Data Processing on Modern Hardware

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A Few Words About Me

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1996–2001 Diploma in Physics, U Konstanz
2001–2005 Research assistant, DBIS Group, U Konstanz
2005–2007 Research assistant, Database Group, TU München
Oct 2006 PhD in Computer Science (XML query processing)
2007–2008 Postdoc, IBM T. J. Watson Research Center, NY, USA
2008–2013 Senior Researcher, Systems Group, ETH Zurich
since 4/2013 Full Professor, DBIS Group, TU Dortmund University

Topic: Database systems on modern computing hardware
A Motivating Example (Memory Access)

Task: sum up all entries in a two-dimensional array.

Alternative 1:

```c
for (r = 0; r < rows; r++)
    for (c = 0; c < cols; c++)
        sum += src[r * cols + c];
```

Alternative 2:

```c
for (c = 0; c < cols; c++)
    for (r = 0; r < rows; r++)
        sum += src[r * cols + c];
```

Both alternatives touch the same data, but in different order.
A Motivating Example (Memory Access)

![Graph showing the relationship between total execution time and number of rows and columns.](image)

- Total execution time is measured in seconds ranging from 1s to 100s.
- The x-axis represents the number of rows, ranging from $10^0$ to $10^9$.
- The y-axis represents the total execution time, ranging from $10^0$ to $10^9$.
- The graph indicates a nonlinear relationship between the number of rows and the execution time, with execution time increasing as the number of rows increases.

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A Motivating Example (Multi-Core)

Task: run parallel instances of the query

```
SELECT SUM(lo_revenue)
FROM part, lineorder
WHERE p_partkey = lo_partkey
AND p_category <= 5
```

To implement \( \sigma \) use either

- a hash join or
- an index nested loops join.

A Motivating Example (Multi-Core)

Co-run independent instances on different CPU cores.

Concurrent queries may seriously affect each other’s performance.
A Motivating Example (Non-Commodity Hardware)

Task: in a long stream of items, find those items that occur most often.

Algorithm *Space-Saving* (Metwally *et al.*, TODS, vol. 31(3), 2006):

1. **foreach** stream item $x \in S$ **do**
2. find bin $b_x$ with $b_x.item = x$;
3. **if** such a bin was found **then**
   4. $b_x.count \leftarrow b_x.count + 1$;
4. **else**
   5. $b_{\text{min}} \leftarrow \text{bin with minimum count value}$;
   6. $b_{\text{min}}.count \leftarrow b_{\text{min}}.count + 1$;
   7. $b_{\text{min}}.item \leftarrow x$;
A Motivating Example (Non-Commodity Hardware)

Jens Teubner, René Müller, and Gustavo Alonso. FPGA Acceleration for the Frequent Item Problem. *ICDE 2010.*
Course Content

- **Cache Awareness**
  - How can we place data in memory and access it in a way that makes optimal use of memory caches?

- **Query Execution**
  - How can we tune our algorithms to fit modern processor architectures?

- **Multi-Core Architectures**
  - How can we exploit the parallelism provided by multi-core architectures?

- **Specialized Hardware**
  - How can we (mis-)use specialized hardware for data processing (*e.g.*, GPUs, FPGAs, modern NICs)?
Course Organization

Lecture:
- Mondays, 14–16h, OH 12, E.003
  Please visit this website **regularly**. We will frequently post new information during the semester.

Exercises: (also done by me)
- Mondays, 16–18h, OH 12, E.003
- First exercise: today
- Exercise material is part of the course content!
Information about the exam will follow!
Course Setup

- I’d like to make this course highly interactive.
  - Please speak up, discuss, ask questions!

- The material we discuss is relevant in practice.
  - We’ll provide practical examples and exercises.
  - You achieve maximum fun factor if you verify techniques on your machine.
This is **not** a standard course (often even “bleeding edge”).

- There is **no real textbook** for this course. Computer architecture basics are covered in “Computer Architecture: A Quantitative Approach” by Hennessy and Patterson, though.

- I’ll make **lecture slides** available on the web.

- Most material is taken out of **research papers**.
  - I’ll give references to those papers.
  - These are all good and easy-to-read papers.

- The techniques that we discuss are related to classical database implementation techniques. If you’ve heard a course like “Architecture of DBMS” before, you might recognize some ideas again.
MonetDB implements many of the techniques we’ll talk about.

- MonetDB is open-source: http://monetdb.cwi.nl/
- Support for SQL and XQuery, multi-platform
- Numerous tools to look “under the hood” of MonetDB.
- Primary development: CWI Amsterdam
- Try it out yourself!

HyPer is another very successful “in-memory database.”

- Developed originally at TU München
- Web site: http://www.hyper-db.de/
- Just acquired by Tableau Software
We want **You**

The topics that we discuss in this lecture are highly related to the topics of my research group.

- **Our work is internationally very successful**
  - *Avalanche* is a research project that I started at ETH Zurich and it is well-known by now in the research community.

- **You** could help us:
  - Bachelor/Master Theses, contribution as student assistant, etc.

- **Approach me** if you’d like to contribute to a vibrant project at the forefront of research.