Responsible Data Science - Dealing with Uncertainty

DBGroup

Boris Glavic[1]

DBGroup

Illinois Institute of Technology

October 22, 2021

[1] bglavic@iit.edu

Outline

ILLINOIS INSTITUTE OF TECHNOLOGY

Hi, I am **Boris**

Who I am

Hi, I am **Boris**

I am a **database** guy!

Who I am

Hi, I am **Boris**

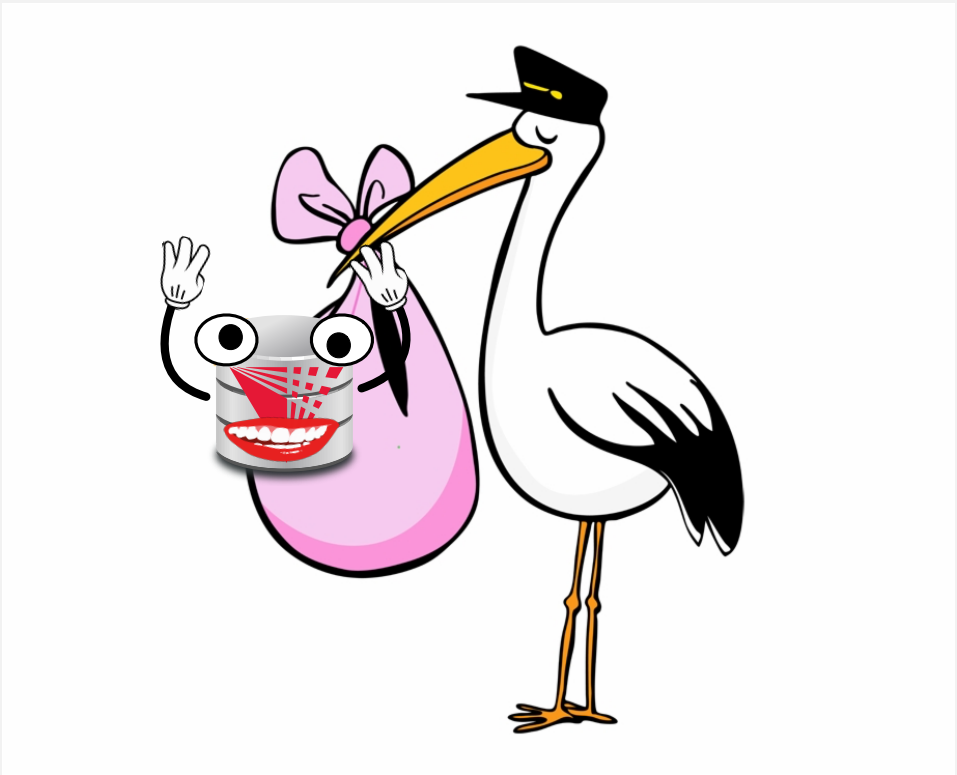
I am a **database** guy!

I will tell you:
1) Why DBs are important
2) Why DBs are interesting
3) My Research

Outline

Where do data come from?

You might have heard . . .



What Are Databases?

Database systems and databases

- **database systems** manage databases
- a **database** is a collection of structured data

What do database systems do?

1. Provide **persistent** storage of data
2. Efficient **declarative** access to data: querying
3. **Protection from data loss** under failures
4. **Safe concurrent access** to data

Who Uses Databases?

- **Most large software systems use databases!**
  - Business Intelligence, e.g., *IBM cognos*
  - Web-based systems
- **Desktop software**
  - Your music player
  - Your email client (most likely at least)
- **Every big company uses DBs**
  - Banks
  - Insurance
  - Government agencies
  - ...
- **Your mobile phone**
  - Many apps use an embedded database called Sqlite

Who Builds Database Systems?

- **Relational databases is big business**
  - IBM DB2
  - Oracle
  - Microsoft SQLServer
  - Teradata
  - Open Source Systems: PostgreSQL, MySQL
- **Distributed systems**
  - Cloud storage and Key-value stores
    - Amazon S3, Google Big Table, Cassandra
  - Big Data Analytics
    - MapReduce, Spark, Flink

Why Are Database Interesting?

Combination of systems and theoretical research

- **Interesting systems problems**
  - Hacking complex and large systems
  - Low-level optimizations
    - exploit modern hardware
- **Interesting theoretical foundations**
  - Complexity of answering queries
  - Expressiveness of query languages
  - Strong connections to logic

Why Are Databases Interesting (cont.)

Connections to other CS fields

- **Distributed systems**
  - getting more and more important
- **Compilers and Programming Languages**
- **Modeling**
- **Logic**
- **AI and machine learning**
  - Data mining
- **Operating and File Systems**

Relations aka Tables

- a table consists of **columns** and **rows**
- tables store one type of entity
  - *e.g., students, bank accounts, loans, . . .*
- each row is one entity
  - *e.g., one student*
- columns store a particular type of information about an entity
  - *e.g., name of a student*

Example Tables

Students table

CWID	Name	Major	GPA	Phone
A1333331	Peter	CS	3.5	312 555 8888
A5552341	Alice	CS	4.0	312 555 7777
A1325324	Elisa	Bio	3.2	312 555 5555

Grades table

CWID	Course	Grade
A1333331	CS100	A
A5552341	CS425	C
A1325324	CS525	A
A1325324	CS566	B

What do I do with the data in my database?

- You can interrogate the database system to extract information about your data
- This is done using a programming language called SQL
- SQL is a **declarative** language
  - say what data you want not how to compute it
- Queries return tables (closed language)

Queries (cont.)

CWID	Name	Major	GPA	Phone
A1333331	Peter	CS	3.5	312 555 8888
A5552341	Alice‘	CS	4.0	312 555 7777
A1325324	Elisa	Bio	3.2	312 555 5555

- *How many students are in my database?*

#Students
3

- *Who has the highest GPA?*

Name
Alice

- *What are the names of CS students?*

Name
Peter
Alice

What if you shutdown your computer?

- Will you loose your precious data?

What happens when your computer crashes?

- Will you loose your precious data?

What if you shutdown your computer?

- Will you loose your precious data?

What happens when your computer crashes?

- Will you loose your precious data?

No!

- The database system stores your data on stable storage (disk)
- Database systems know how recover from failures
- When the database system signals to you that a change you made was applied then you can rely on this

Banking Example

- **Account A**: \$50
- **Account B**: \$50
- Transfer \$25 from `A` to `B`
- Bank gives all accounts 10% interest

Transfer Money

Action
Subtract \$25 from **A**
Add \$25 to **B**

Give 10% interest

Action
Add 10% interest

Balances

Acc. A	**Acc. B**
\$25	\$50
\$27.5	\$55
\$27.5	\$80

We have lost interest!

Concurrent Access (cont.)

Concurrency Control

- Databases manage concurrent operations
- Prevent bad things from happening
- From the user's perspective:
  - Behaves like your program is the only one running!

Can we loose interest?

Nope!

Outline

The Data Age

- We (humanity) are generating data at an ever increasing rate
- Data has become a main driver for many businesses, governments, scientific disciplines, organizations

Some examples

- Online encyclopedias
- Self-driving cars
- Computers beating humans in go
- Open data (e.g., `https://data.cityofchicago.org/`)
- IoT
- ...

What is Data Science?

- **Data Science** is the process of extracting insights from data and includes . . .
  - **Data Collection**: finding relevant data for the analysis task
  - **Data Preparation/Curation**: cleaning and integrating the data
  - **Data Analysis**: analyzing the data, e.g., building machine learning models
  - **Interpretation + Presentation**: creating visualizations / documents for conveying the results to a consumer

Is this linear process realistic?

- **No!** - typically requires backtracking & iteration until the results are sufficient

Example

- The analysis result is wrong / misleading because the dataset was too small to yield statistically significant results
- Workaround: collect more data, augment existing data with synthetically generated data, ...
- This new data needs to cleaned be integrated with the existing data
- No we have duplicate and conflicting information
- Ok, need more cleaning
- Repeat analysis (fingers crossed)
- ...

What are computational notebooks?

- a mix of documentation, computation, and results
- consist of cells:
  - documentation cells (typically a lightweight markup language like markdown)
  - code blocks
- results of execution of code is shown inline

Demo (Jupyter)

- `https://www.kaggle.com/pouyaaskari/avocado-classification`

Almost all data is uncertain!

- missing values
- typos and manual entry errors
- logical errors (zip code with incorrect city)
- misinterpretation of semantics (*e.g., date is a contract start date instead of end data*)

Data curation is heuristic

- typically insufficient information is available to determine how to correctly clean and integrate the data
- curation decisions are based on informed guesses (made by humans/code)

Can/Should we Trust Data Science?

- Uncertainty is everywhere
- Traditional data cleaning methods are heuristic
- Unless a human tracks uncertainty, after cleaning we loose all information about uncertainty
- $\Rightarrow$ We do not know whether a result is based on real data or just an artifact of cleaning / errors in the data

What can be done?

ILLINOIS INSTITUTE OF TECHNOLOGY

Support for modeling uncertainty

- We need to enable humans and algorithms to model the uncertainty in their data and decisions

Support for tracking uncertainty

- We need to track information about uncertainty through curation / analysis / visualization steps

Support for visualizing uncertainty

- We need to present uncertainty information to the data consumer

Demo (Vizier)

- `https://vizierdb.info/`

Outline

DBGroup - What else do we do?

ILLINOIS INSTITUTE OF TECHNOLOGY

Distributed and High-performance Databases

- HRDBMS - a scalable database with high per-node performance
- **HCDF** - operating system - database co-design

Data Integration and Cleaning

- How to systematically evaluate cleaning and integration systems
  - Bart
  - iBench

Data Provenance

- GProM - a generic provenance middleware
- Relevance-based Data Management - optimizing data operations based on what data is relevant

DBGroup - What do we do? (cont.)

ILLINOIS INSTITUTE OF TECHNOLOGY

Uncertain Data Management

- How to model and track uncertainty in data?
  - Uncertainty-Annotated Databases

Data Science

- We are data science enablers!
- Vizier - a data-centric notebook platform with uncertainty tracking, provenance, spreadsheets, reproducibility

Questions?

- IIT DBGroup
  - **students**: 7 Ph.D., 2 Undergraduates
  - **research group**: `http://www.cs.iit.edu/~dbgroup/`
  - **personal page**: `http://www.cs.iit.edu/~dbgroup/members/bglavic.html`
  - **github**: `https://github.com/IITDBGroup`