Lessons from coding theory

ICME Xpo 2017

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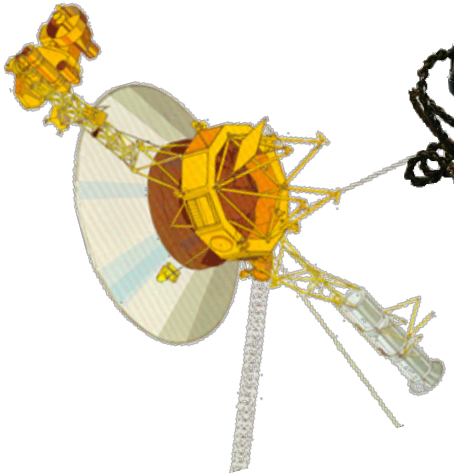
This talk is about

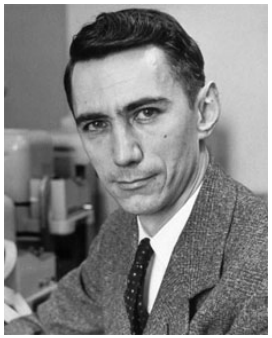
Error correcting codes

You may be thinking

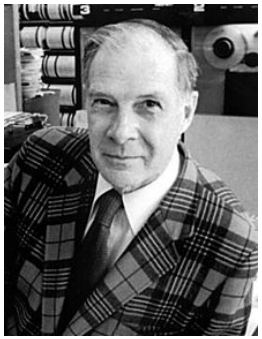
- What are error correcting codes?
  - Tools for protecting data from errors
- Classical solutions to problems in communication and storage…

Isn't that a solved problem?





Shannon



Hamming

Actually…

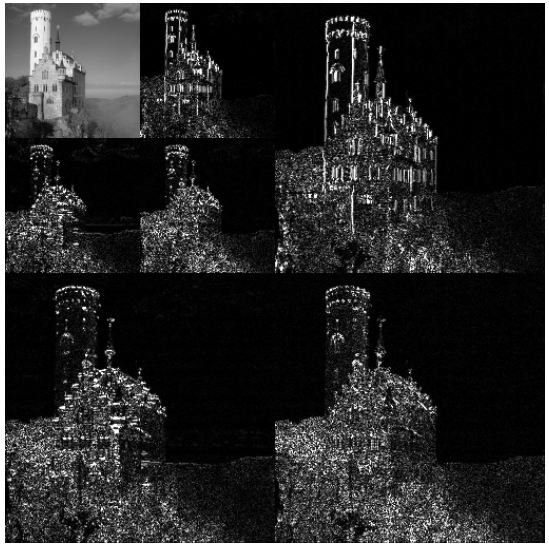
- Lots of old problems still open
  - Fun to think about!
- Lots of new applications in communication and storage
  - Distributed storage is a big one
- But even if you are not into communication and storage
  - **Lots of applications everywhere!**

this is what this talk is really about.

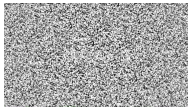
Common set-up

- We have some data
- It has some structure
  - which we don’t control
- We want to take advantage of that structure
  - learn stuff about the data
  - do it efficiently

Taking advantage of structure



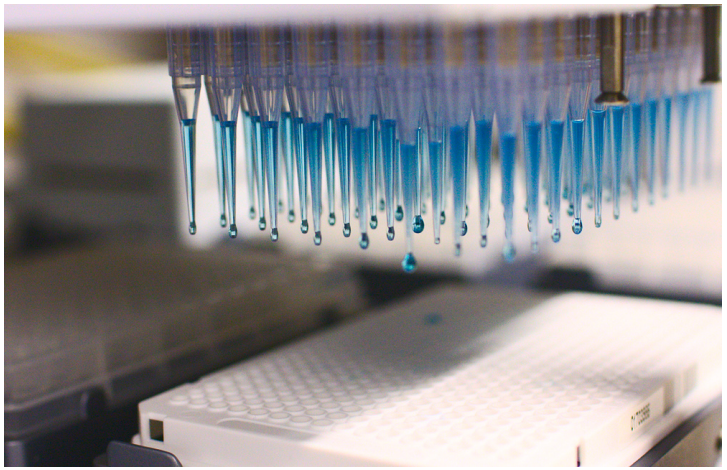
linear
measurements

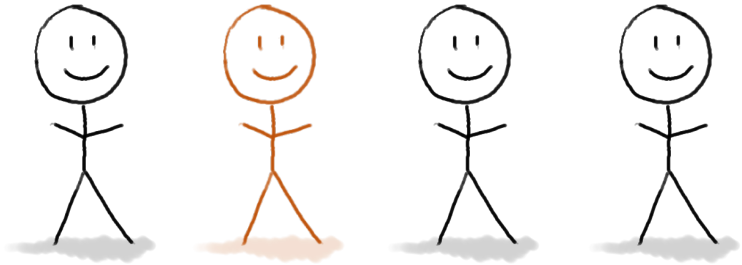


Compressed sensing/
sparse recovery

Taking advantage of structure

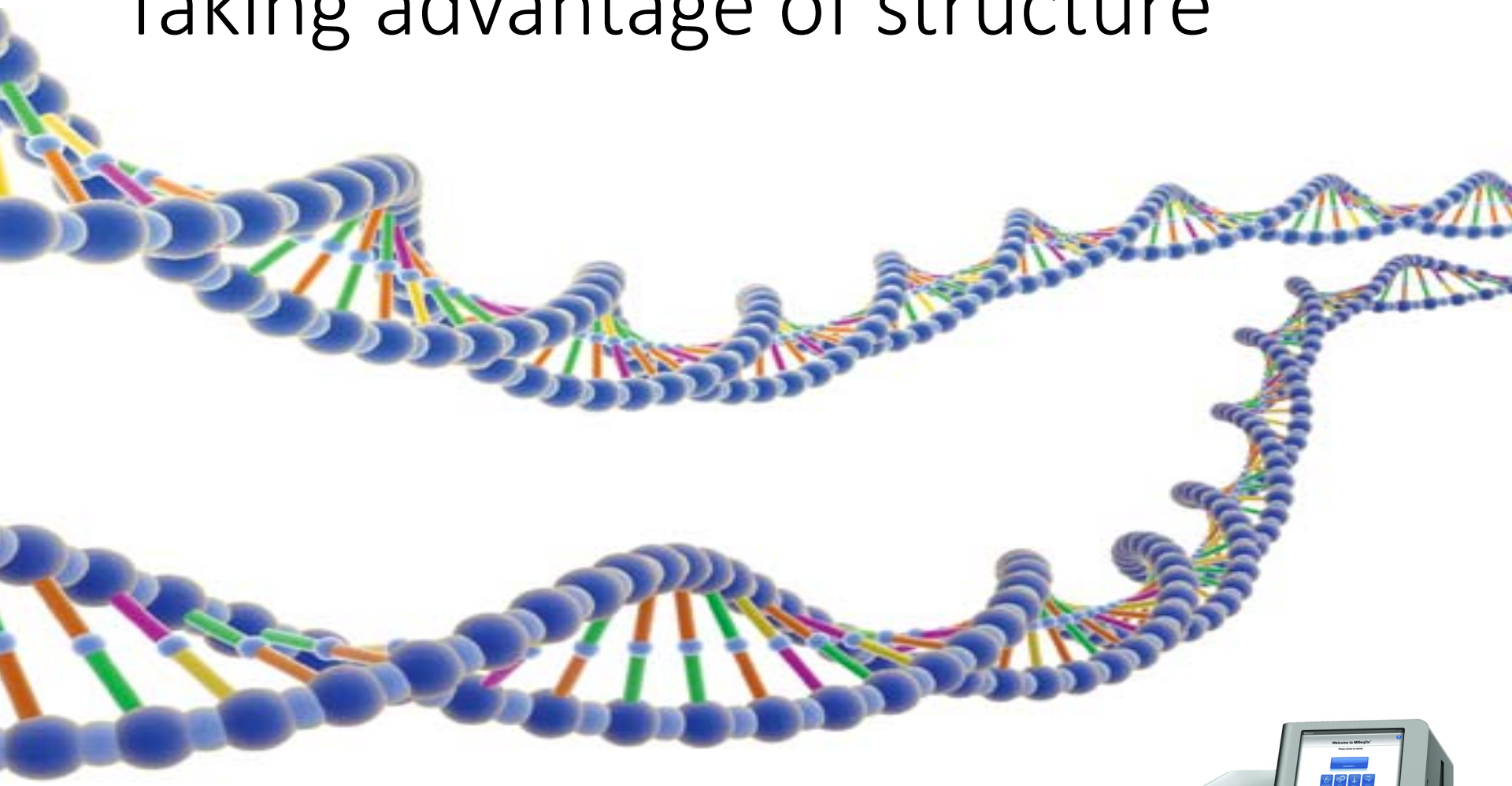
Taking advantage of structure





High-throughput screening

Taking advantage of structure



De novo sequencing

etc…

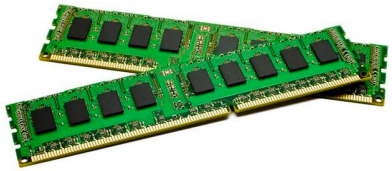
- We don’t control the structure
- We do (partially) control what happens to the data

The other side of the coin

- We do control the structure
- We don't control what happens to the data

Taking advantage of the most advantageous structure

Taking advantage of the most advantageous structure



Error correcting codes

are, by design, the **most advantageous** structure.

- Used in communication and storage since the 1950's
- Over half a century of beautiful work!

Two questions

- Haven't we figured that out by now?
- What about this other stuff?
  - If we control measurements but not structure?

As mentioned before

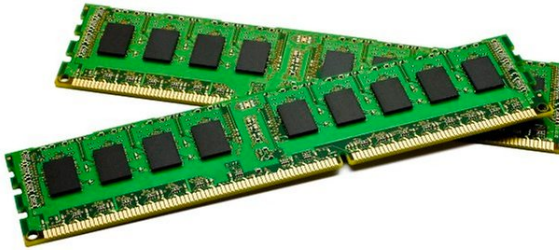
- Okay, so we haven't really figured everything out.
  - Coding and information theory for communication and storage is still a vibrant research area.

- But also!
  - Lessons from classical coding theory are relevant in a wide variety of these sorts of applications.

My work

- Some of this:

- Some of that:



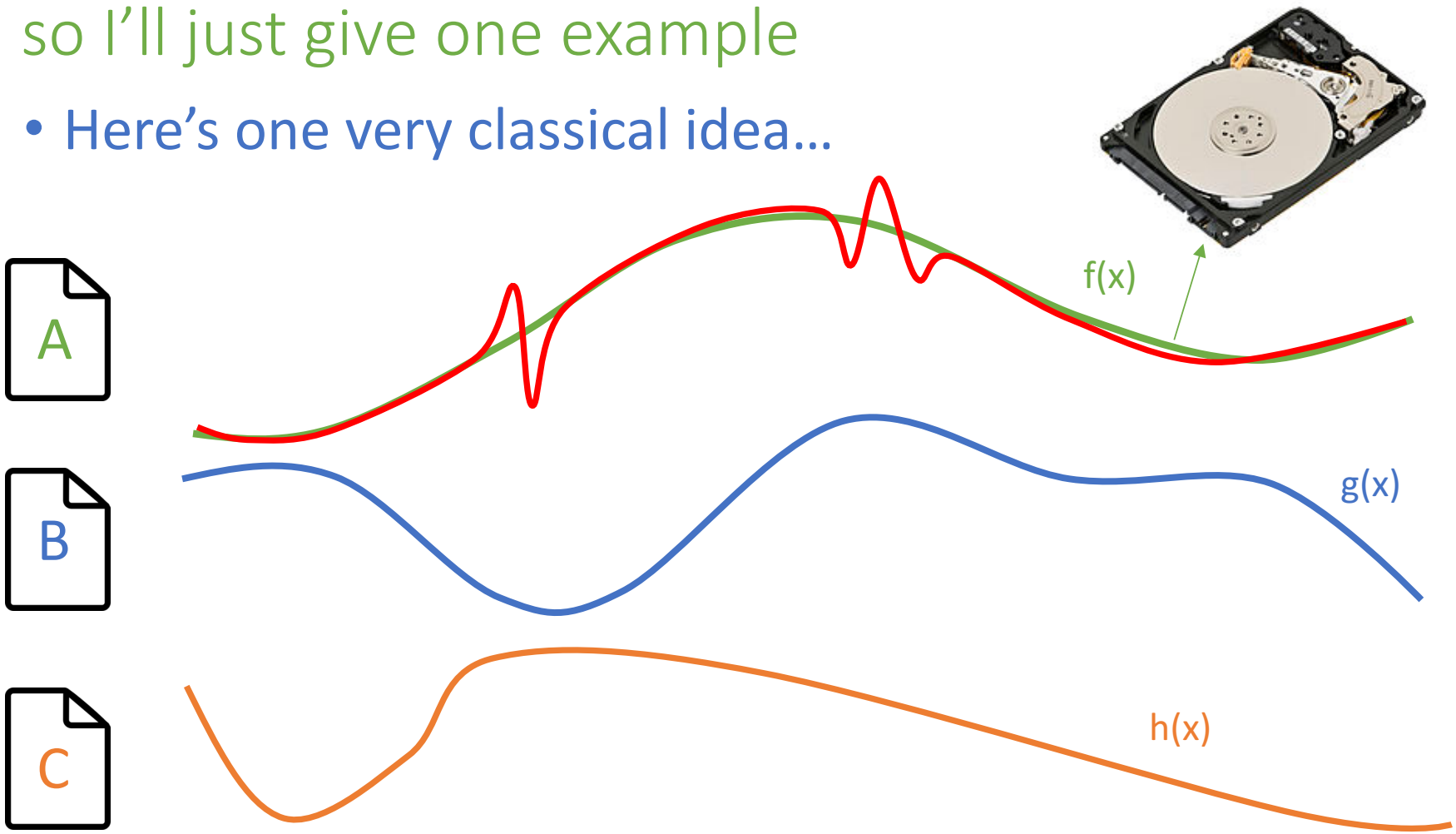
- Right now I'm really excited about the interplay between the two.

Disclaimer: many of the ideas I'll mention in the next five minutes are not mine and not new…but they are super cool!

We don't have too much time

so I'll just give one example

- Here's one very classical idea…



This is "Reed-Solomon encoding"

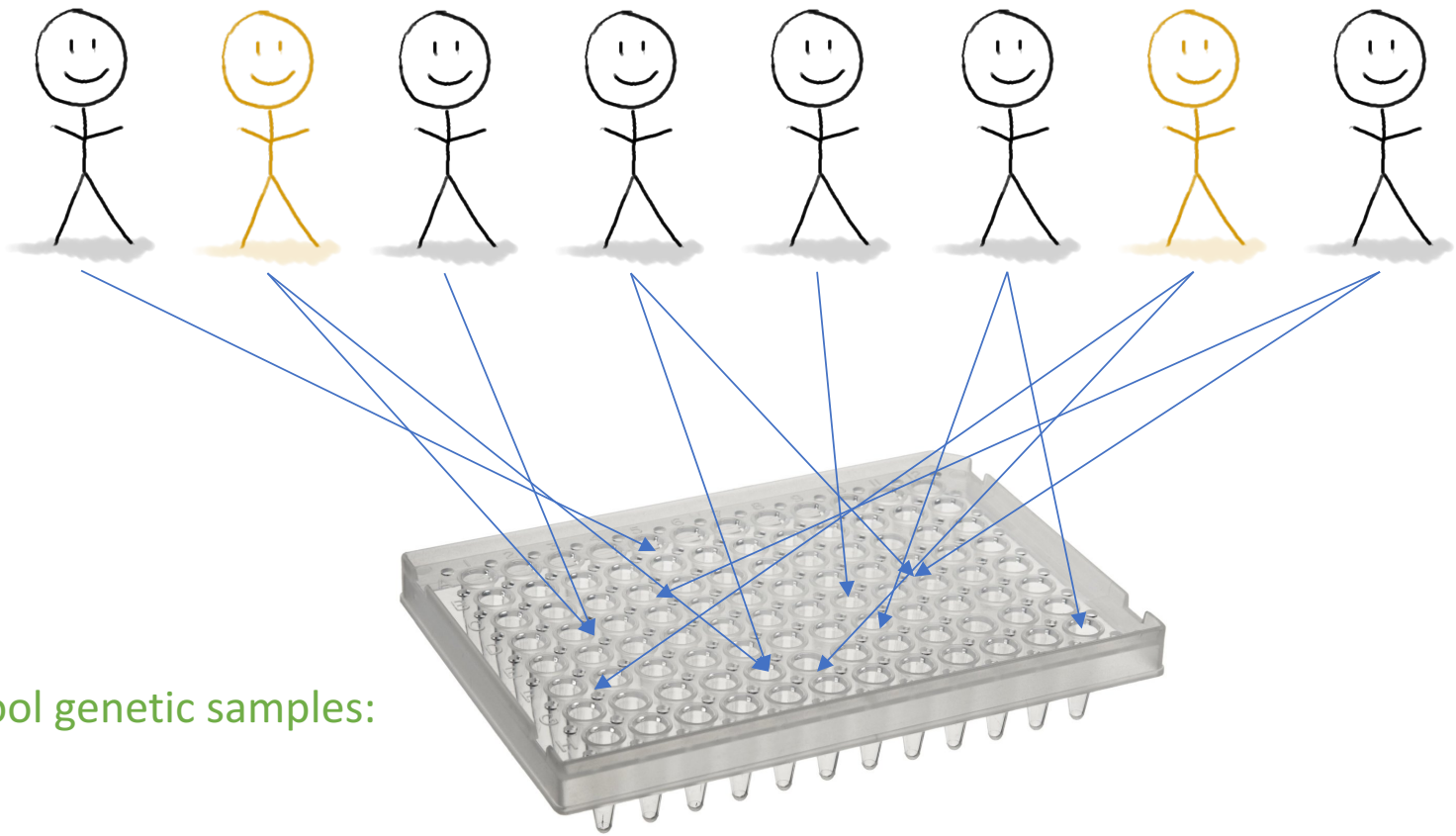
Low-degree polynomials are the most advantageous structure*

- Really nice combinatorial properties
- Admit really fast algorithms
- Used all over the place in communication and storage

*personal opinion

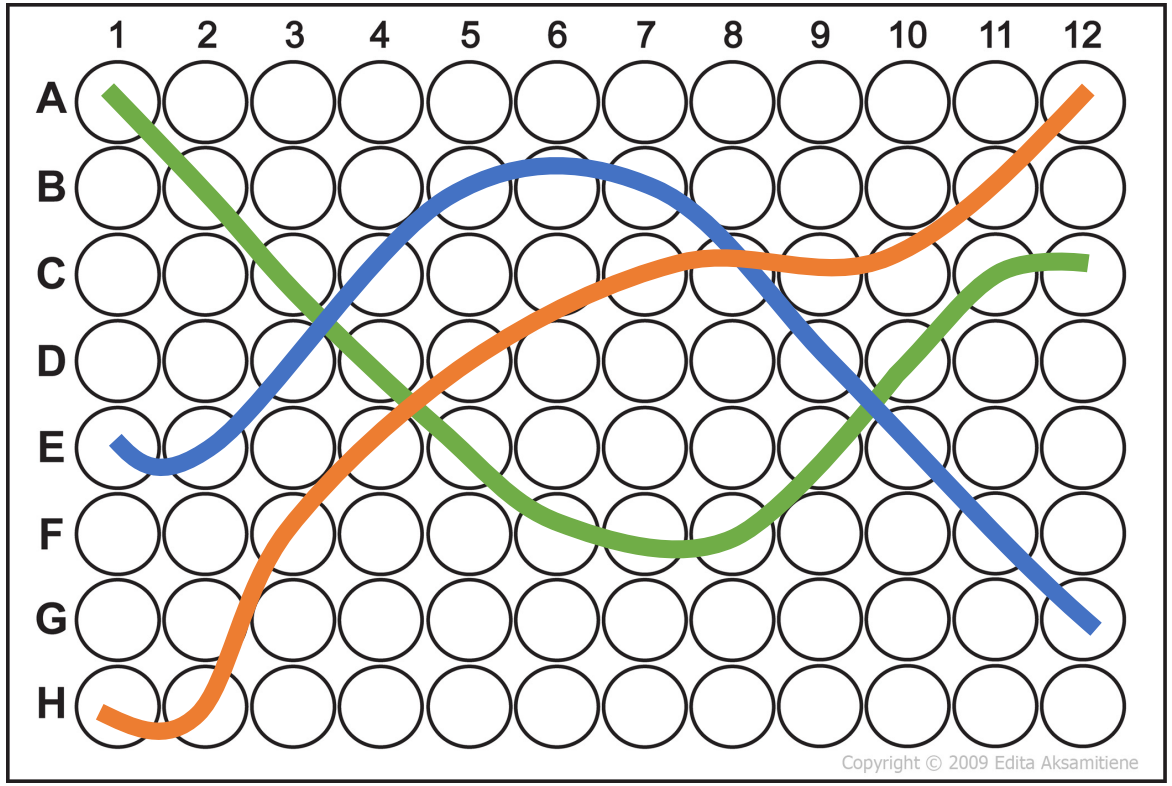
Not just in communication and storage

- High-throughput screening



Pool genetic samples:

Pool samples according to low-degree polynomials

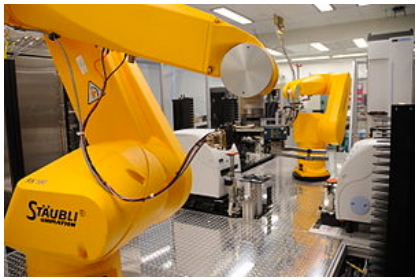


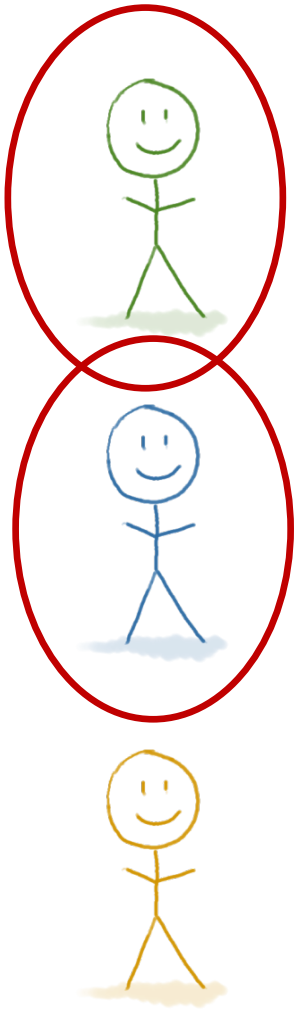
Imagine there are way more people than there are pools…

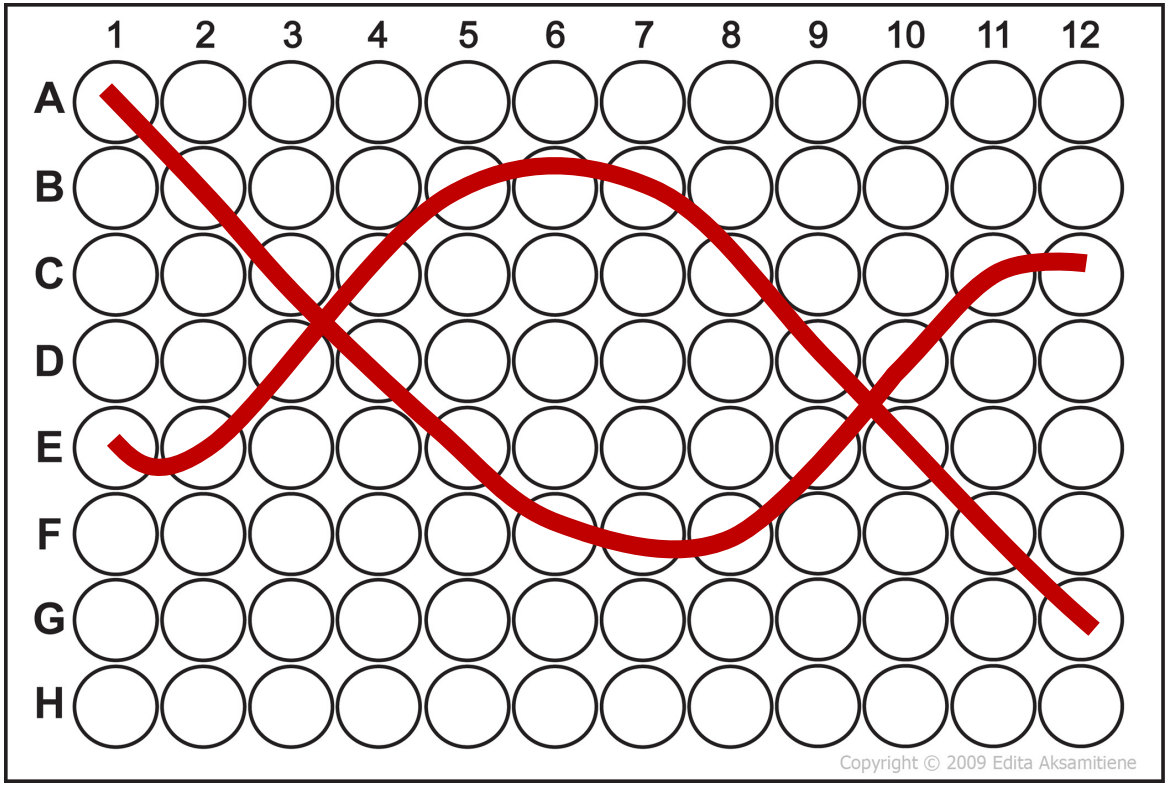
*taking some artistic liberties

Pool samples according to low-degree polynomials

- Not a new idea [Kautz & Singleton 1964]
- But making it work for modern problems comes with new challenges!





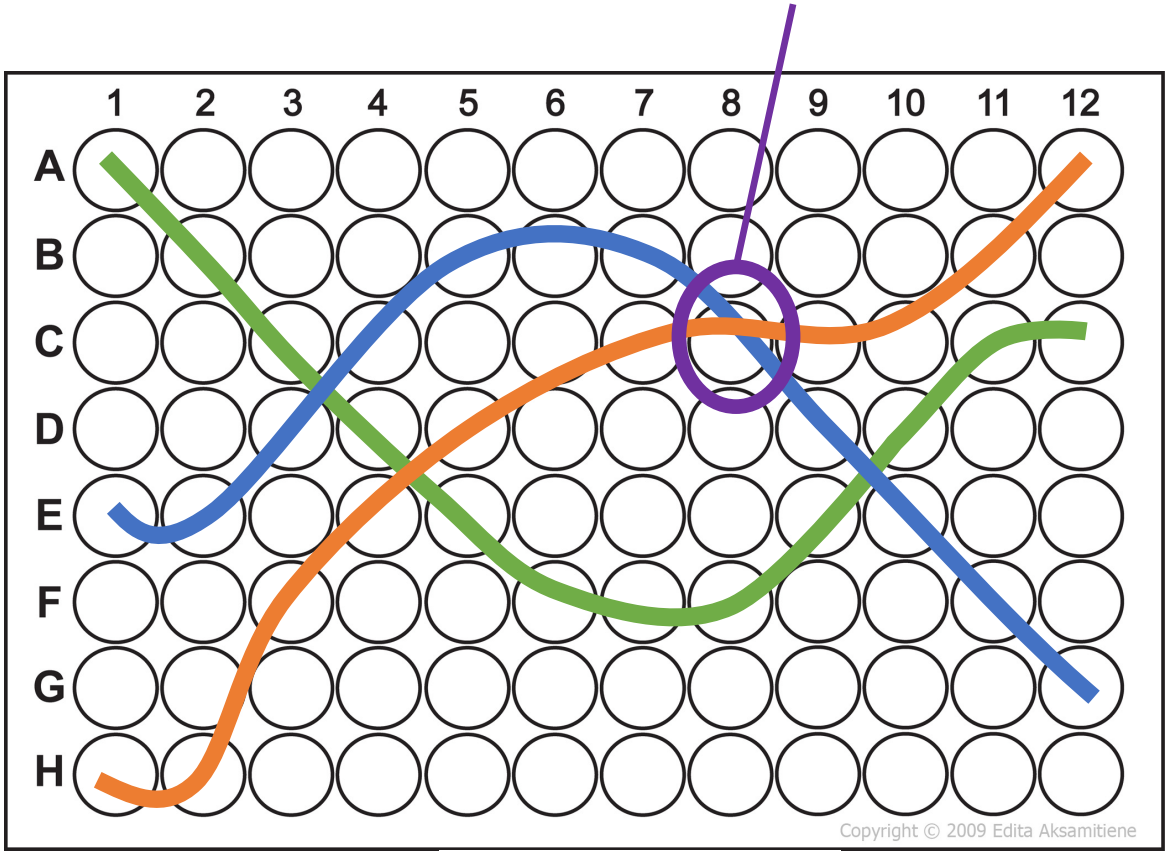


[Thierry-Mieg 2006], …,
[Erlich, Gilbert, Ngo, Rudra, Thierry-Mieg, W., Zielinski, Zuk 2015],…

*taking some artistic liberties

Also, de novo genome sequencing

Sequence this pool altogether, get a bunch of reads…what came from what?



[Lonardi, Duma, Alpert 2013]
[Duma, W., Gilbert, Ngo, Rudra, Alpert, Close, Ciardo, Lonardi 2013]

*Taking even more artistic liberties…

Even if you don’t control the structure…

- If you do control how you process the data, tricks like this work.
- Many examples in compressed sensing, group testing, streaming algorithms,…
  - Cheraghchi, Gilbert, Indyk, Nelson, Ngo, Porat, Rudra, Strauss,…

Summary

- I think error correcting codes are cool.
  - And still an exciting area of research!
  - Talk to me later about distributed storage!

- But even if you don't care about communication, storage, or information theory,

error correcting codes are still cool.

Thanks!

Contact me to talk more!
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Gates 468