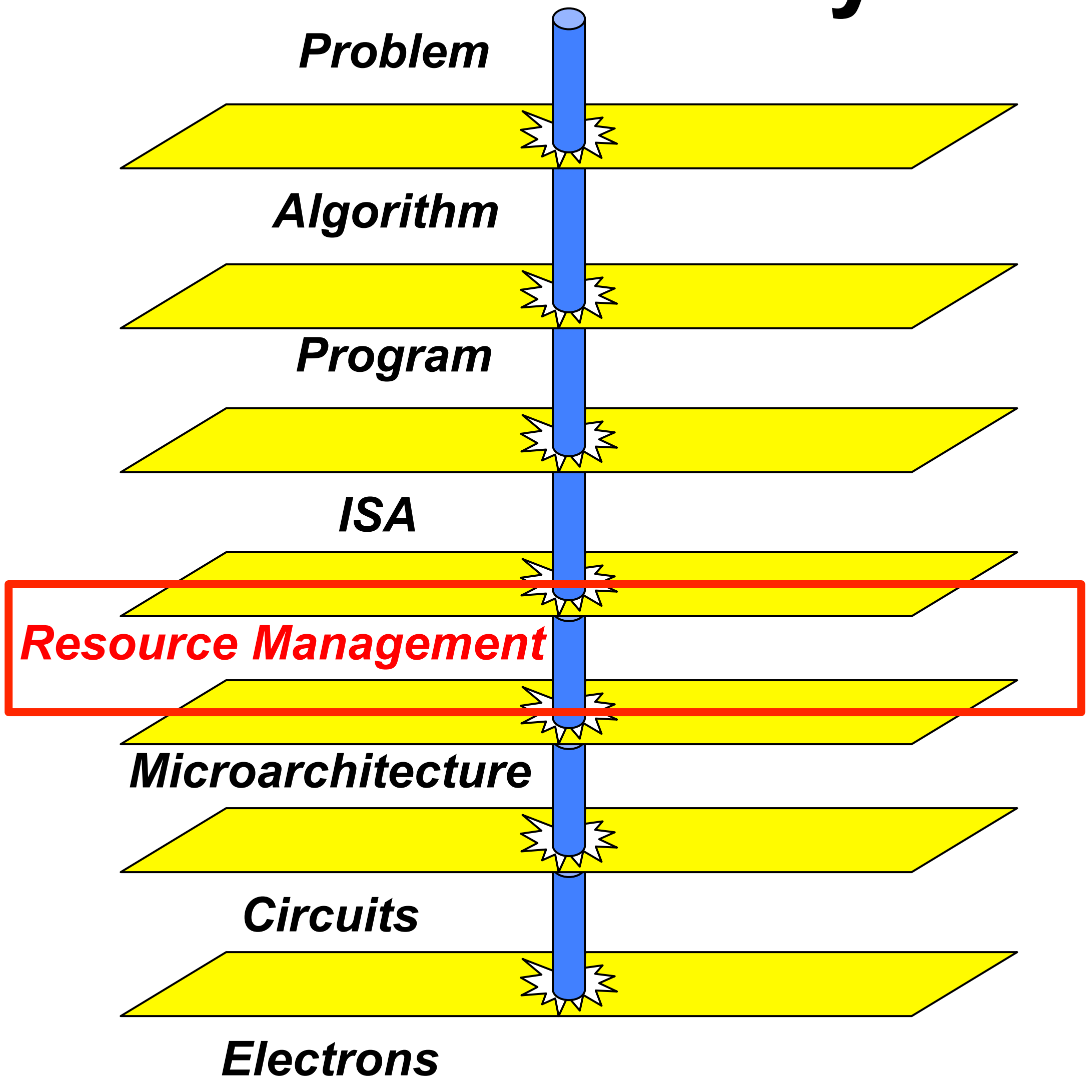
Yale’s Transformation Hierarchy



First Revision



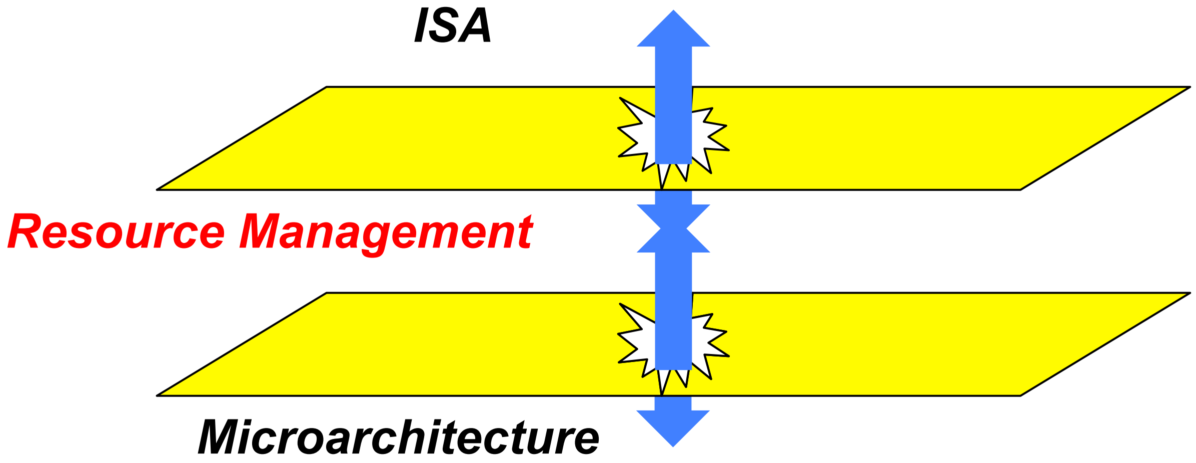
Second Revision: My Hierarchy



(My) Vision for Efficient Computing

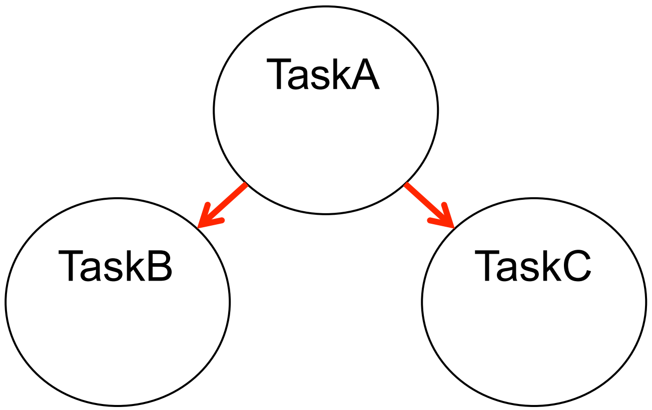
- **P1: Parallelism:**
  - **Programmers:** Unlock parallelism and give hints
  - **Resource manager:** Translate it into higher performance "under the hood"
- **P2: Power:**
  - **Programmers:** Express quality of service attributes
  - **Resource manager:** Translate it into more efficient use of hardware resources "under the hood"
- **P3: Predictability:**
  - **Programmers:** Express deadlines (absolute or "soft")
  - **Resource manager:** Manage parallelism predictably "under the hood"

Approach – Interaction Across Layers



Parallelism Management

Task-based Dataflow Prog. Models




```
#pragma css task output(a)
void TaskA( float a[M][M]);

#pragma css task input(a)
void TaskB( float a[M][M]);

#pragma css task input(a)
void TaskC( float a[M][M]);
```

- Programmer annotations for task dependences
- Annotations used by run-time for scheduling
- Dataflow task graph constructed dynamically

Important: Conveys semantic information to run-time for efficient scheduling

Possible Optimizations

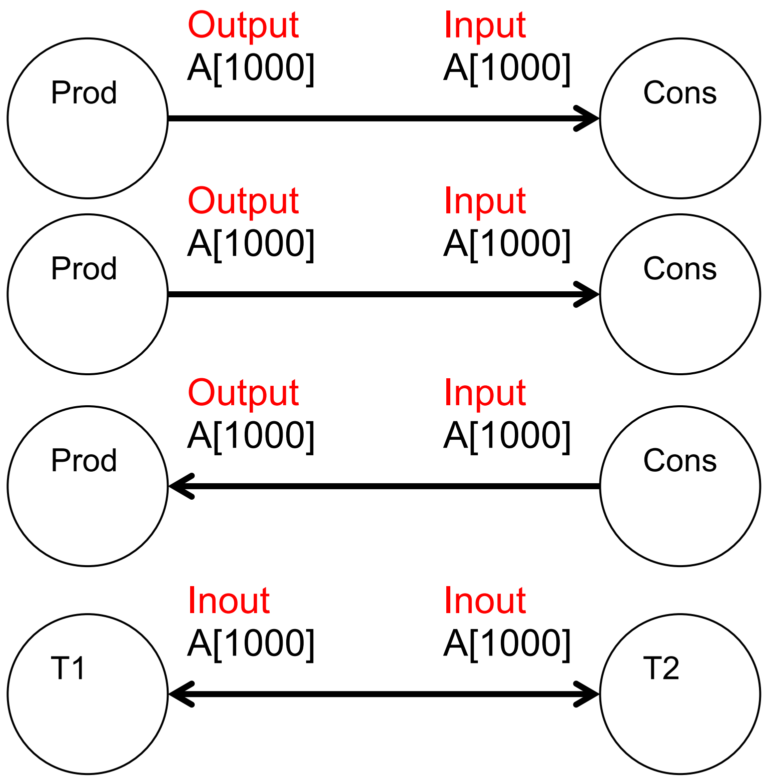
Dependency annotations allow for optimizations with high accuracy (like in message passing)

Bulk data transfer

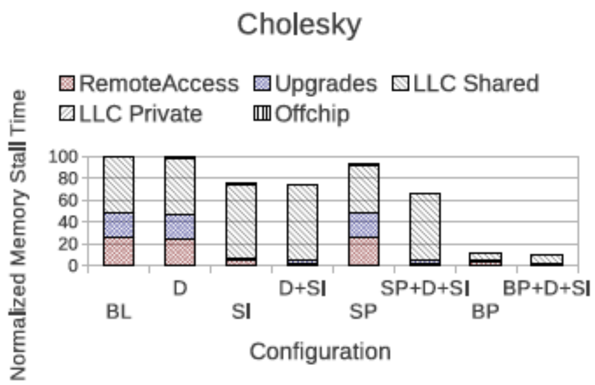
Forwarding

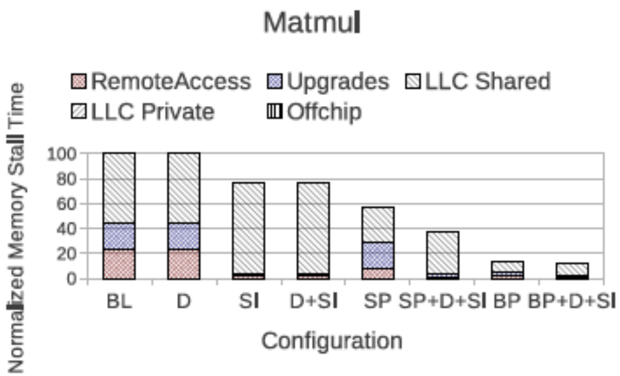
Prefetching

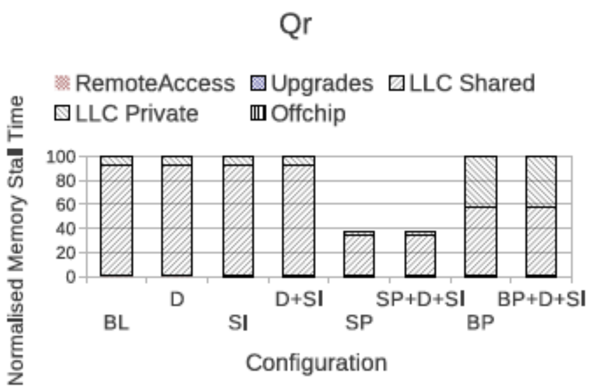
Migratory sharing optimization

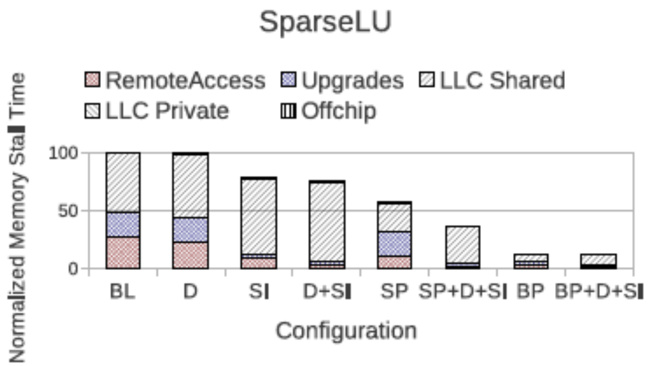


Run-time Guided Cache Coherence









- Self-invalidation provides significant gains
- SP+D+I provides added gains

Other Opportunities

- Give run-time system the responsibility to manage cache hierarchy resources just like virtual memory manager or hypervisor manages memory resources
- Use data-flow graph notion (explicit or inferred dynamically) to exploit speculative parallelism with high success rate
- Migrating computation rather than data, by exploiting semantic information about data usage

MECCA is investigating these opportunities

Power Management

What if

- Users expressed how long time a computation must take?
- Resource manager could **track** progress against deadlines?
- Resource manager could **predict** the remaining time as a function of resources?

Opportunities:

- Controlled throttling of resources
- Controlled scheduling of computations on heterogeneous substrates

In general: Considerable room for trading performance for reduced power consumption

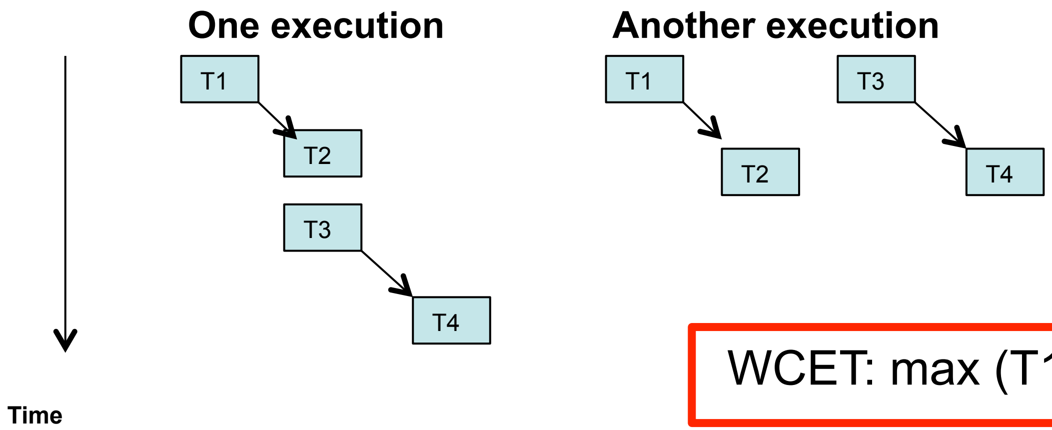
MECCA is investigating these opportunities

Predictability Management

Context: Real-time applications

Sequential processing: Establishing tight bounds on execution time (WCET) is fairly well understood

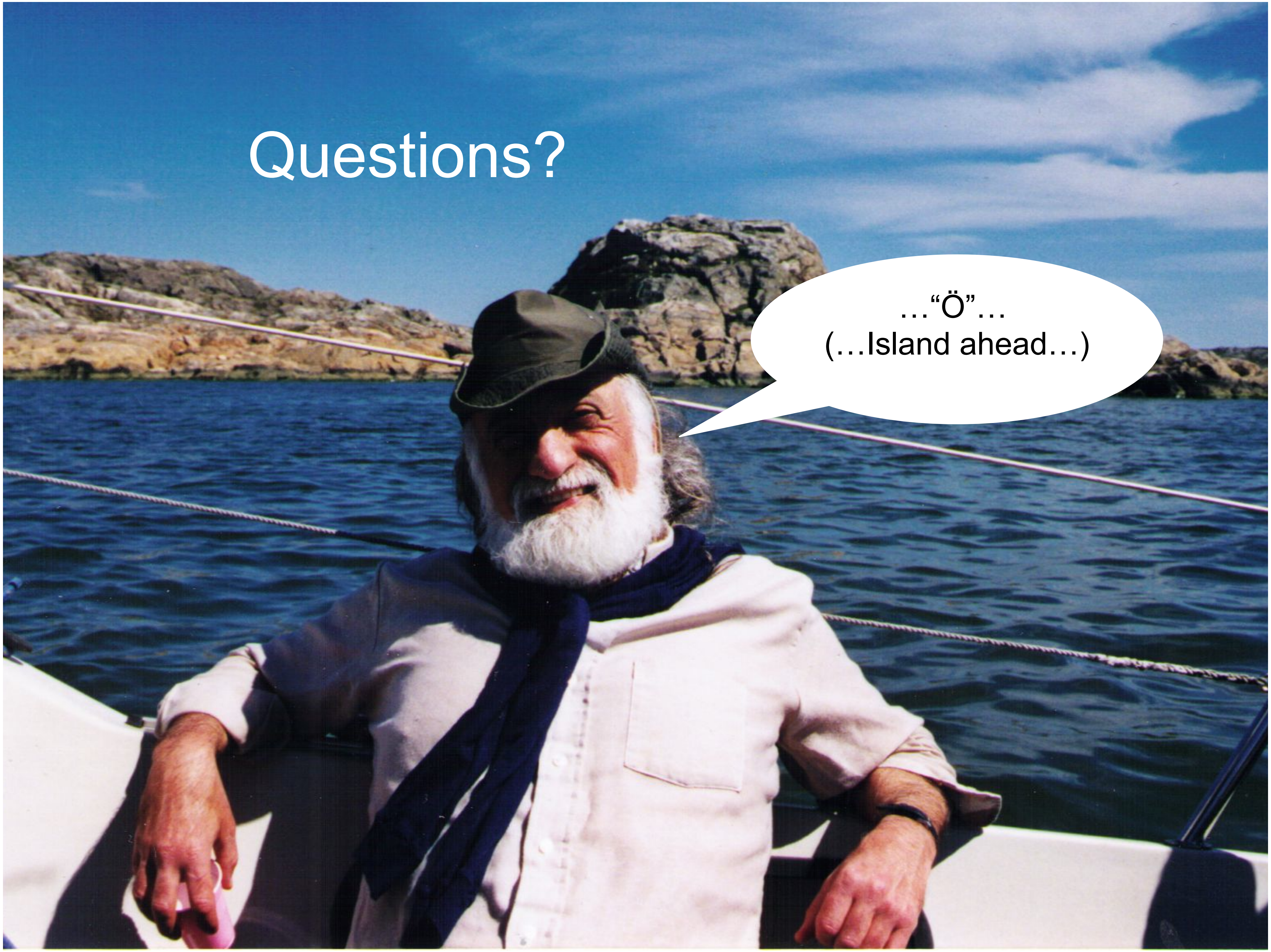
Parallel processing: Unexplored terrain



WCET: max (T1+T2, T3+T4)

Deterministic scheduling => New playground for trading performance for power under strict timing guarantees

MECCA is investigating these opportunities


Questions?
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