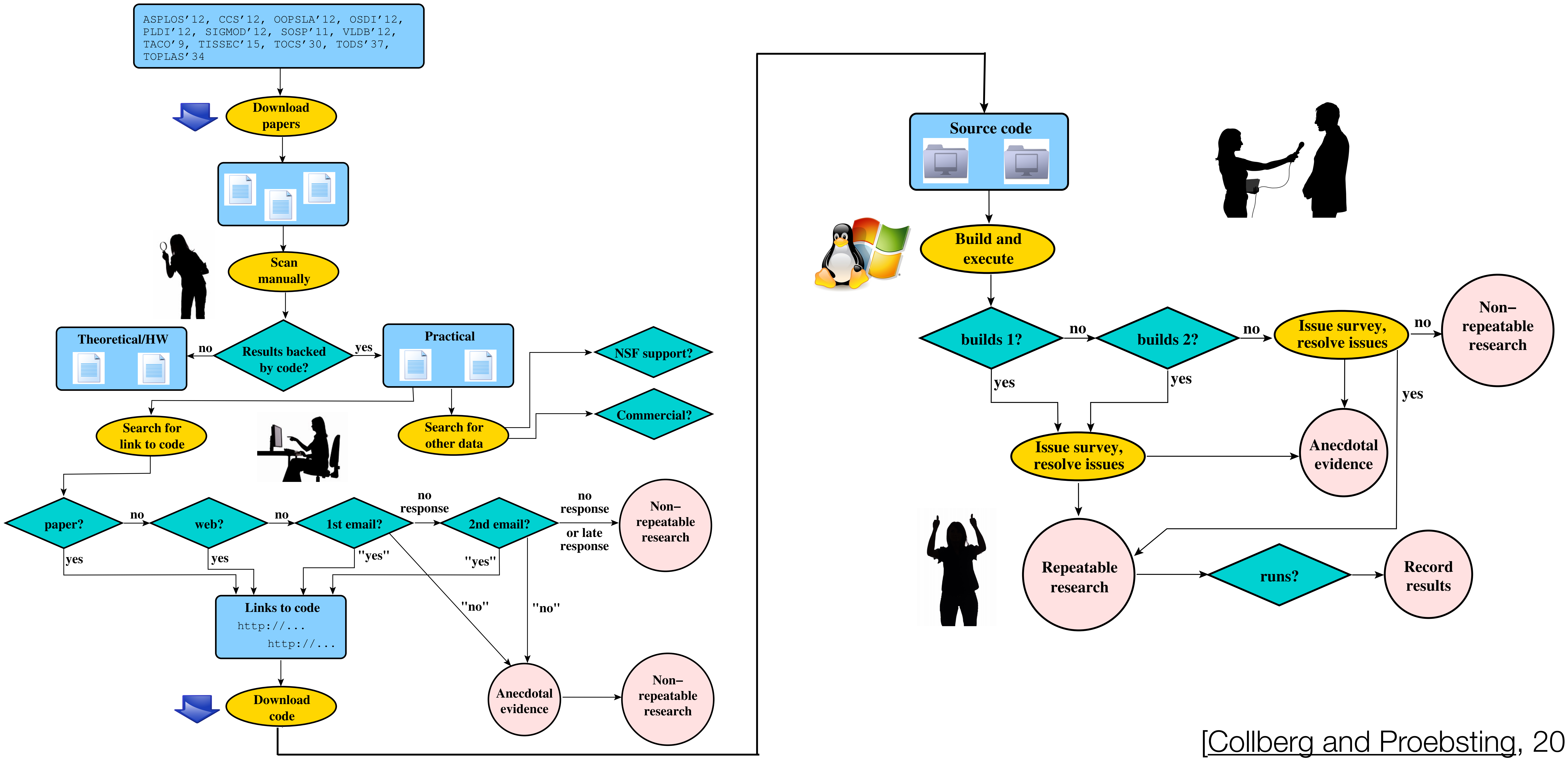
Advanced Data Management (CSCI 640/490)

Machine Learning in Databases

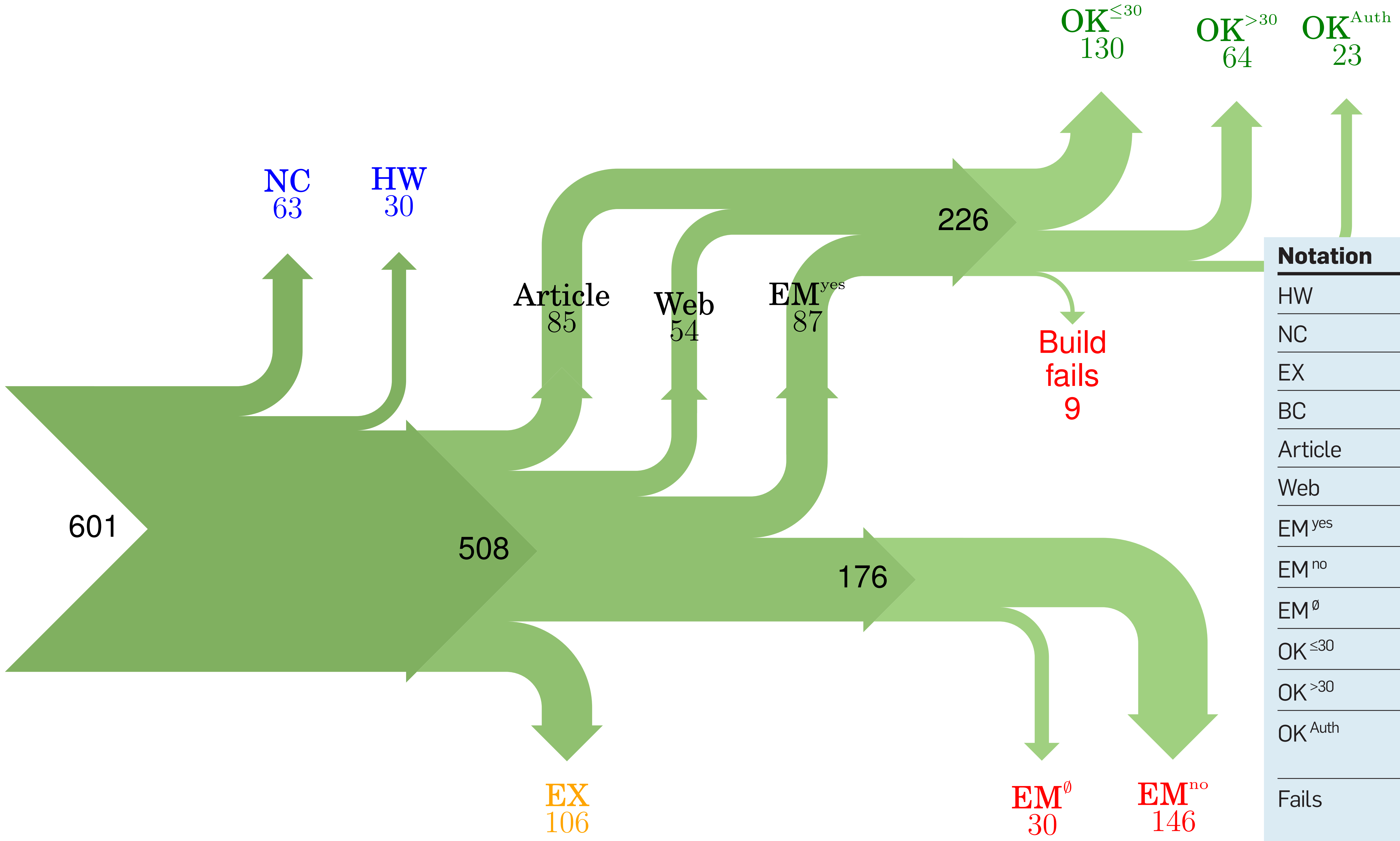
Dr. David Koop

Checking Computational Results in Systems



[Collberg and Proebsting, 2015]

Repeatability Results



Notation	Number of papers ...
HW	excluded due to replication requiring special hardware
NC	excluded due to results not being backed by code
EX	excluded due to overlapping author lists
BC	where the results are backed by code
Article	where code was found in the paper itself
Web	where code was found through a Web search
EM^{yes}	where the author provides code after receiving an email message
EM^{no}	where the author responds to an email message saying code cannot be provided
$EM^{\emptyset}$	where the author does not respond to email requests within two months
$OK^{\leq 30}$	where code is available and we succeed in building the system in ≤30 minutes
$OK^{>30}$	where code is available and we succeed in building the system in >30 minutes
OK^{Auth}	where code is available and we fail to build, and the author says the code builds with reasonable effort
Fails	where code is available and we fail to build, and the author says the code may have problems building

Figure 11: Study result. Blue numbers represent papers that were excluded from consideration, green numbers papers that are weakly repeatable, red numbers papers that are non-weakly repeatable, and orange numbers represent papers that were excluded (due to our restriction of sending at most one email to each author).

[Collberg and Proebsting, 2015]

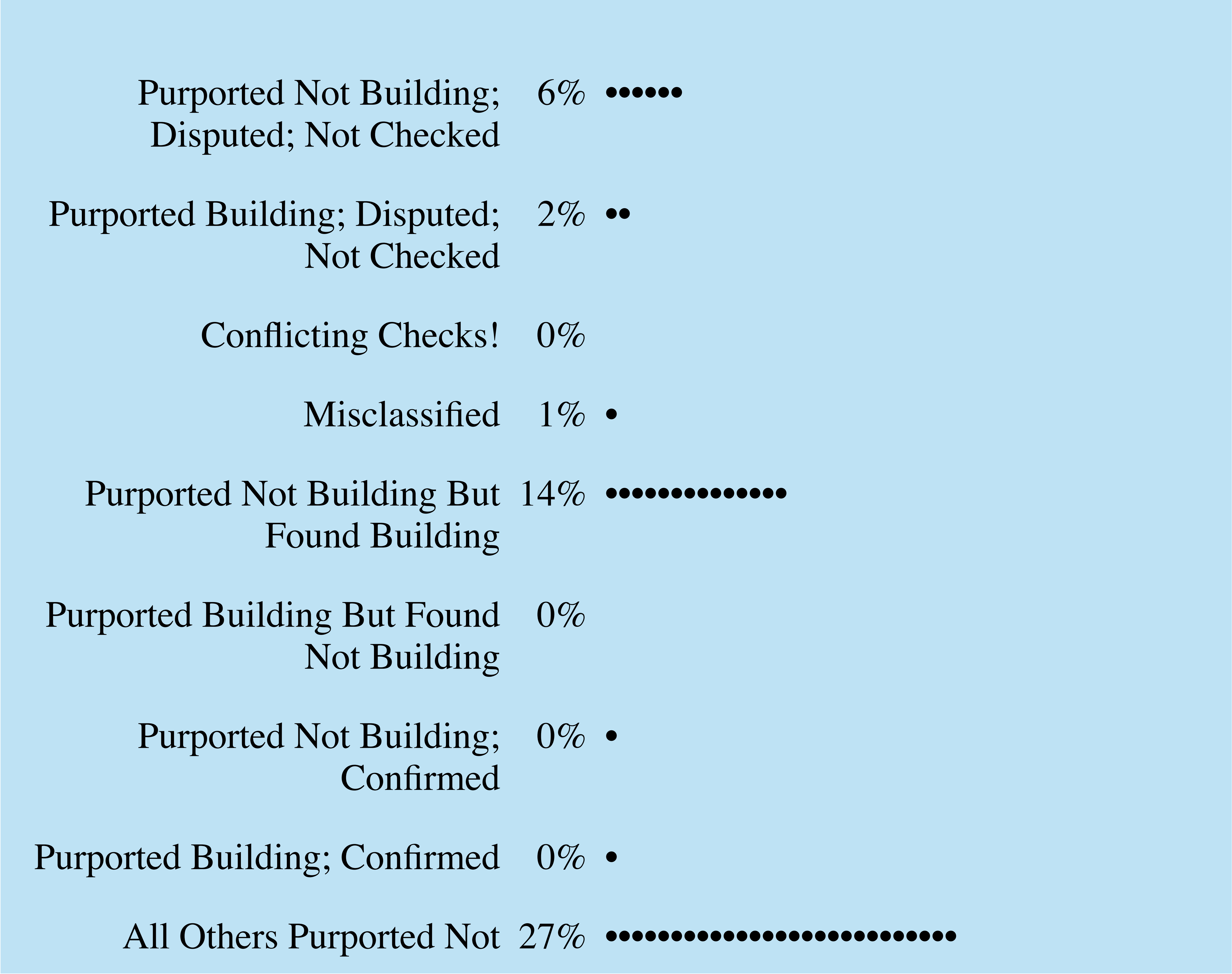
Excuses for not sharing

- Versioning
- Available Soon
- No Intention to Share
- Personnel Issues
- Lost Code
- Academic Tradeoffs
- Industrial Lab Tradeoffs
- Obsolete HW/SW
- Controlled Usage
- Privacy/Security
- Design Issues

[Collberg and Proebsting, 2015]

Examining 'Reproducibility in Computer Science'

- Repeat the experiment in reproducibility!
- Differences from original
- Shows issues with trying to classify experiments



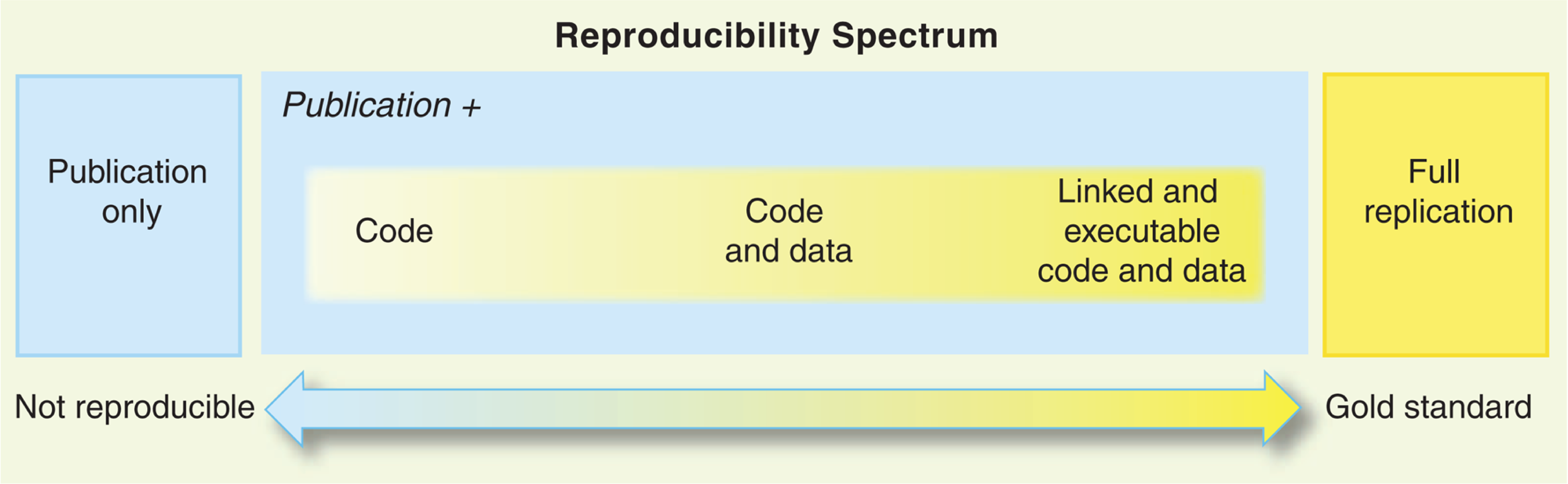
[S. Krishnamurthi et al.]

Reproducible Research

- Science is verified by replicating work independently
- Replication Issues:
  - Requires many resources to replicate (Sloan Digital Sky Survey)
  - Requires significant computing power (Climate Model Simulation)
  - Requires too much time or very specific circumstances (Environment Epidemiology)
- Reproducibility
  - Replication of the analysis based on the collected data (not replicating the data collection itself)
  - Better if we have the actual code or available executables

[R. D. Peng]

Reproducibility Spectrum



[R. D. Peng]

10 Rules for Reproducible Computational Research

- Rule 1: For Every Result, Keep Track of How It Was Produced
- Rule 2: Avoid Manual Data Manipulation Steps
- Rule 3: Archive the Exact Versions of All External Programs Used
- Rule 4: Version Control All Custom Scripts
- Rule 5: Record All Intermediate Results, When Possible in Standardized Formats

[Sandve et al., 2013]

10 Rules for Reproducible Computational Research

- Rule 6: For Analyses That Include Randomness, Note Underlying Random Seeds
- Rule 7: Always Store Raw Data behind Plots
- Rule 8: Generate Hierarchical Analysis Output, Allowing Layers of Increasing Detail to Be Inspected
- Rule 9: Connect Textual Statements to Underlying Results
- Rule 10: Provide Public Access to Scripts, Runs, and Results

[Sandve et al., 2013]

Notebook Reproducibility

- Use notebooks from Github (~1 million)
  - Unambiguous cell order? 81.99%
- Study notebook dependencies
  - Dependencies Available? 13.72%
  - Dependencies Install? 5.03%
- Study notebook executability
  - Execute: 24.11% of unambiguous cell order
  - Matched results: 4.03%

[Pimentel et al., 2019]

Dataflow Notebooks: Resolve Notebook Ambiguities

In [d51f8eab]:

```
import pandas as pd
df = pd.read_csv('guardian-top100-female-2019.csv')
```

df:

	Name	Rank	Position	Age on 1 Dec 2019	Nationality
0	Sam Kerr	1	Forward	26	Australia
...	...	...	...	...	...
99	Ludmila	100	Forward	25	Brazil

100 rows × 5 columns

In [full]:

```
df = df.rename(columns={'Age on 1 Dec 2019': 'Age'})
```

df:

	Name	Rank	Position	Age	Nationality
0	Sam Kerr	1	Forward	26	Australia
...	...	...	...	...	...
99	Ludmila	100	Forward	25	Brazil

100 rows × 5 columns

In [over30]:

```
df = df$full[df$full.Age >= 31]
```

df:

	Name	Rank	Position	Age	Nationality
2	Megan Rapinoe	3	Midfielder	34	USA
...	...	...	...	...	...
96	Cláudia Neto	97	Midfielder	31	Portugal

19 rows × 5 columns

In [under25]:

```
df = df$full[df$full.Age <= 24]
```

df:

	Name	Rank	Position	Age	Nationality
3	Ada Hegerberg	4	Forward	24	Norway
...	...	...	...	...	...
98	Lena Oberdorf	99	Midfielder	17	Germany

25 rows × 5 columns

Assignment 5

- Chicago Bike Sharing Data
  - Spatial Analysis
  - Temporal Analysis
  - Graph Database (neo4j)

Final Exam

- Wednesday, May 10, **8:00**-9:50pm, PM 253
- Similar format
- More comprehensive (questions from topics covered in Test 1 & 2)
- Will also have questions from graph/spatial/temporal data, provenance, reproducibility, machine learning

Improving Databases

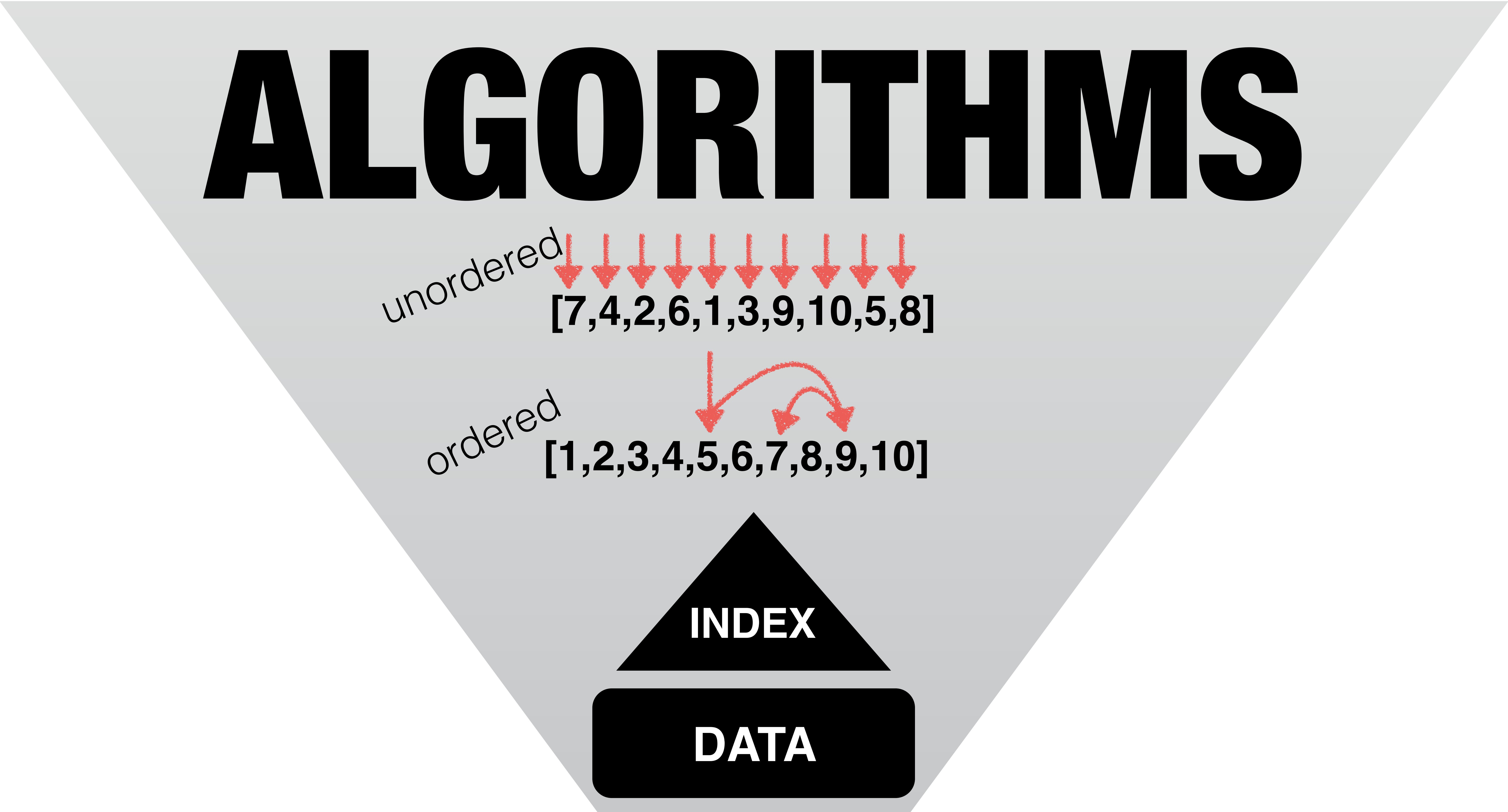
LEARNED AND **SELF-DESIGNING** DATA STRUCTURES

DASlab @ Harvard SEAS

MIT DSAIL
Data Systems and AI Lab

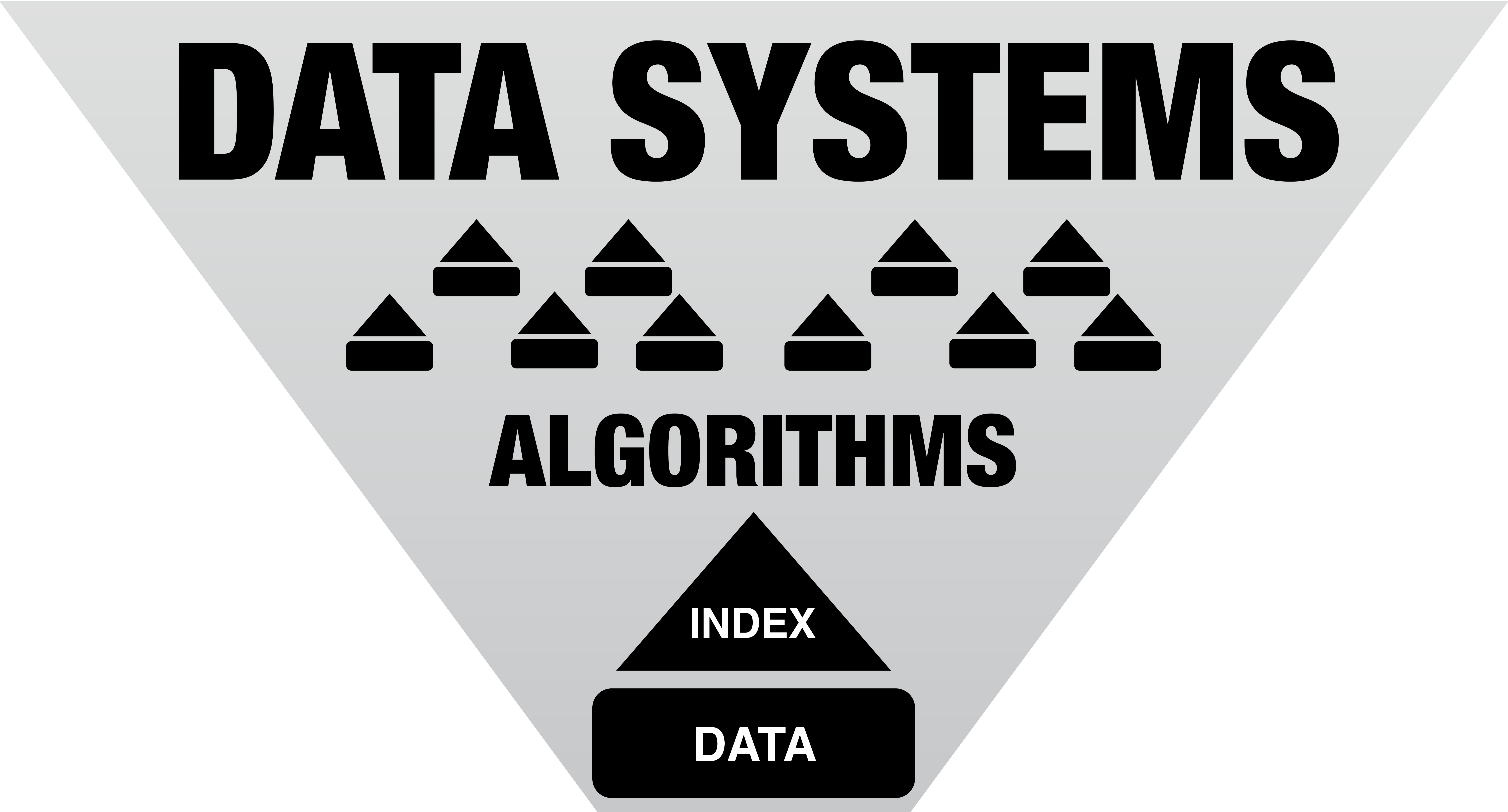
Stratos Idreos & Tim Kraska

Algorithms rely on the order of data



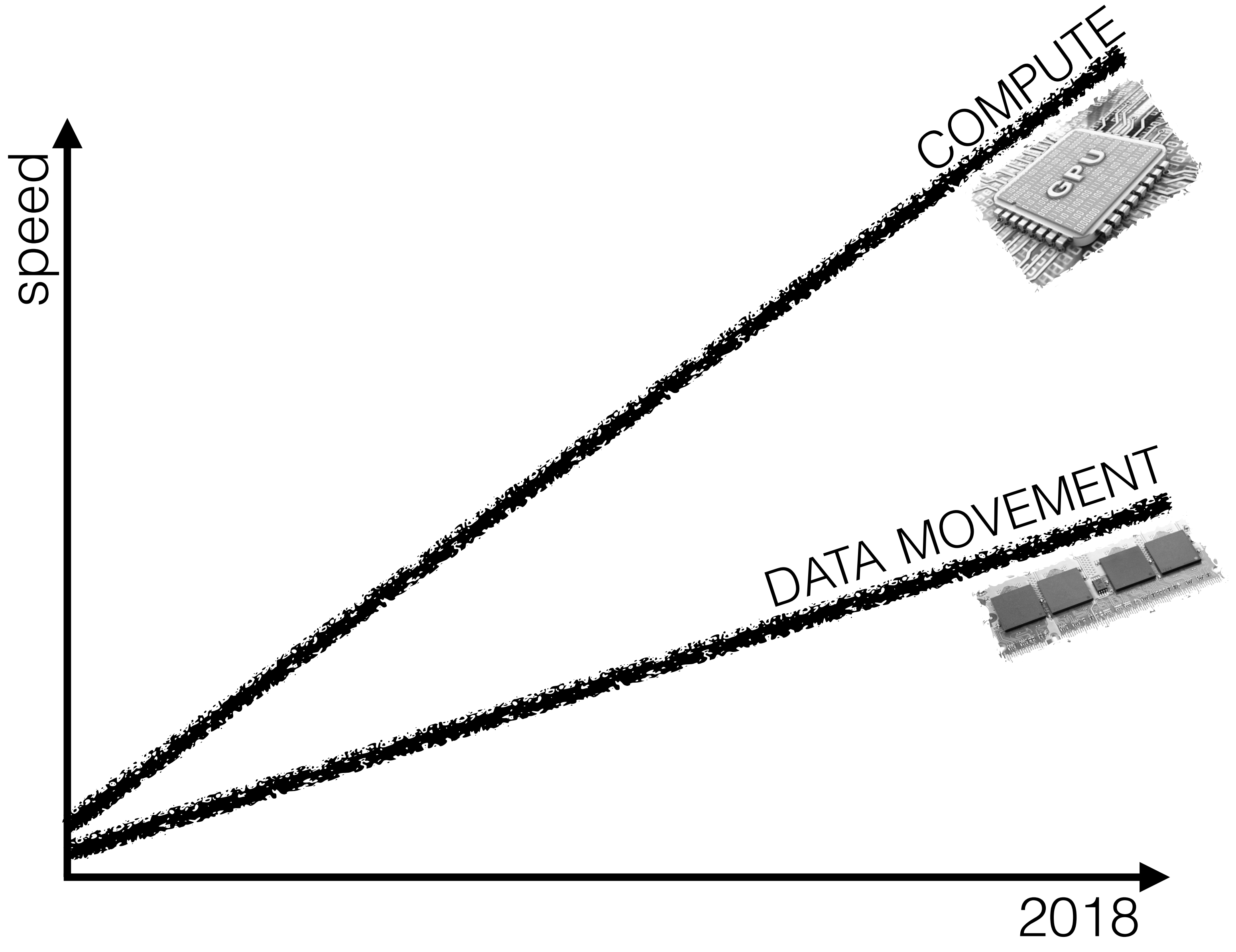
[S. Idreos, 2019]

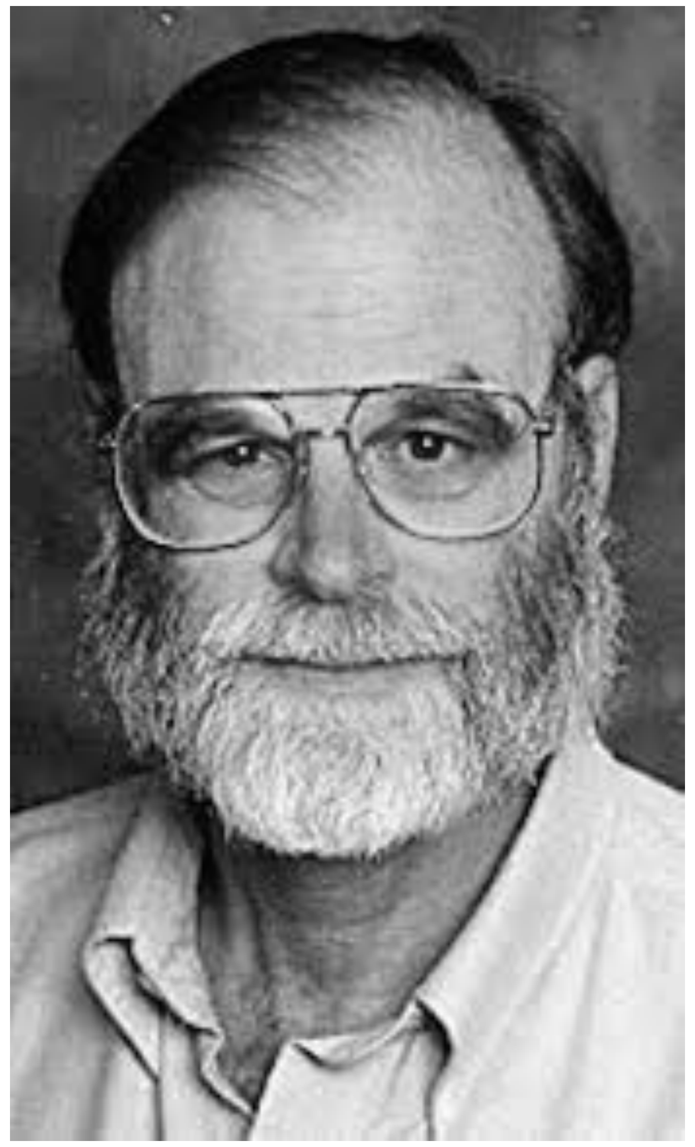
Data systems rely on algorithms



[S. Idreos, 2019]

Data structures define performance





register = this room
caches = this city
memory = nearby city
disk = Pluto

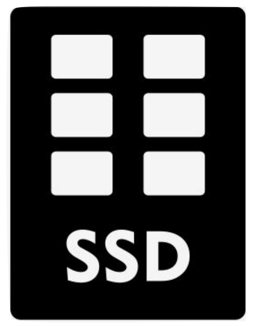
Jim Gray, Turing Award 1998

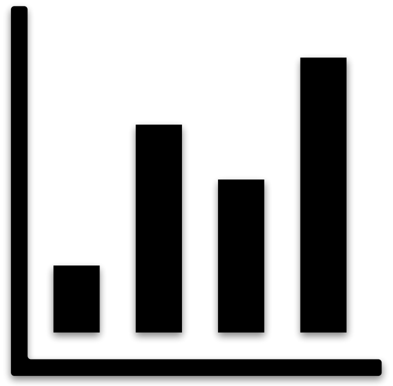
[S. Idreos, 2019]

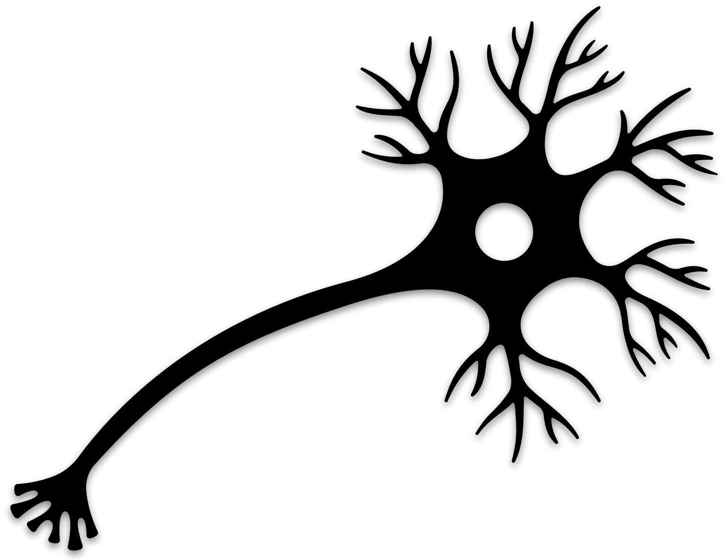
Database Questions

How do I make my **data system** run x times as fast?  (sql,nosql,bigdata, …)

How do I minimize my **bill** in the **cloud**?

How do I extend the **lifetime** of my hardware? 

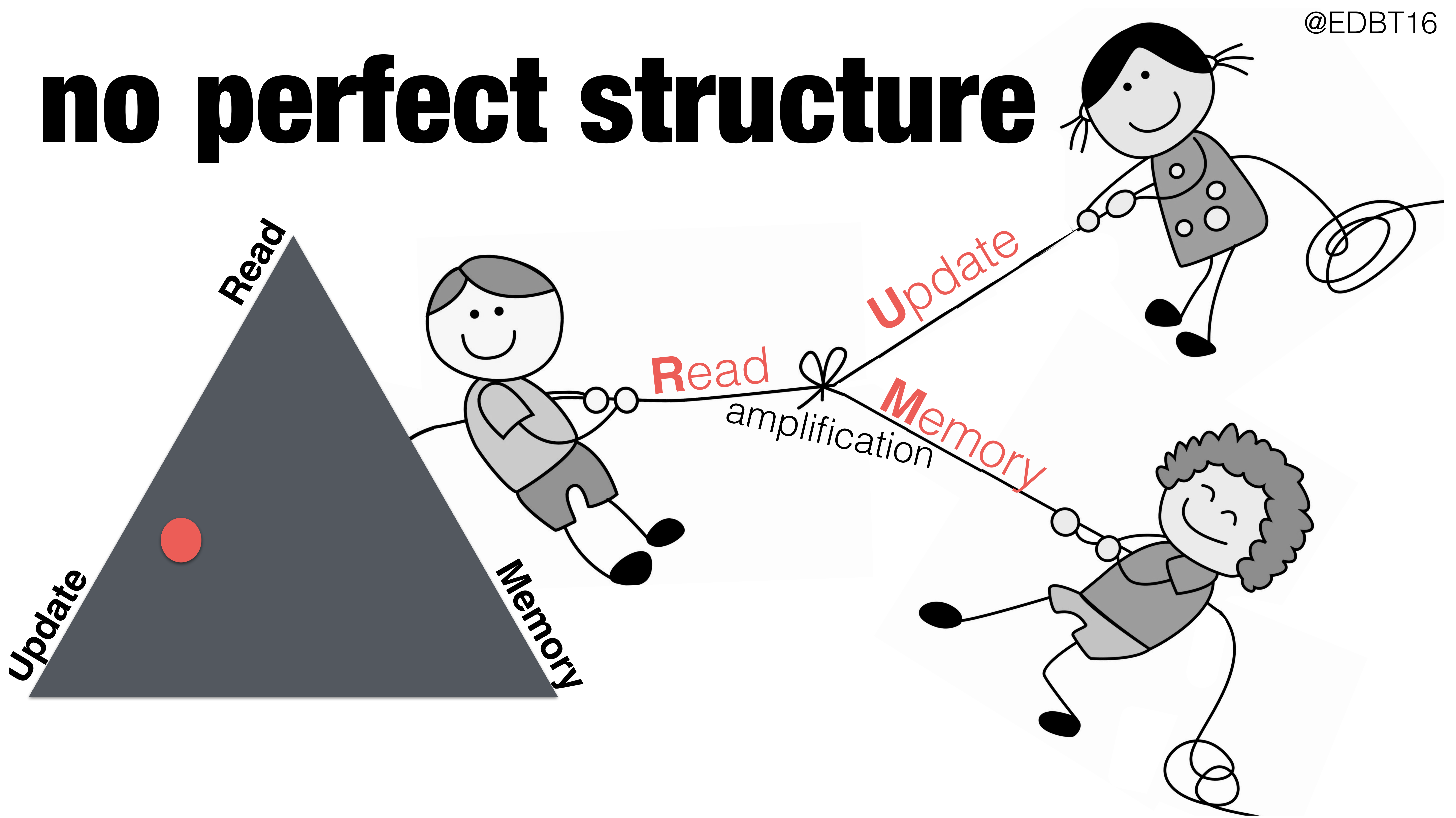
How to accelerate **statistics** computation for data science/ML? 



How do I train my **neural network** x times faster?

[S. Idreos, 2019]

Tradeoffs in each structure

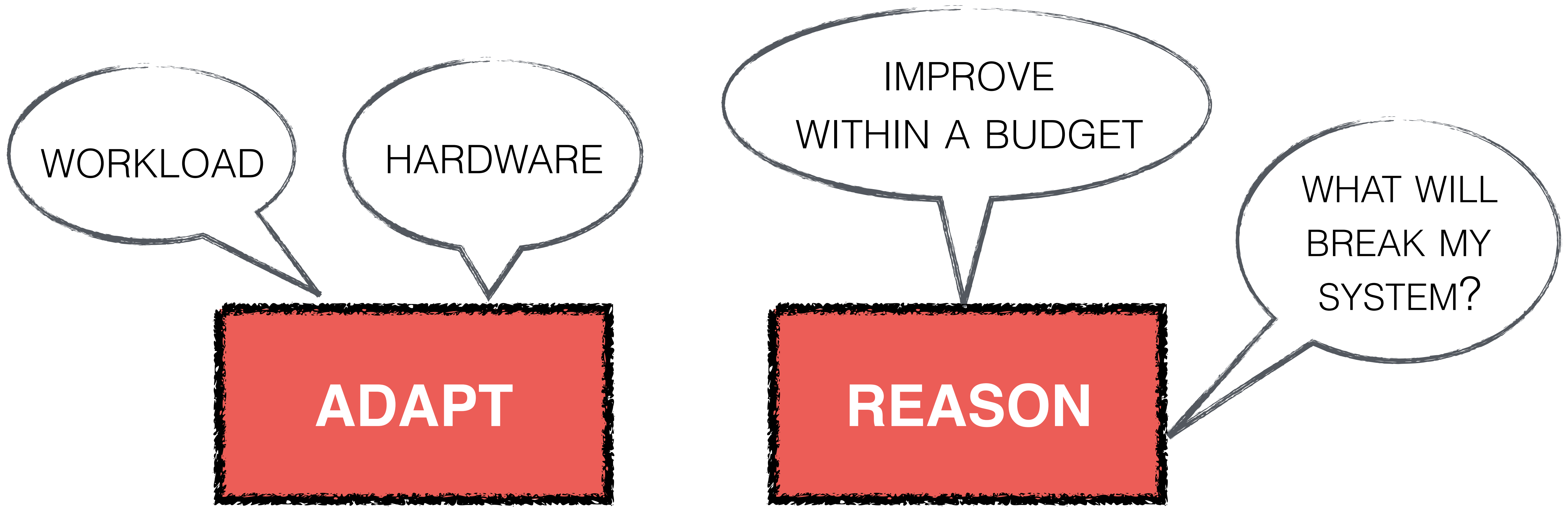


[S. Idreos, 2019]

New Applications Demand Change

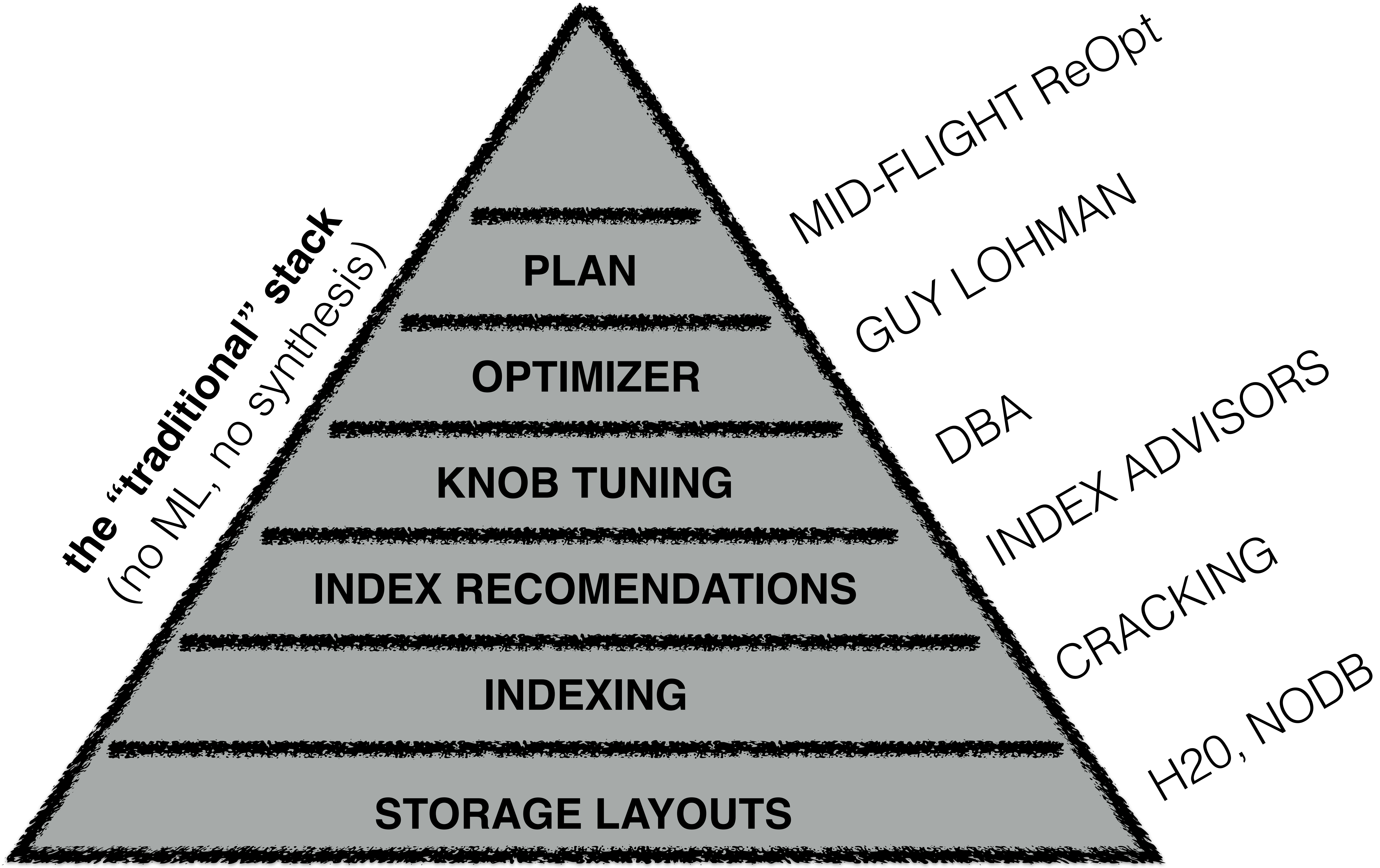
NEW APPLICATIONS 

existing systems need to change too



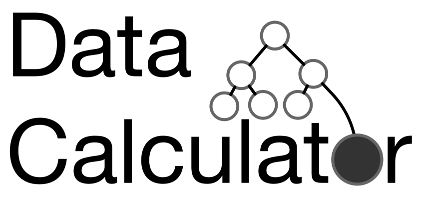
[S. Idreos, 2019]

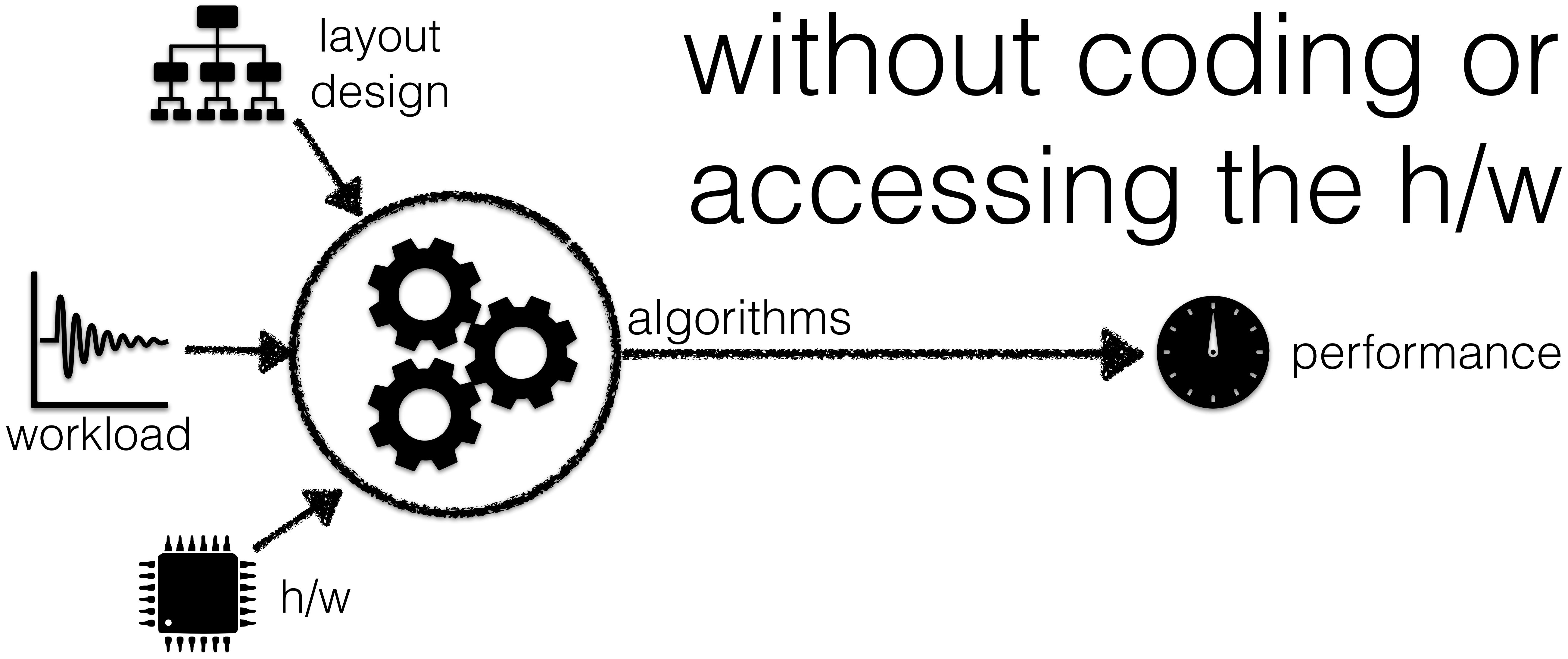
"Traditional" Database Research



[S. Idreos, 2019]

Self-designing systems





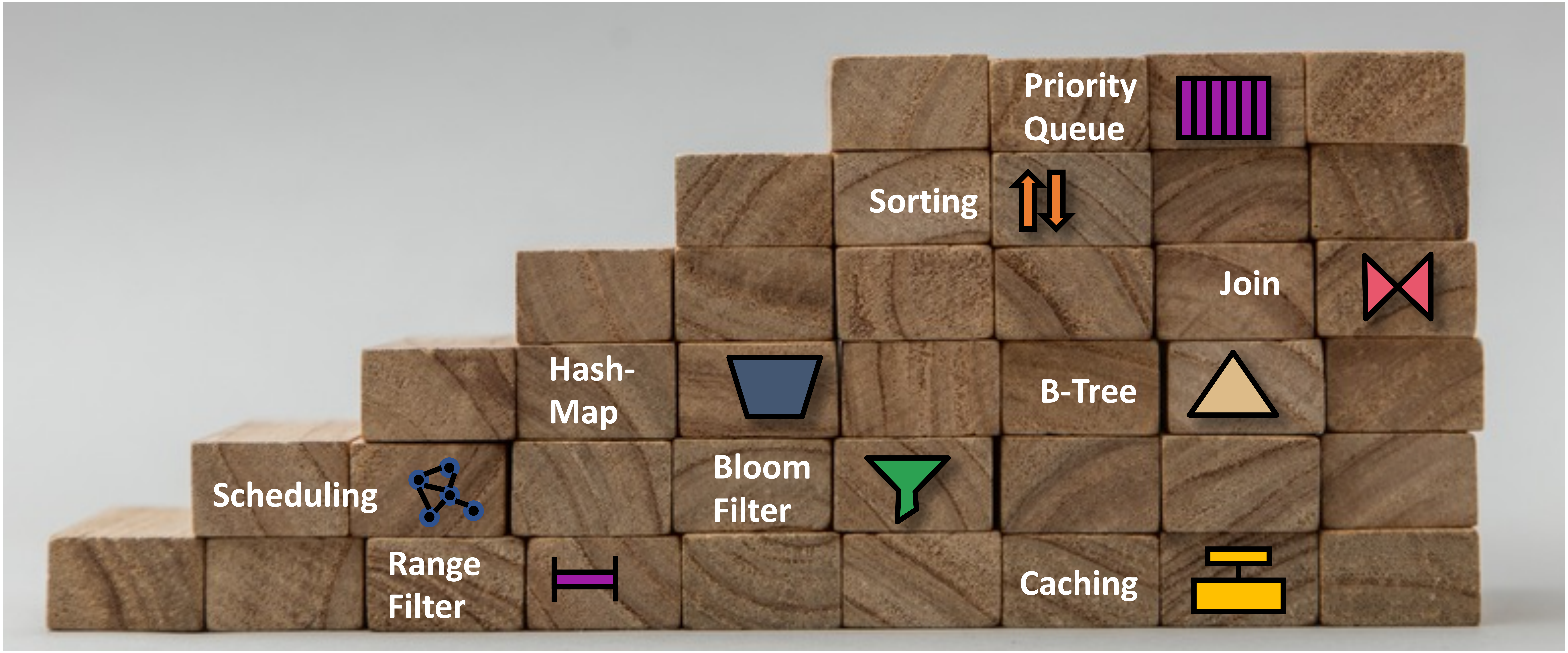
without coding or accessing the h/w

[S. Idreos, 2019]

SageDB: a learned database system

T. Kraska, M. Alizadeh, A. Beutel, E. H. Chi, J. Ding, A. Kristo, G. Leclerc, S. Madden, H. Mao, and V. Nathan

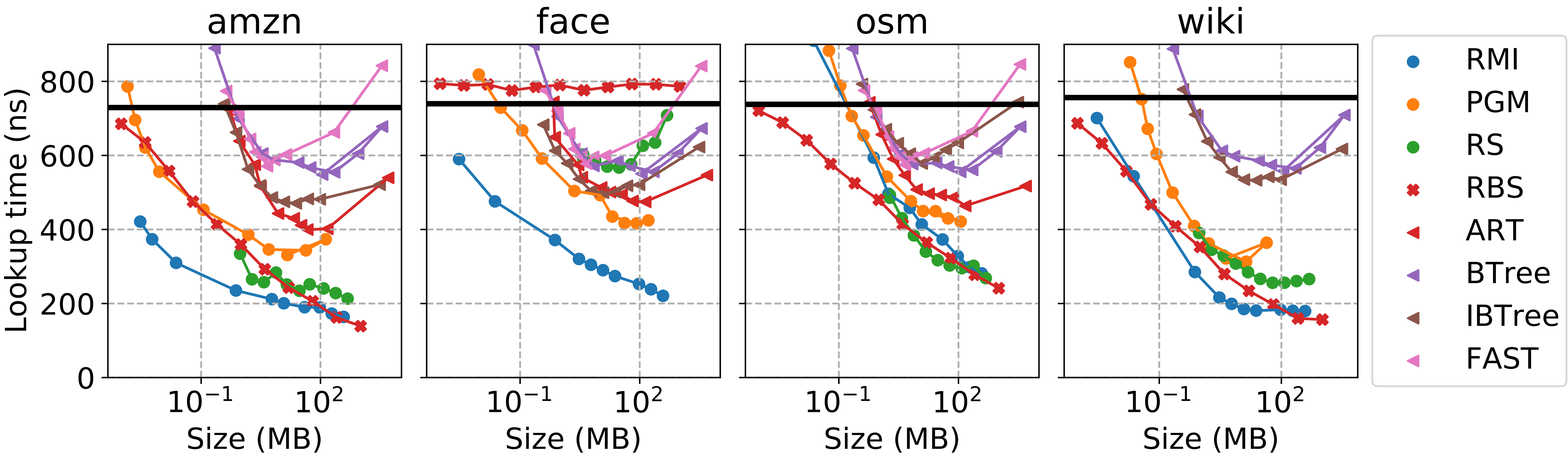
Learned Data Structures and Algorithms



Discussion

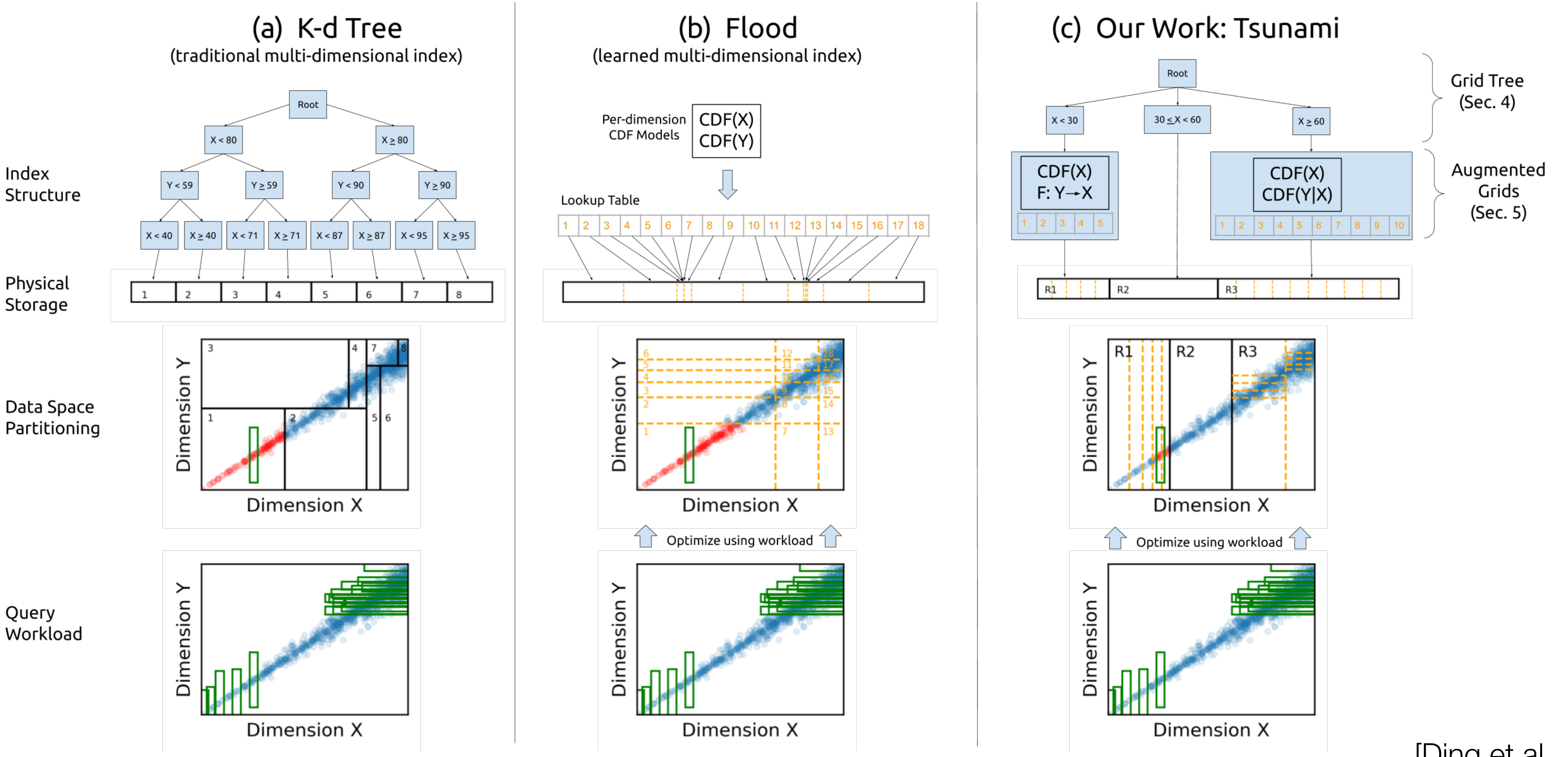
- Is this the future?
- What about comparison baselines?
- Lots of work being done in this area

Benchmarking Learned Indexes



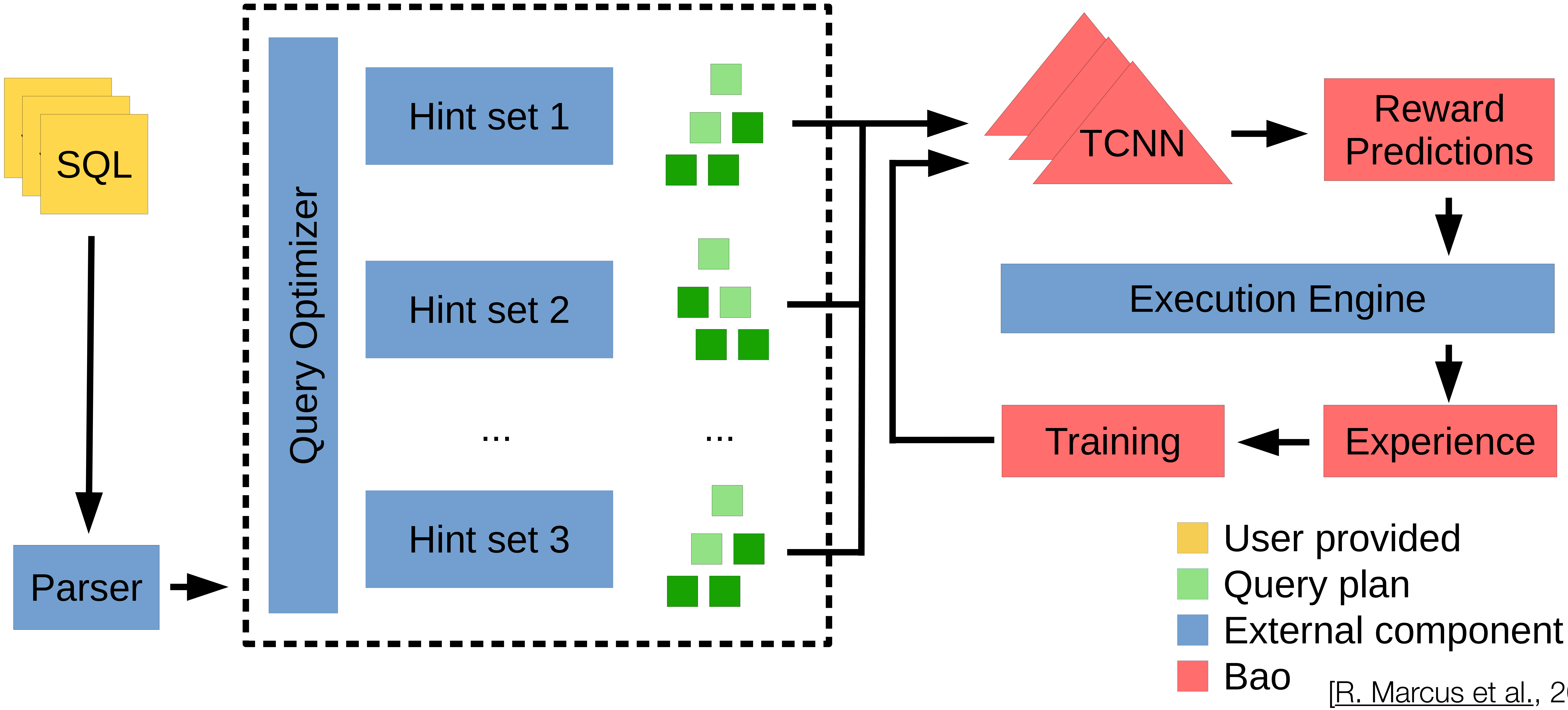
[R. Marcus et al., 2021]

Multi-Dimensional Indexing



[Ding et al., 2021]

Query Optimization



[R. Marcus et al., 2021]

Reminders

- Final Exam Review Wednesday (come with questions!)
- Final Exam on Wednesday, May 10 from **8:00**-9:50am