

# **Simple structures in computation, statistics, and data acquisition**

**Simon Vary**

[simonvary.github.io/talk-exeter.pdf](https://simonvary.github.io/talk-exeter.pdf)

**Exeter Family Subject Dinner, 1/2/2021**

# Transferring analog signals

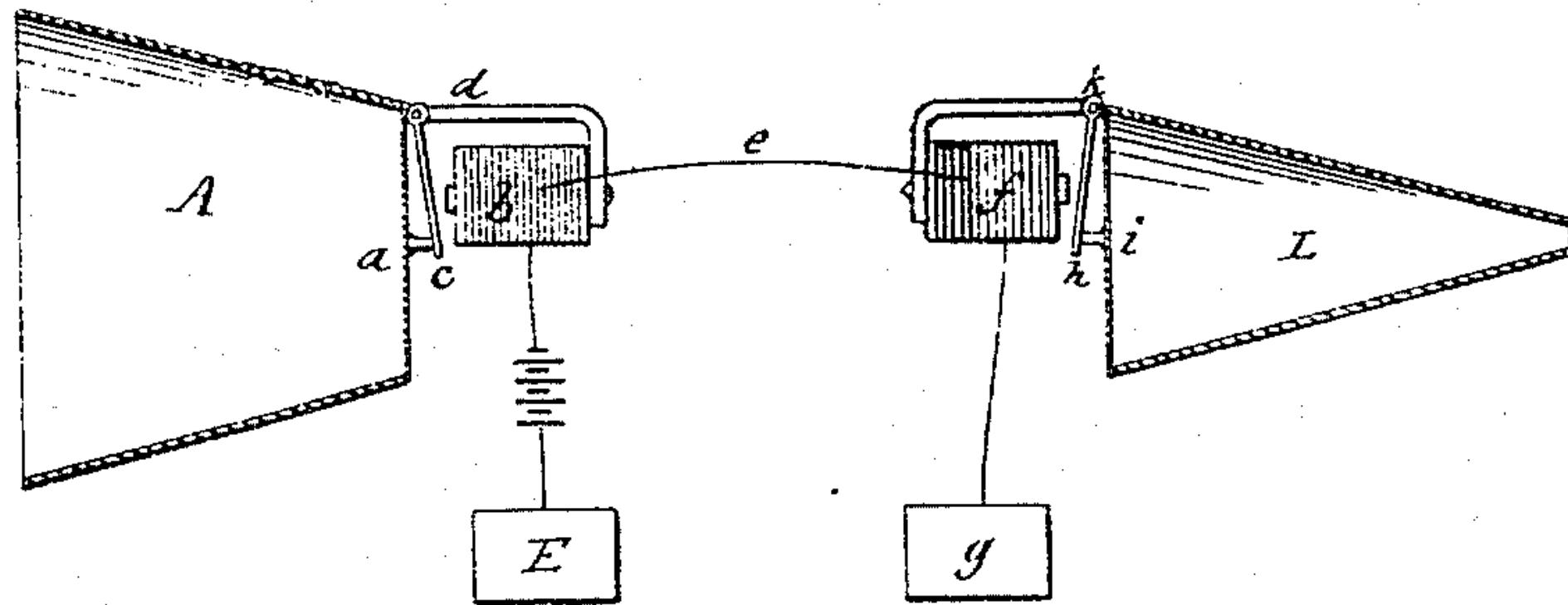
2 Sheets—Sheet 2.

A. G. BELL.  
TELEGRAPHY.

No. 174,465.

Patented March 7, 1876.

Fig. 7



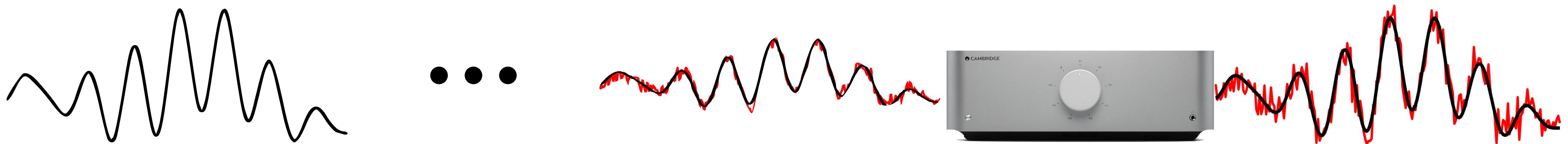
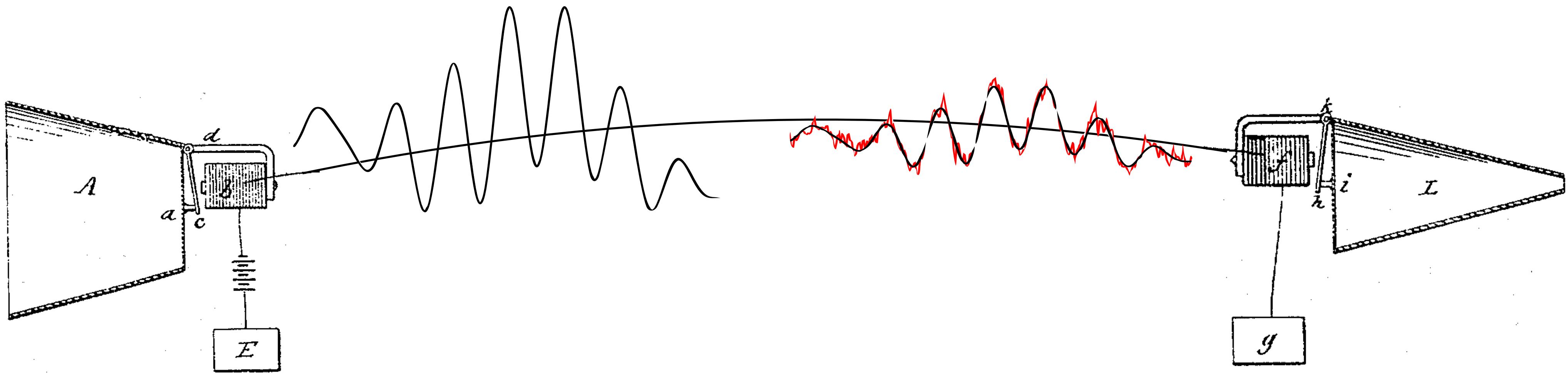
Witnesses

E. Westcott,  
H. J. Hutchinson

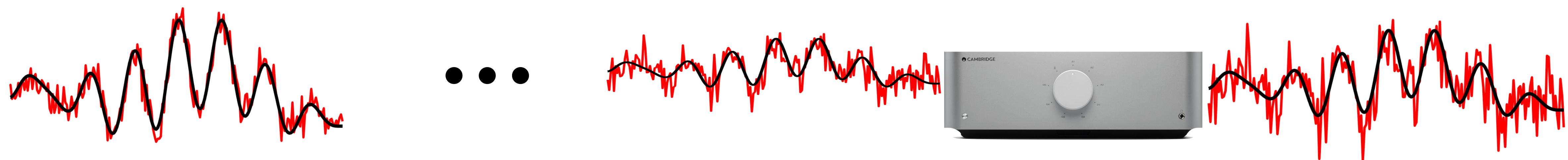
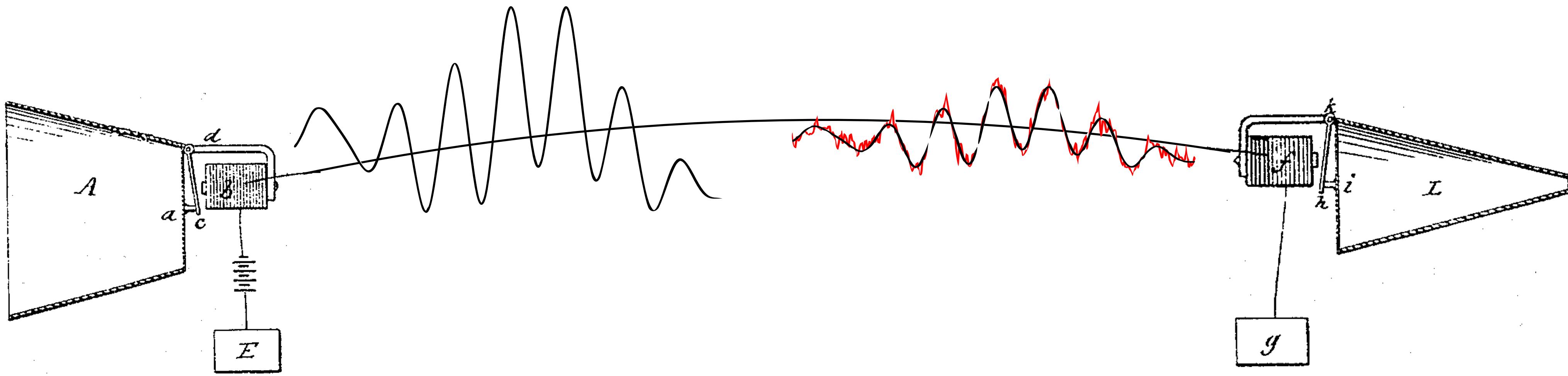
Inventor:

a. Graham Bell  
by alter Robert Bailey

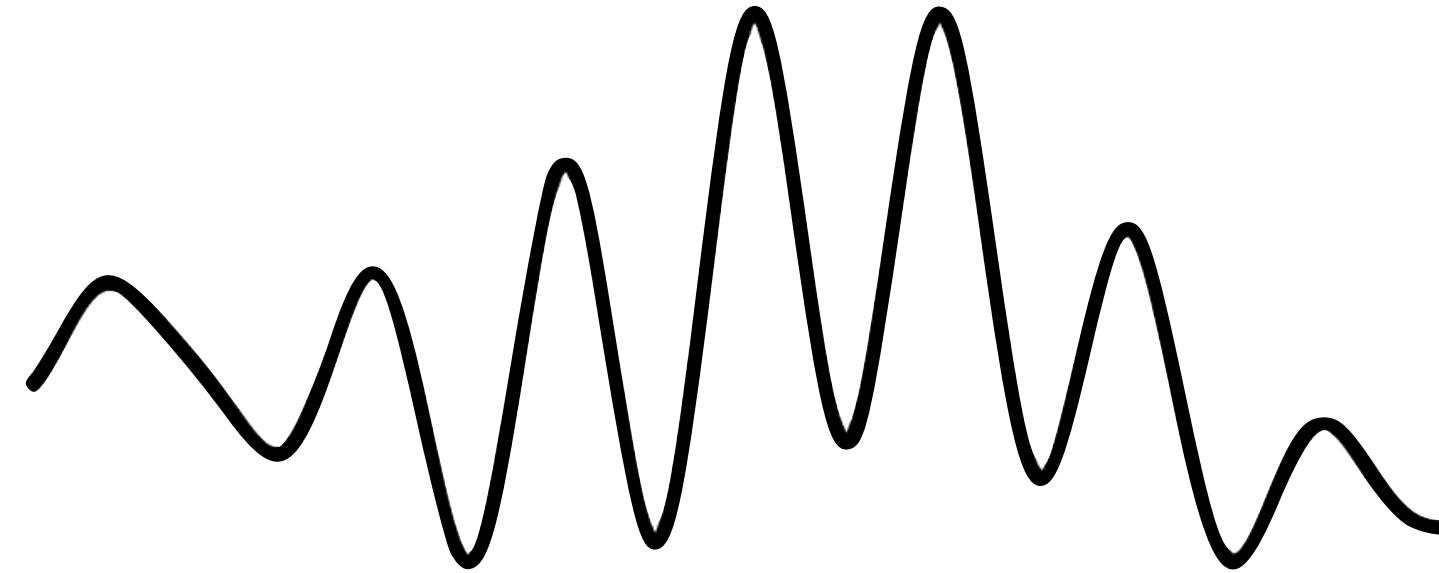
# Transferring analog signals



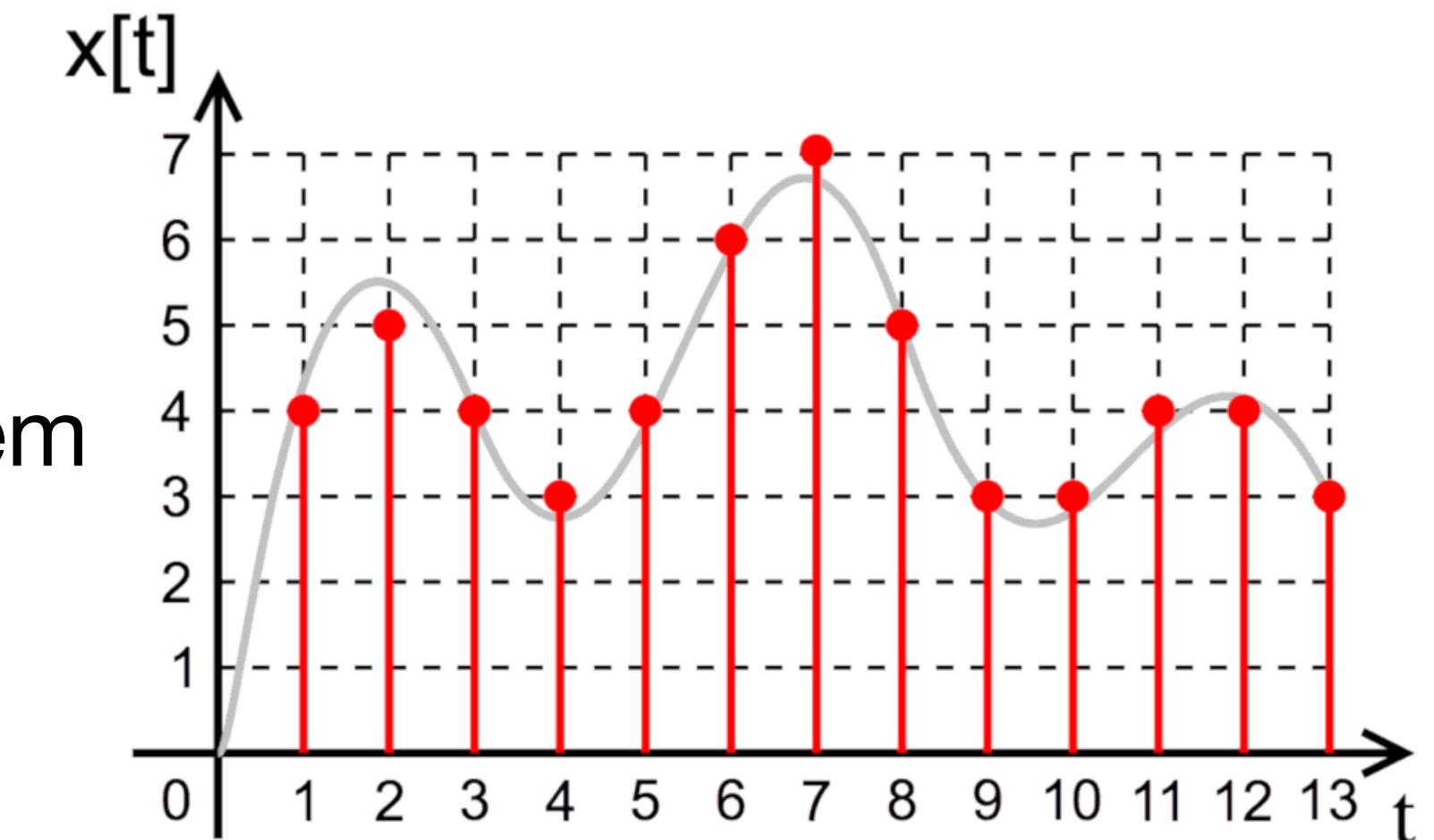
# Transferring analog signals



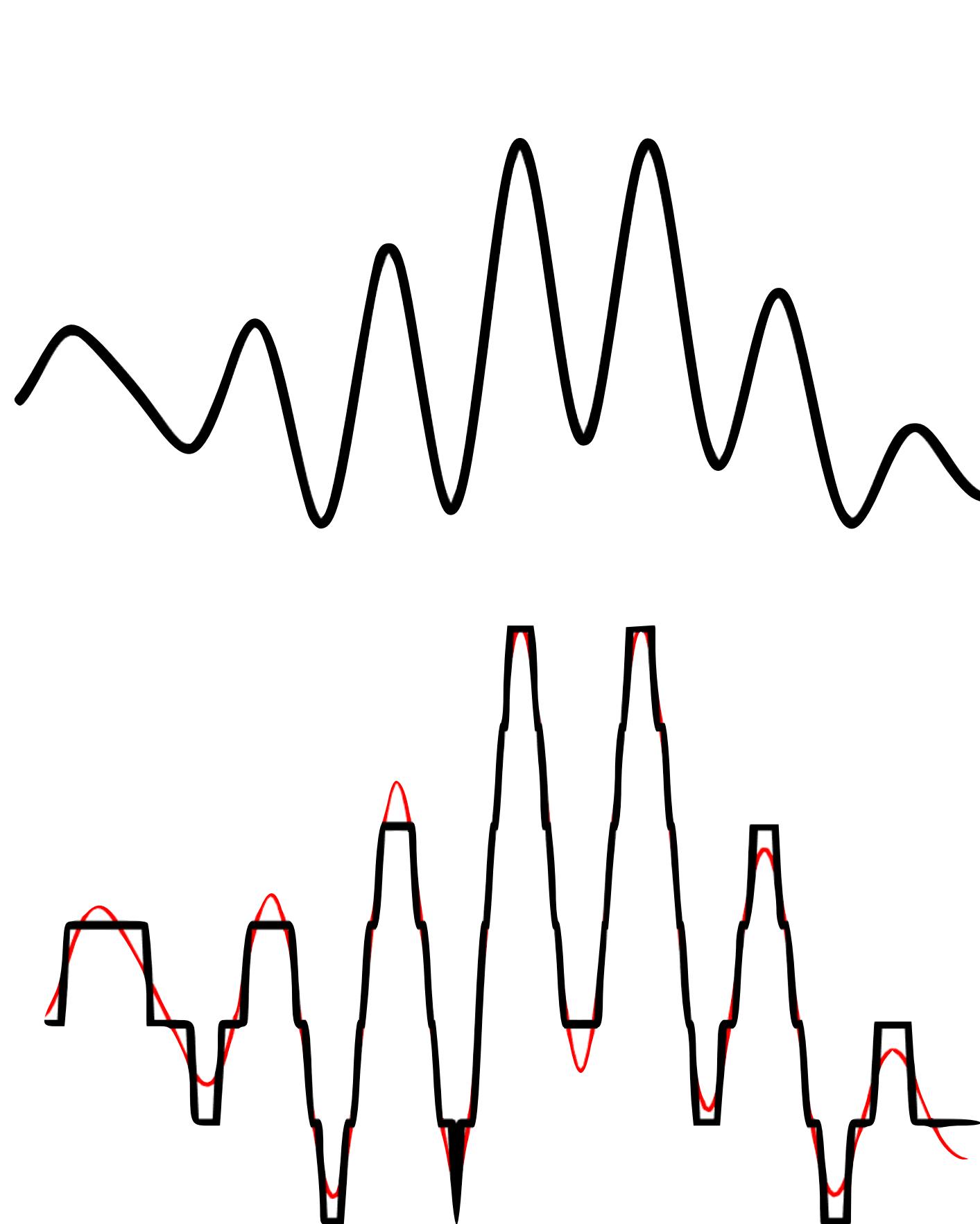
# Analog to digital: Two Shannon's theorems



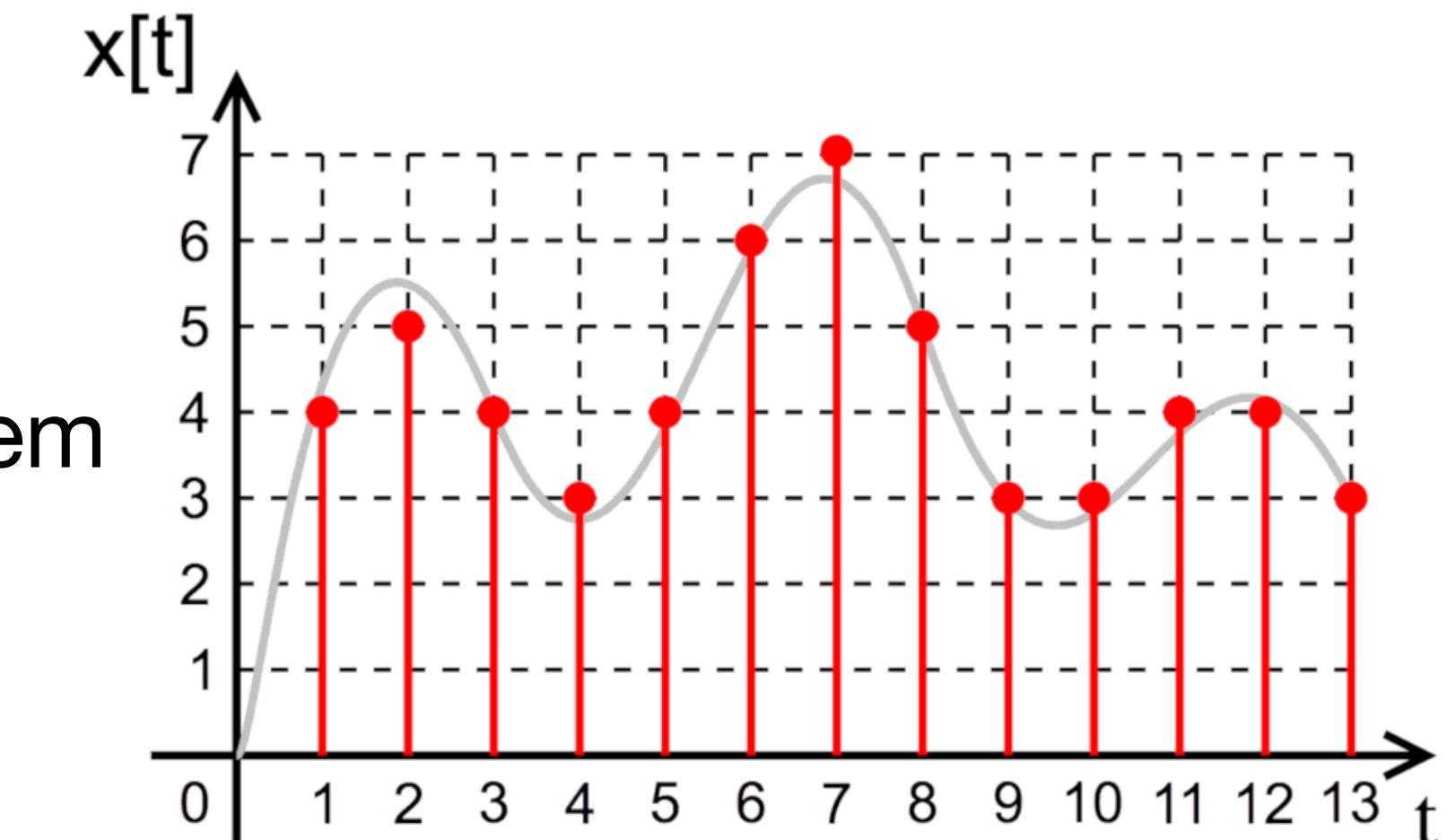
Nyquist-Shannon sampling theorem



# Analog to digital: Two theorems



Nyquist-Shannon sampling theorem



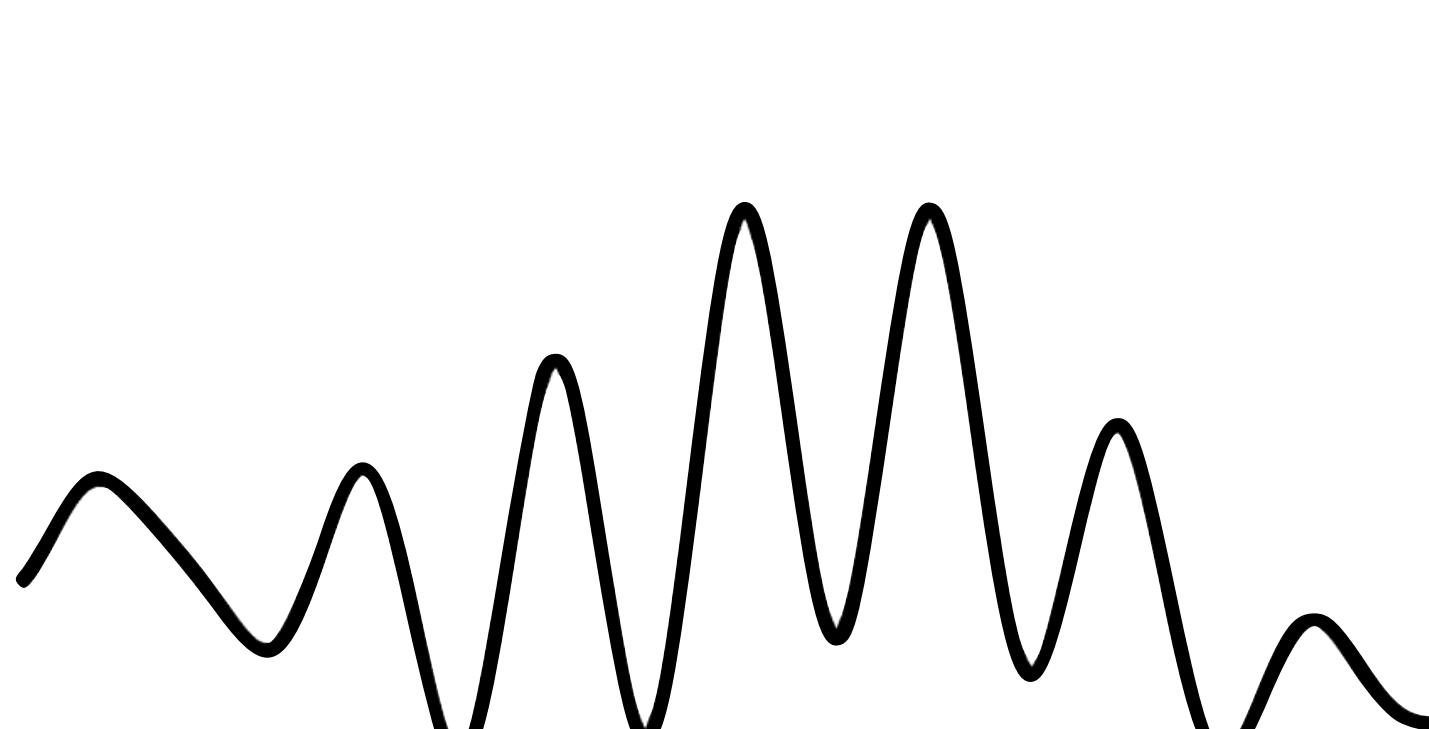
1 1 0 1 0 0 1 0 1 1 1 0 1 0 1 1 0 1 0 1 1

1 1 0 1 0 0 1 0 1 1 1 0 1 0 1 1

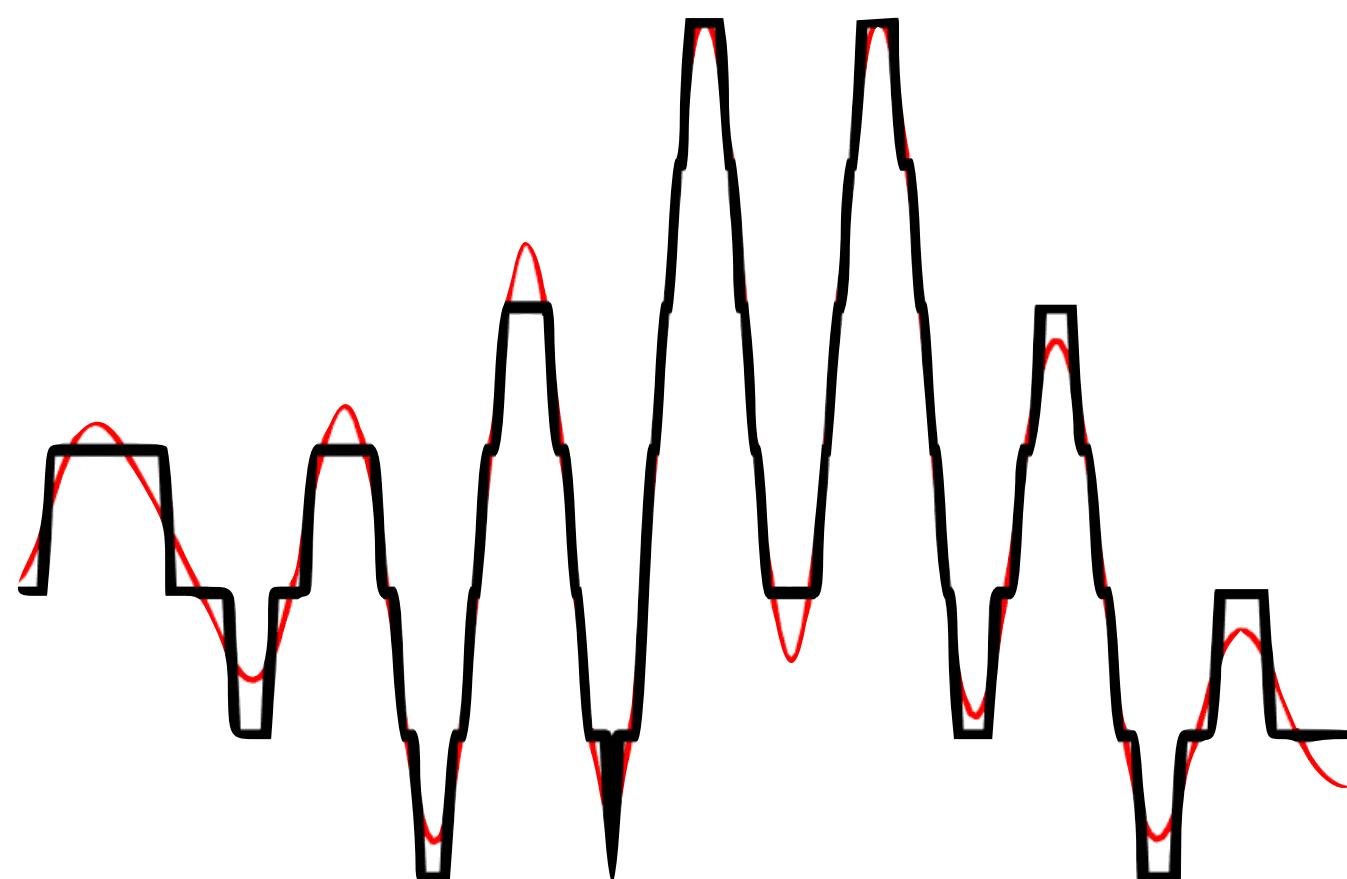
• • •

1 1 0 1 1 0 1 0 1 1 0 0 1 0 1 1 1 1 0 1 1

# Analog to digital: Two theorems



Nyquist-Shannon sampling theorem



1 1 0 1 0 0 1 0 1 1 1 0 1 0 1 1 0 1 0 1 1

• • •

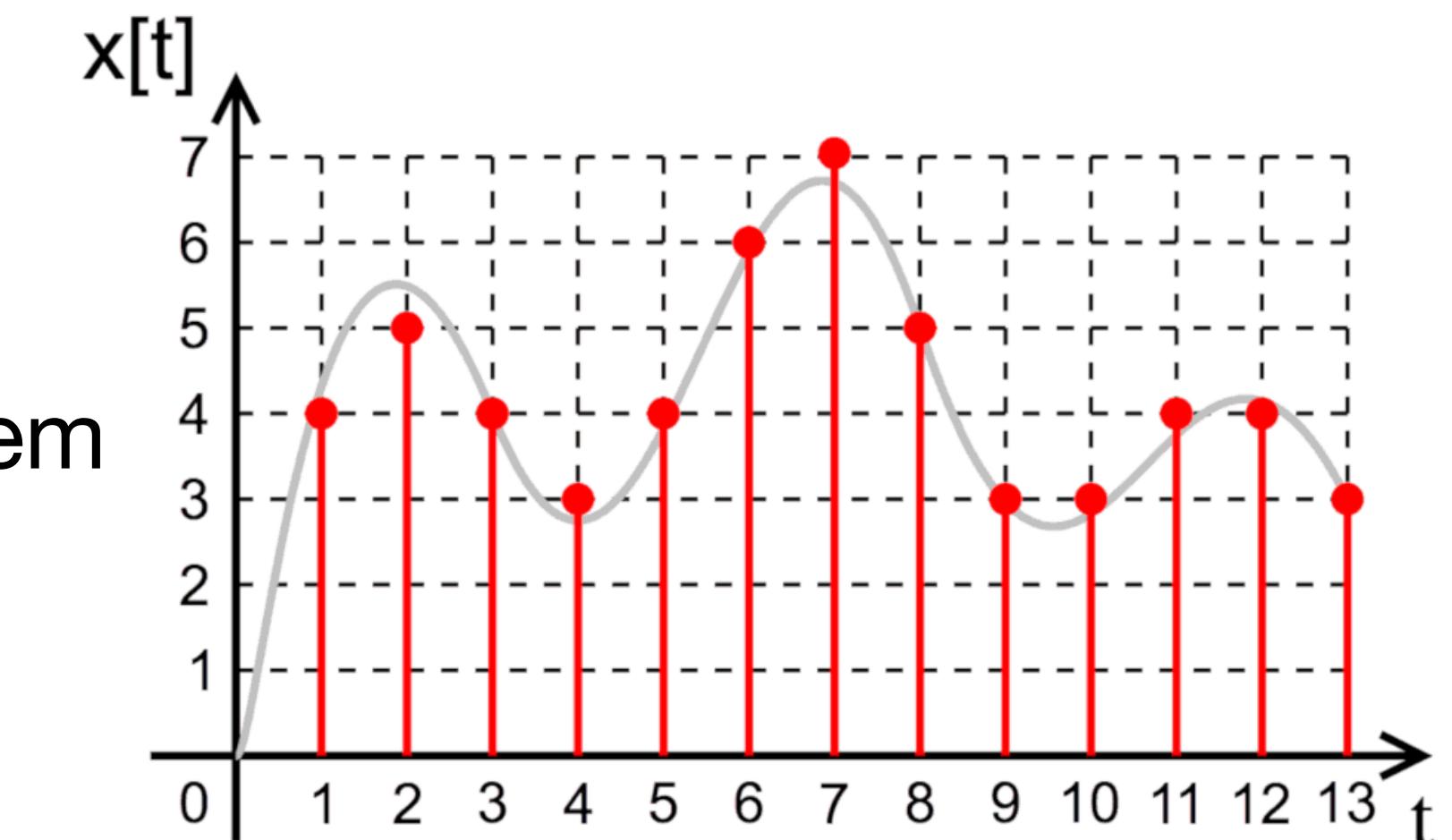
Shannon source coding theorem

1 1 0 1 0 0 1 0 1 1 1 0 1 0 1 1 0 1 0 1 1

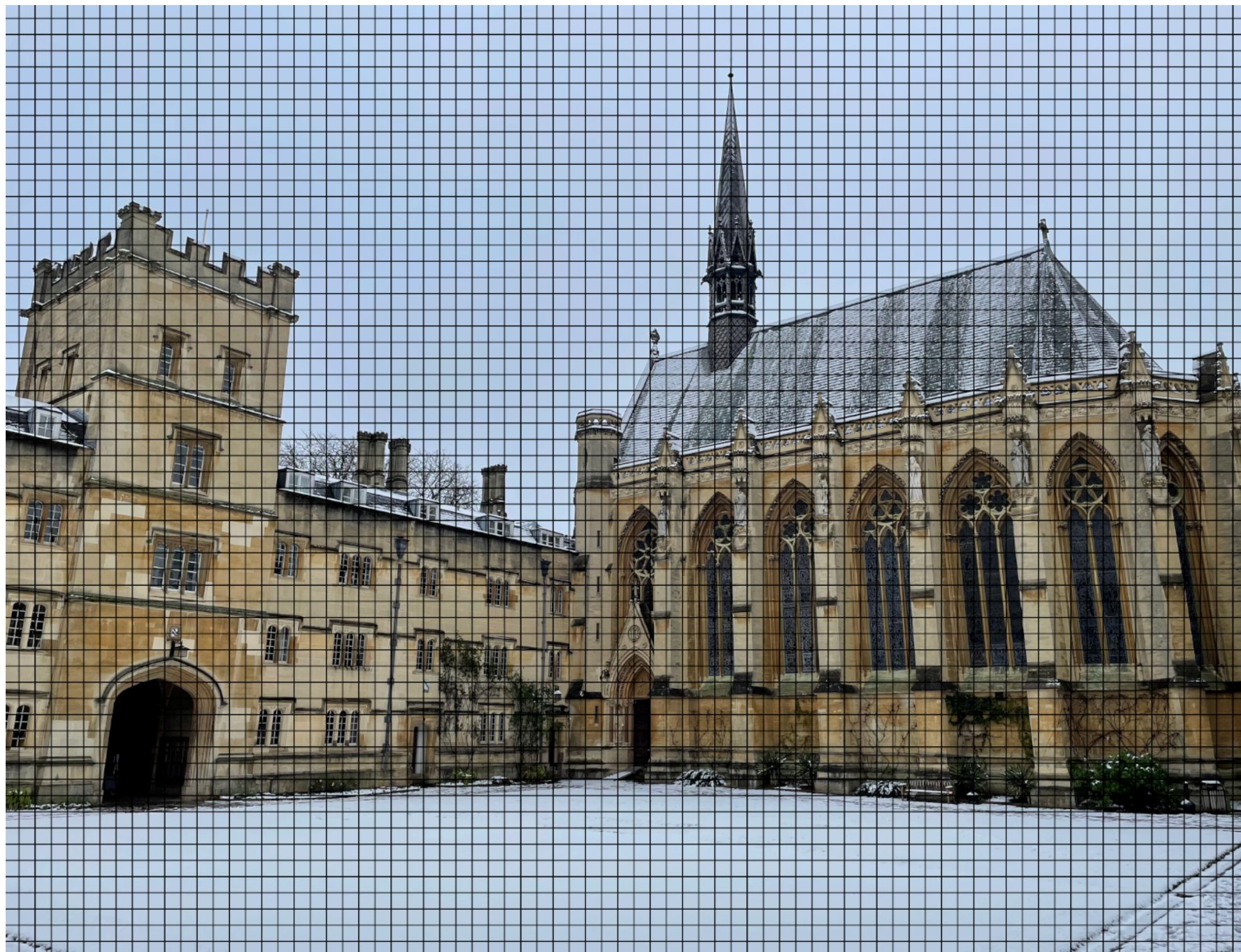
1 1 0 1 0 0 1 0 0 1 1 0 1 1 1 0 1 1 1 1 1

1 1 0 1 1 0 1 0 1 1 0 0 1 0 1 1 1 1 0 1 1

1 1 0 0 0 0 1 1 1 1 0 1 0 1 1 0 0 0 1 1



# High-resolution signals: bandwidth limitation

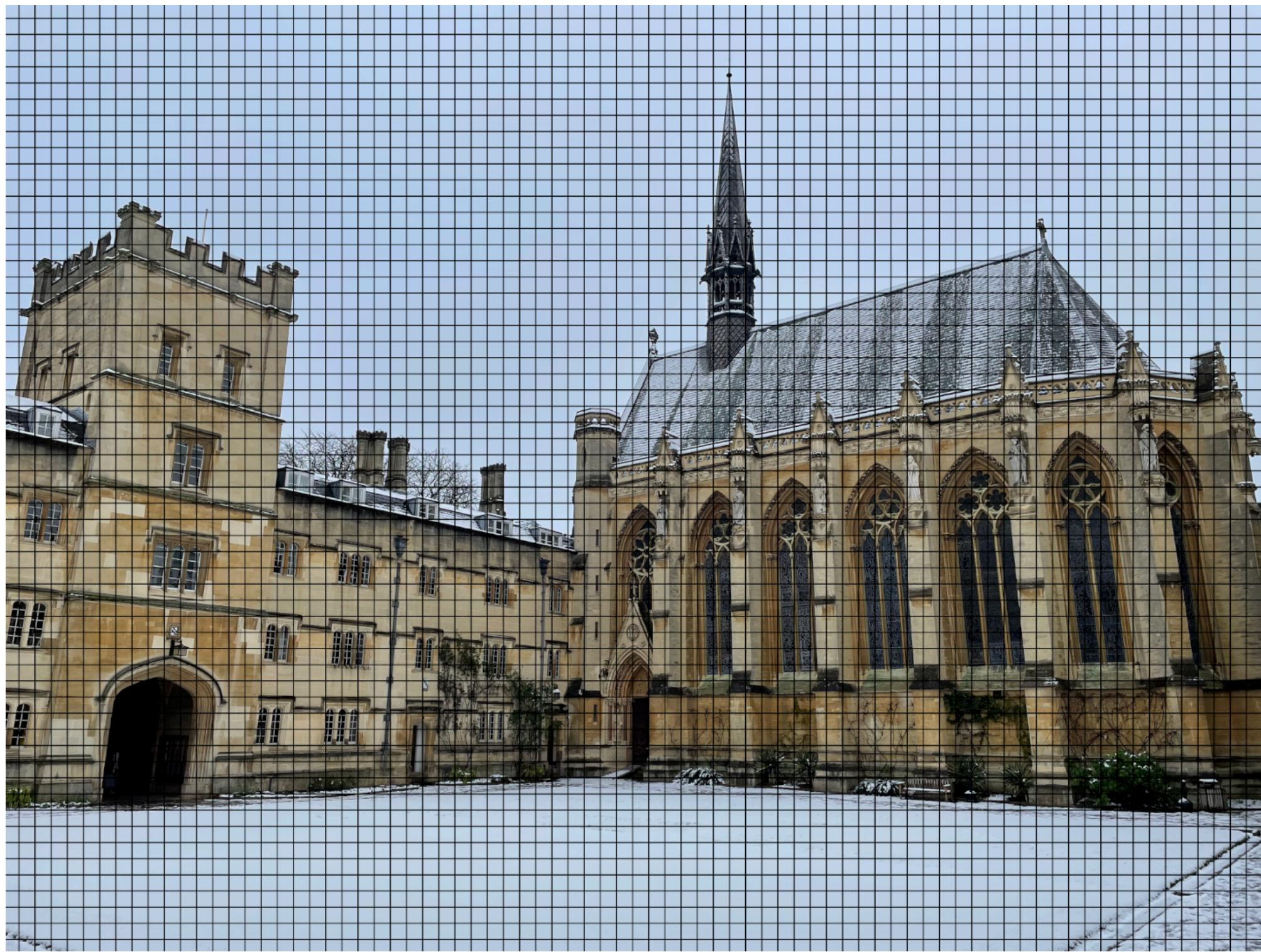


11010010  
11101011  
01011 ...

Full HD movie:

$$1920 \times 1080 \times 24 \text{ fps} \times (120 \times 60) \text{ sec} \times 3 \times 8 = 8.6 \text{ Tb}$$

# High-resolution signals: bandwidth limitation



|                 |                 |
|-----------------|-----------------|
| 1 1 0 1 0 0 1 0 | 1 1 0 1 0 0 1 0 |
| 1 1 1 0 1 0 1 1 | 1 1 1 0 1 0 1 1 |
| 0 1 0 1 1 ...   | 0 1 0 1 1 ...   |

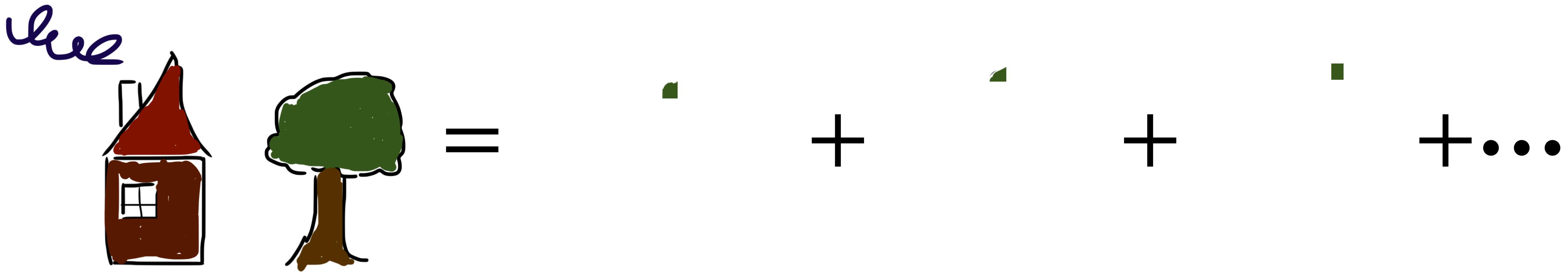
  

|                 |                 |
|-----------------|-----------------|
| 1 1 0 1 0 0 1 0 | 1 1 0 1 0 0 1 0 |
| 1 1 1 0 1 0 1 1 | 1 1 1 0 1 0 1 1 |
| 0 1 0 1 1 ...   | 0 1 0 1 1 ...   |

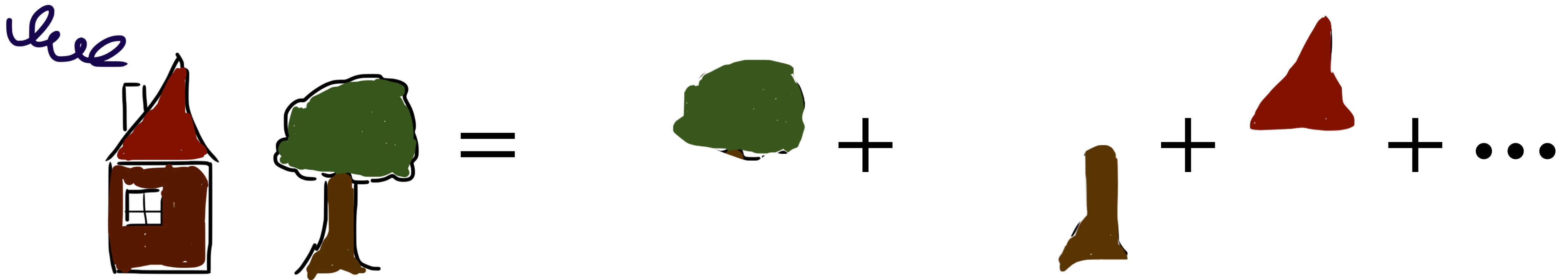
4K movie:

$$3840 \times 2160 \times 24 \text{ fps} \times (120 \times 60) \text{ sec} \times 3 \times 8 = 34.4 \text{ Tb}$$

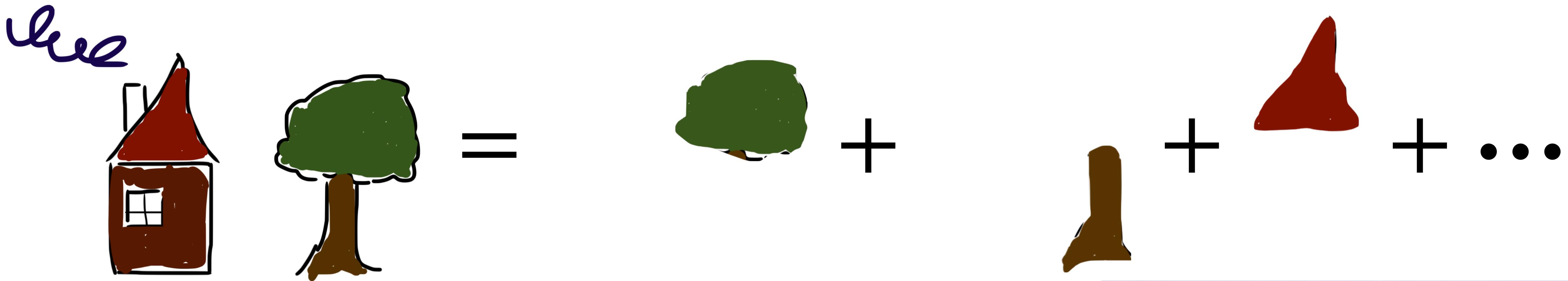
# High-resolution signals: compression



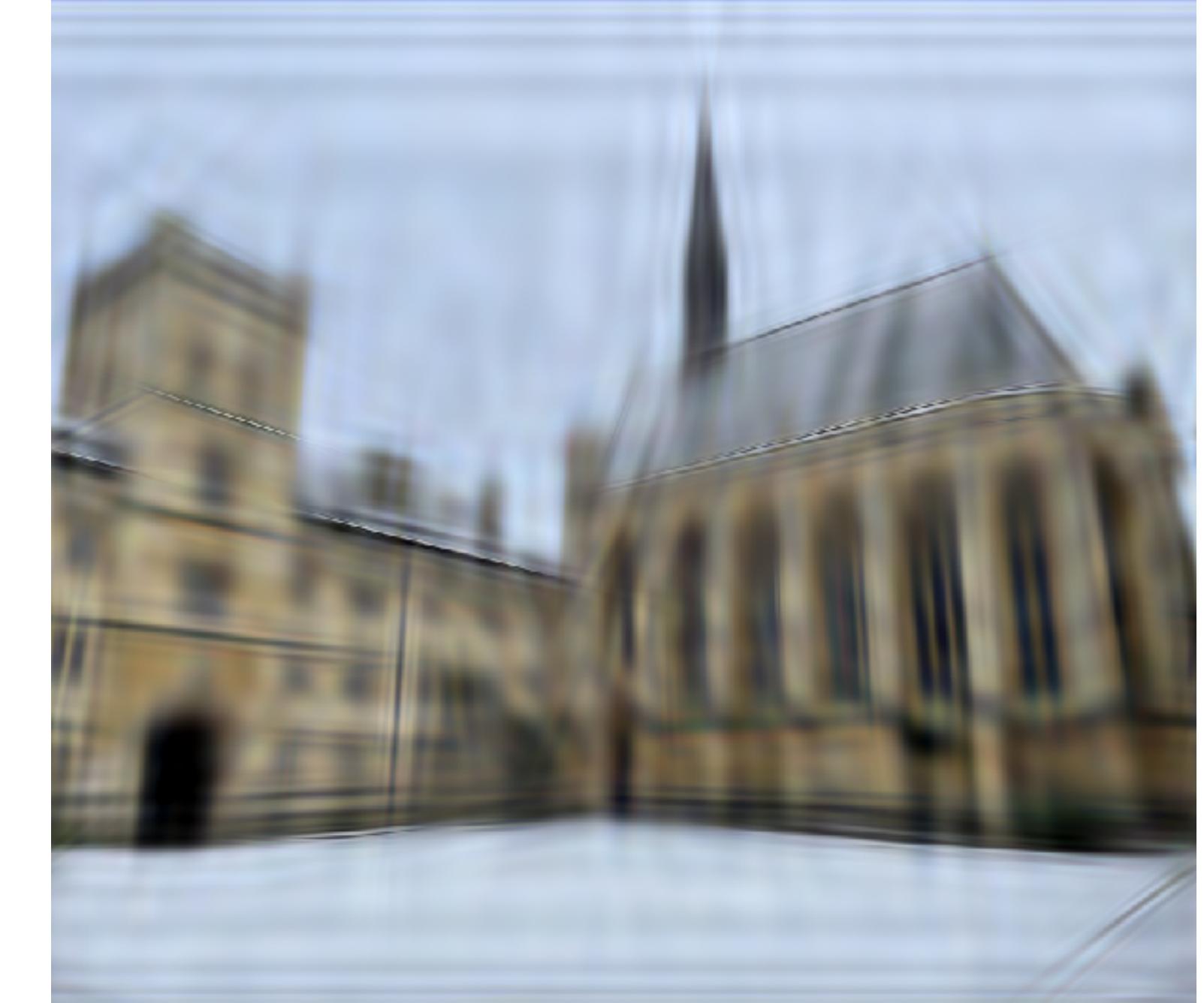
# High-resolution signals: compression



# High-resolution signals: compression

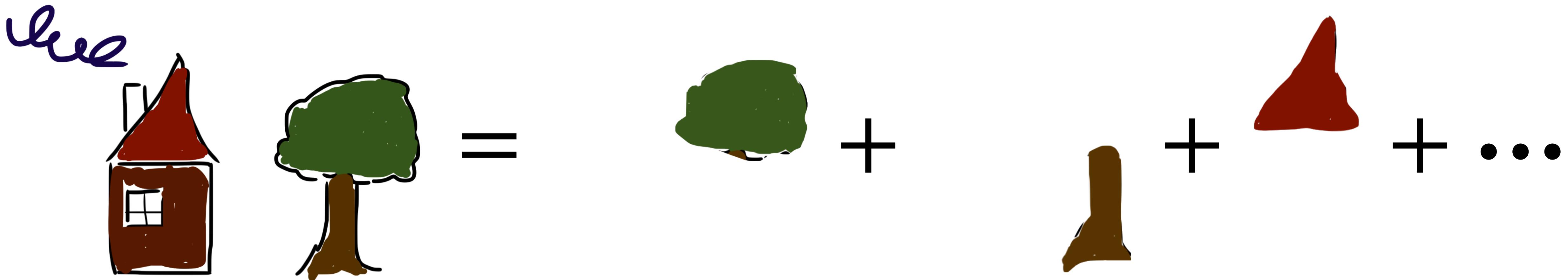


Groundtruth

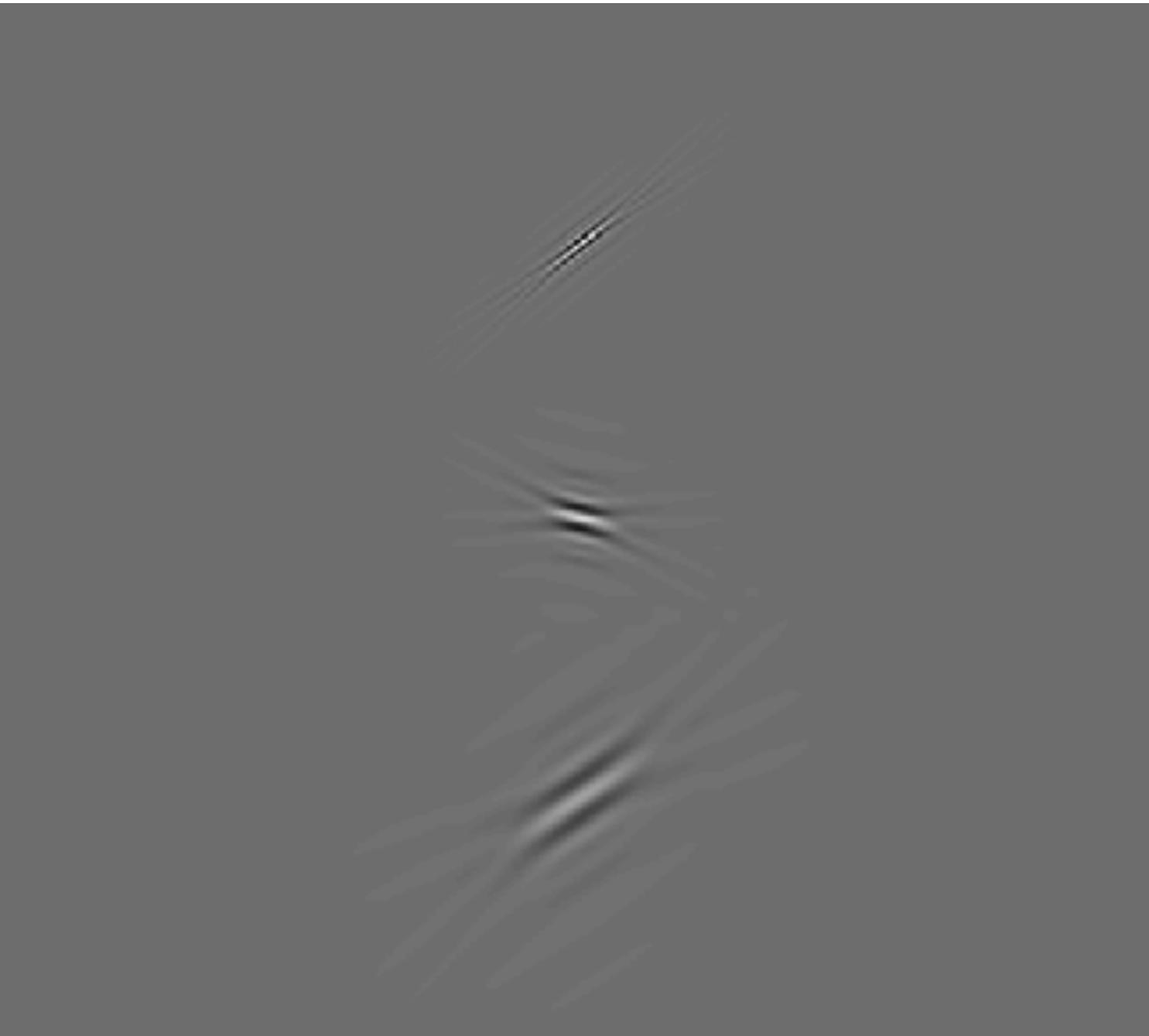


1/200 compression

# High-resolution signals: compression

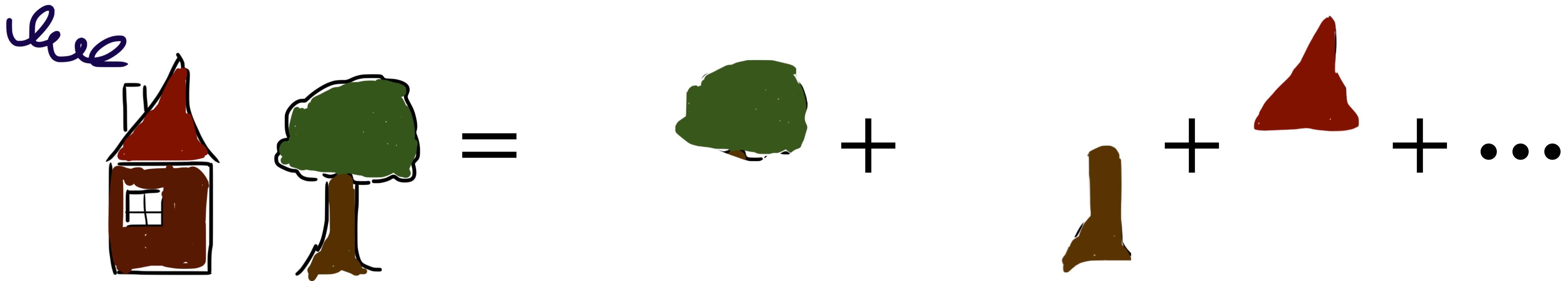


Groundtruth

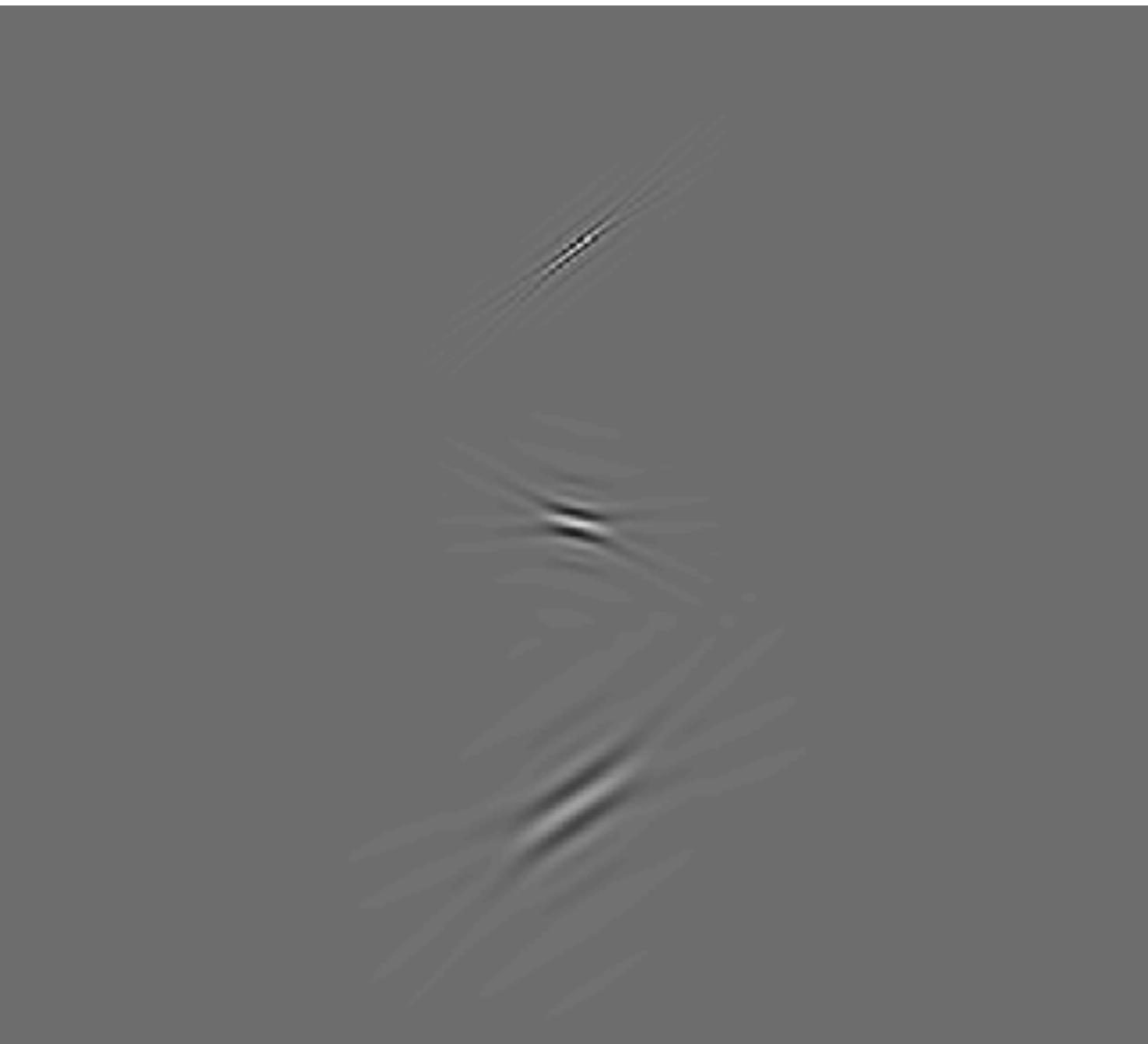


1/20 compression

# High-resolution signals: compression

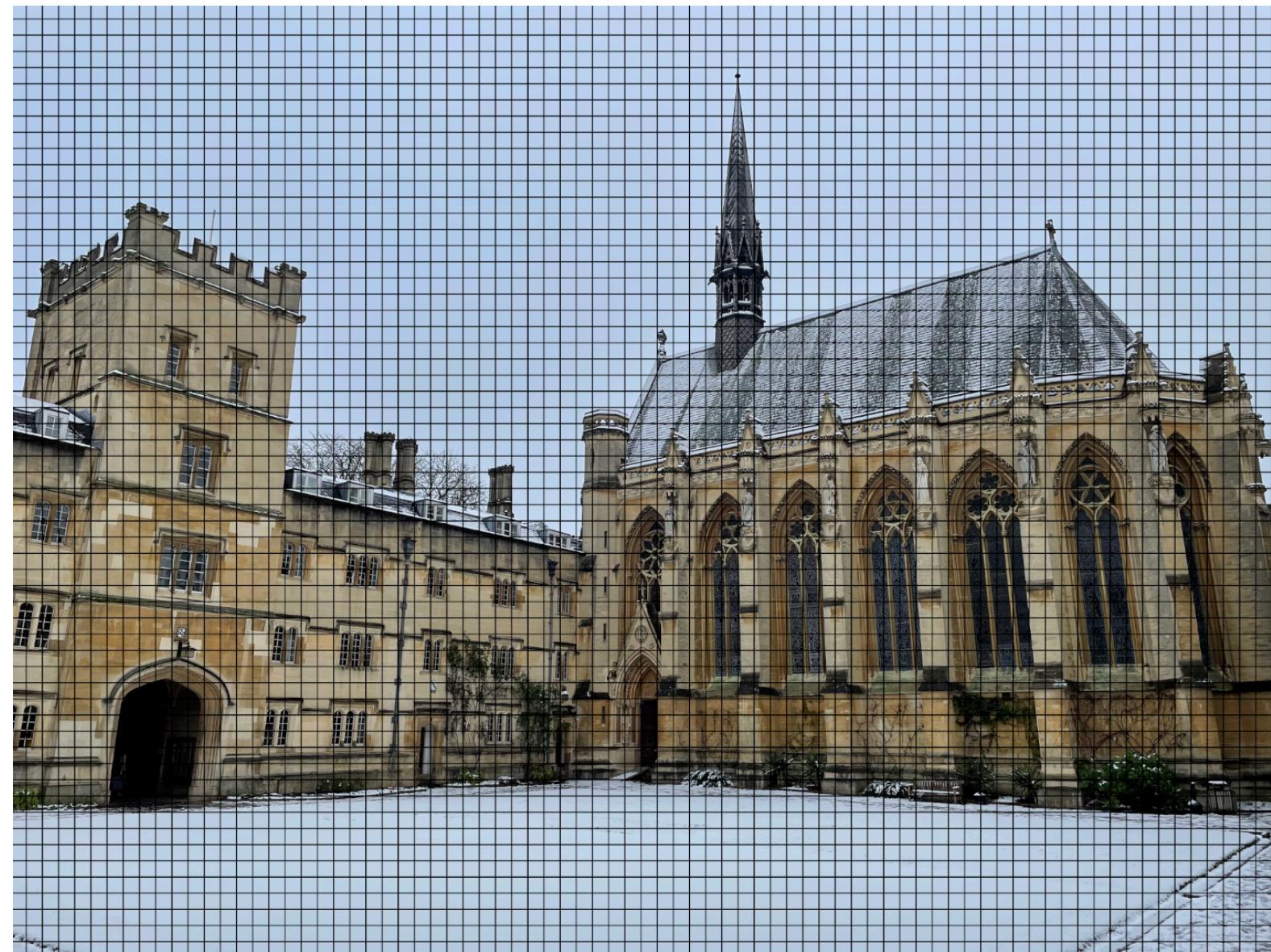


Groundtruth



1/10 compression

# High-resolution signals: compression



11010010  
11101011  
01011110  
10010111  
01011010  
11 ...

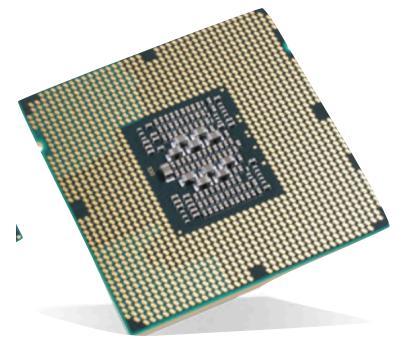
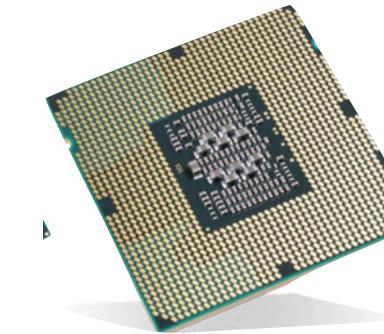
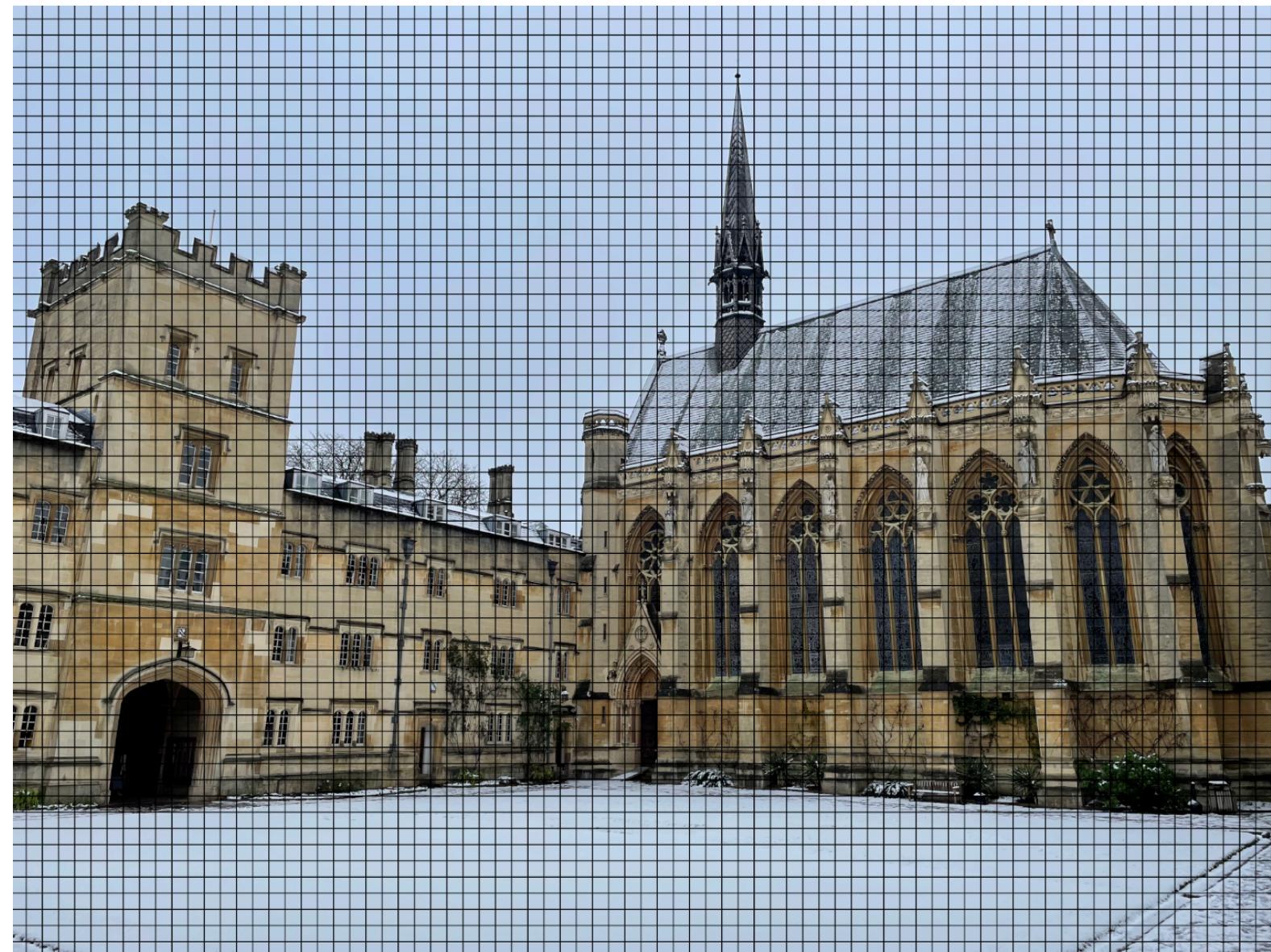


11010010  
11101011  
010 ...



SAMPLING → COMPRESSION → TRANSFER → DECOMPRESSION.

# High-resolution signals: compression



11010010  
11101011  
01011110  
10010111  
01011010  
11 ...

11010010  
11101011  
010 ...

SAMPLING → COMPRESSION → TRANSFER → DECOMPRESSION.

More computation  $\approx$  Less transfer

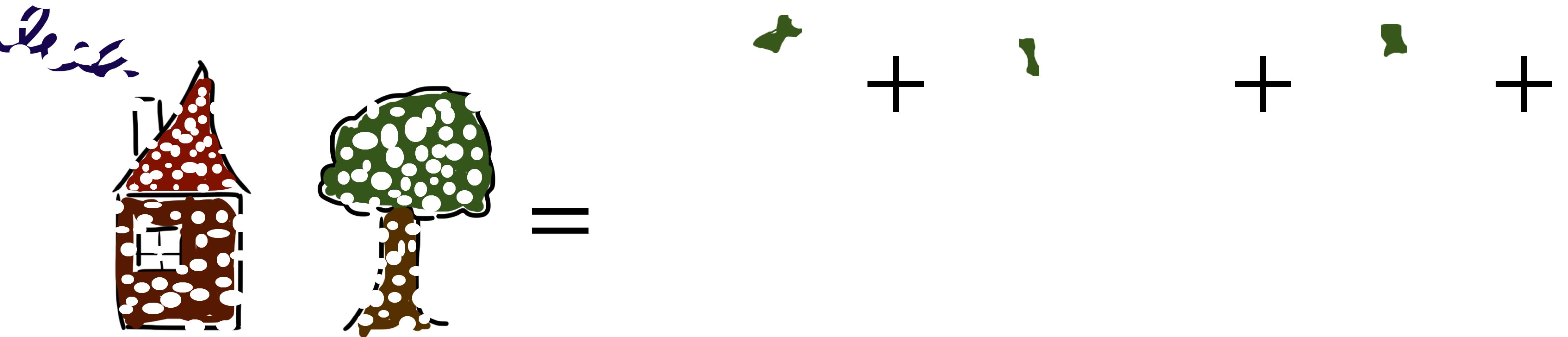
# Compressed sensing

Why sample in such a detail when we compress away most of the information?



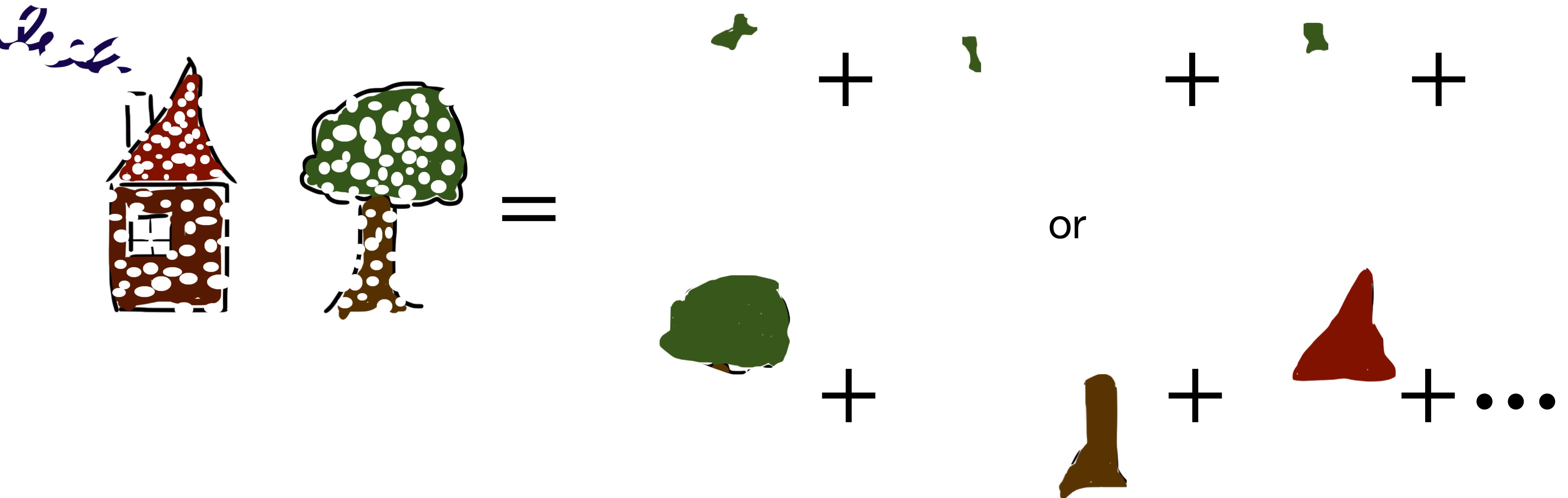
# Compressed sensing

Why sample in such a detail when we compress away most of the information?



# Compressed sensing

Why sample in such a detail when we compress away most of the information?

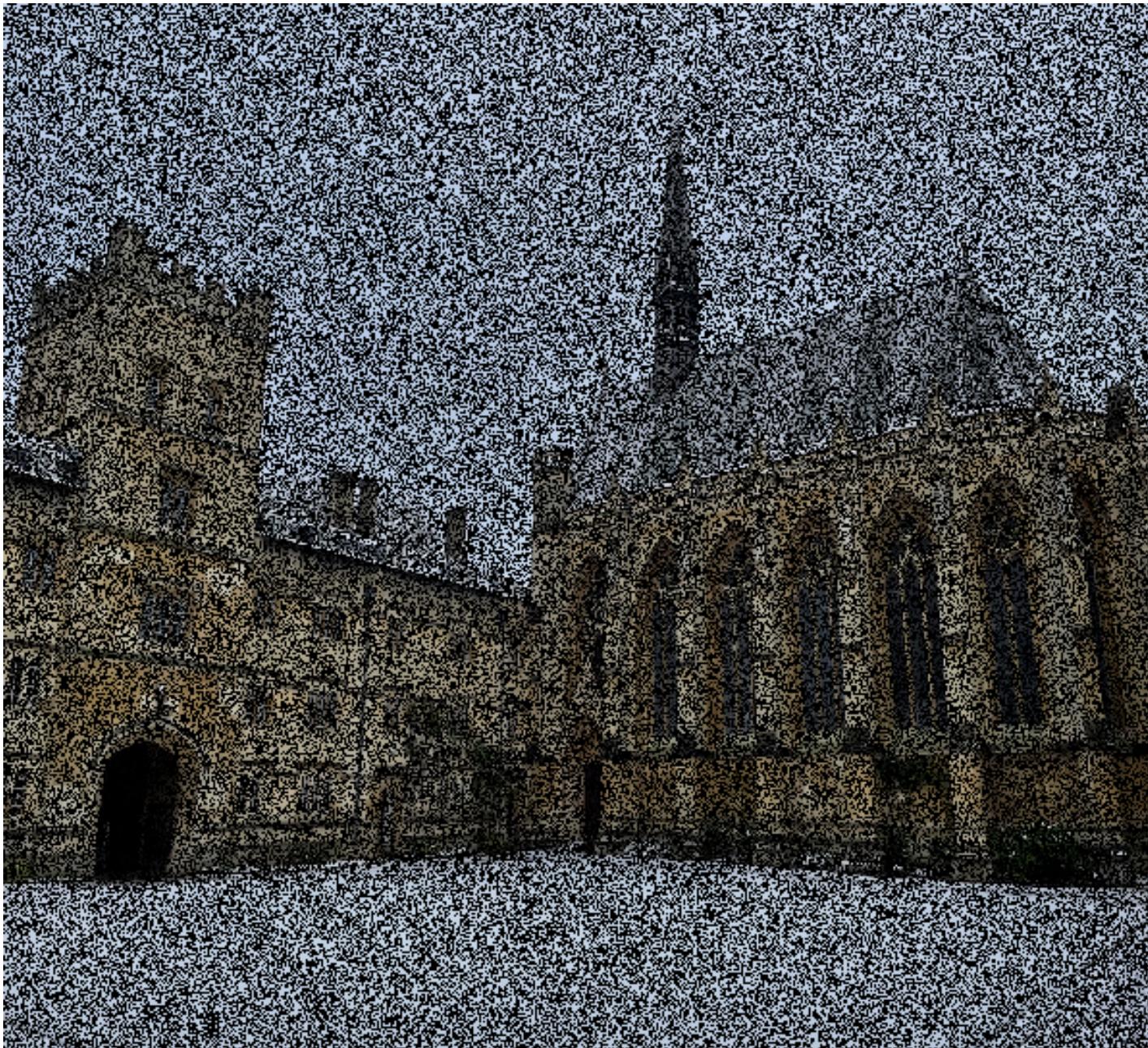


# Compressed sensing

Why sample in such a detail when we compress away most of the information?



Groundtruth



1/2 of pixels



1/20 compression

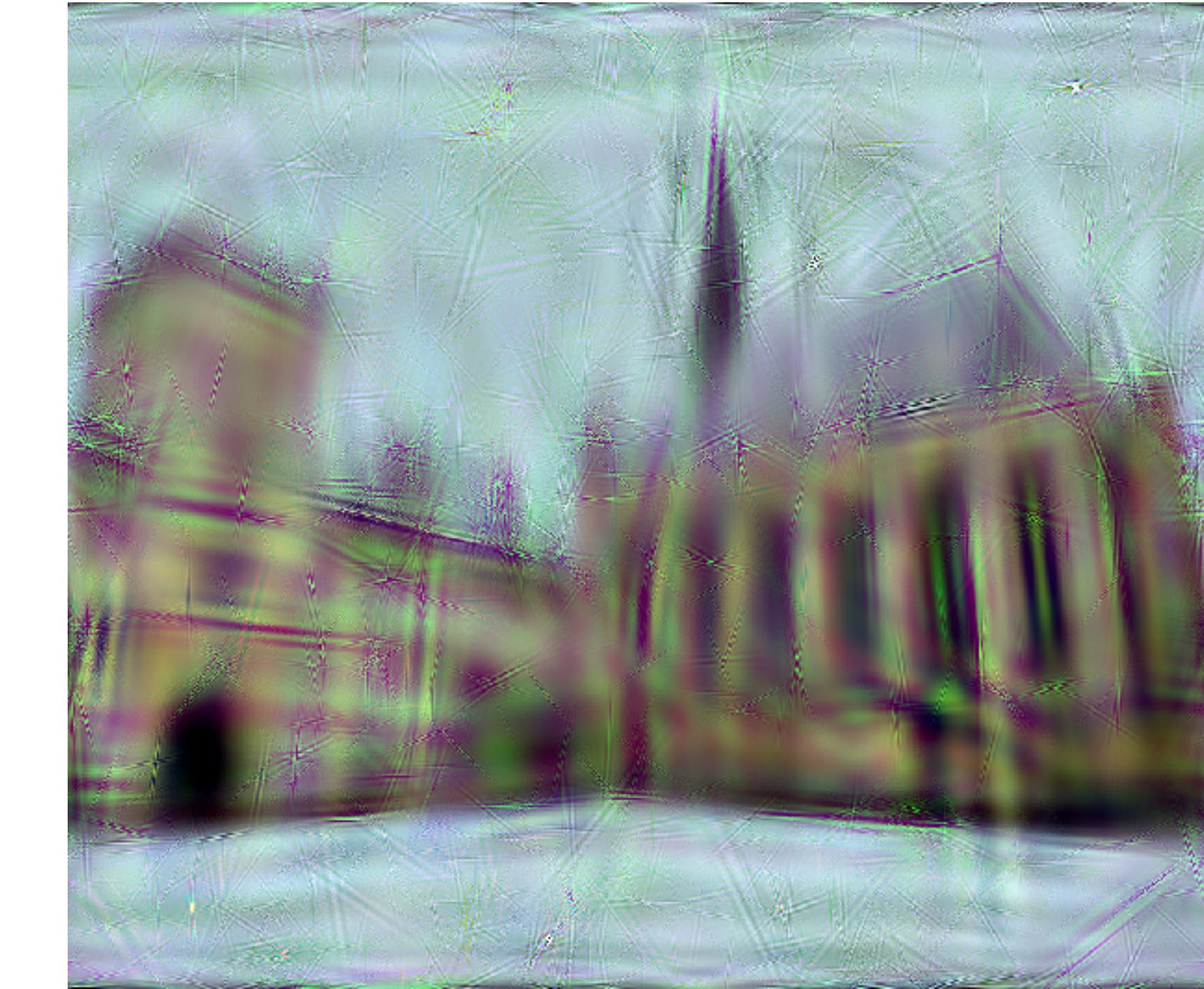
# Compressed sensing



Groundtruth

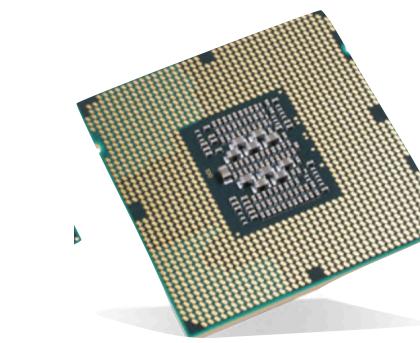
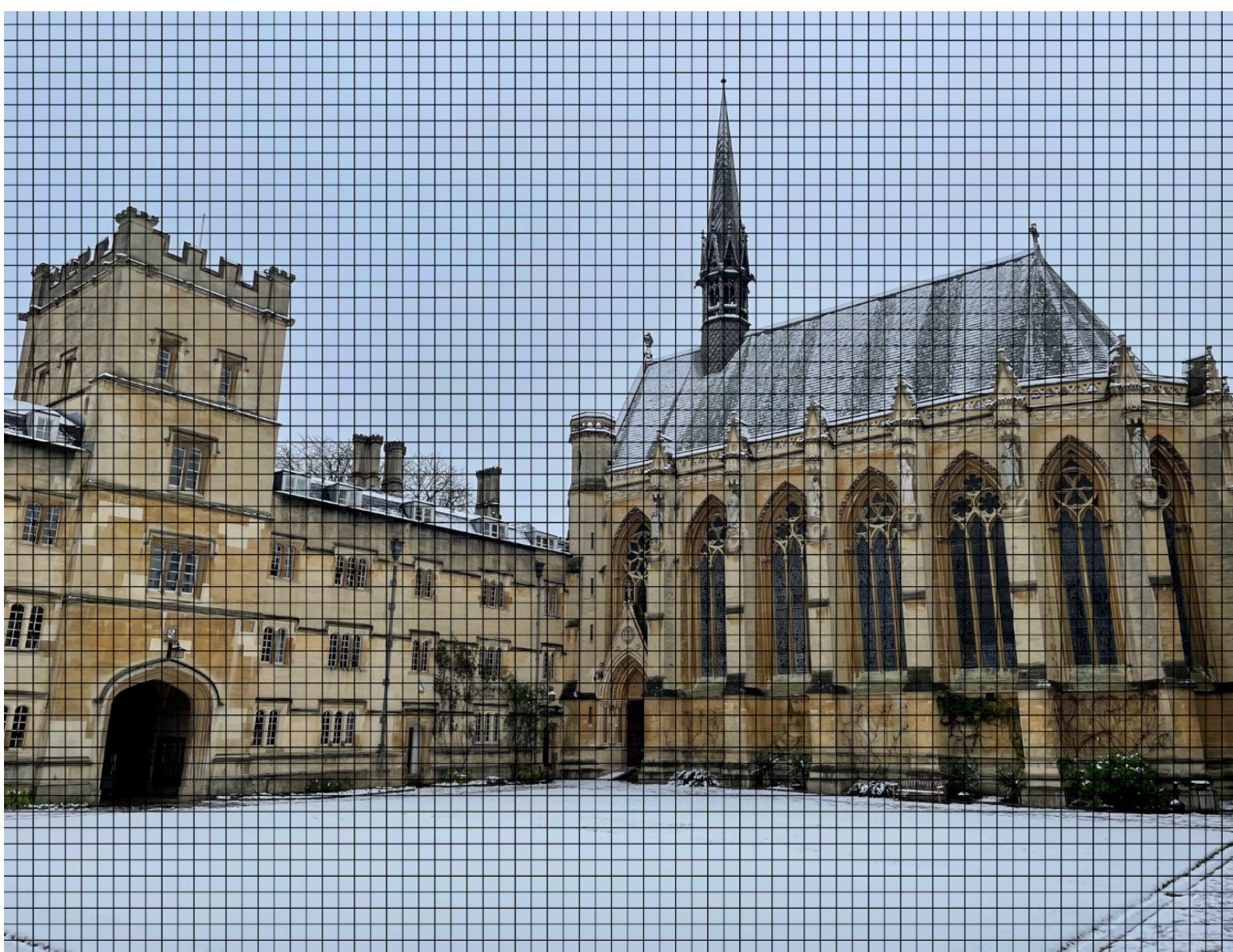


1/25 of pixels



1/200 compression

# Compressed sensing



COMPRESSED  
SENSING

→ 11010010  
11101011  
010 ... →

11010010  
11101011  
01011110  
10010111  
01011010  
11 ...

RECONSTRUCTION

More computation  $\approx$  More precise measurement

# Incomplete information in recommendation systems

|  |   |   |   |   |
|--|---|---|---|---|
|  |   |   |   |   |
|  | 1 | ? | 5 | ? |
|  | 4 | 2 | ? | 3 |
|  | 1 | 5 | 4 | ? |



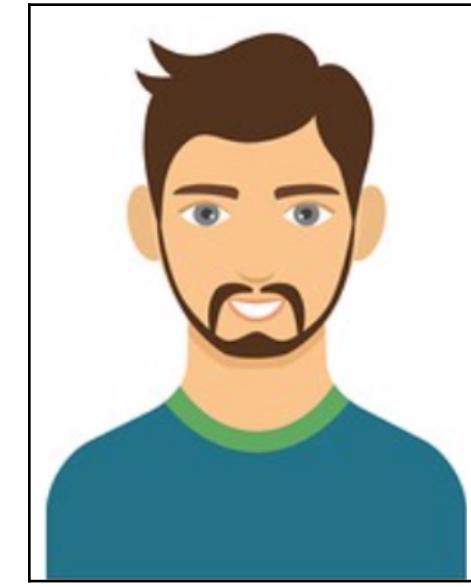
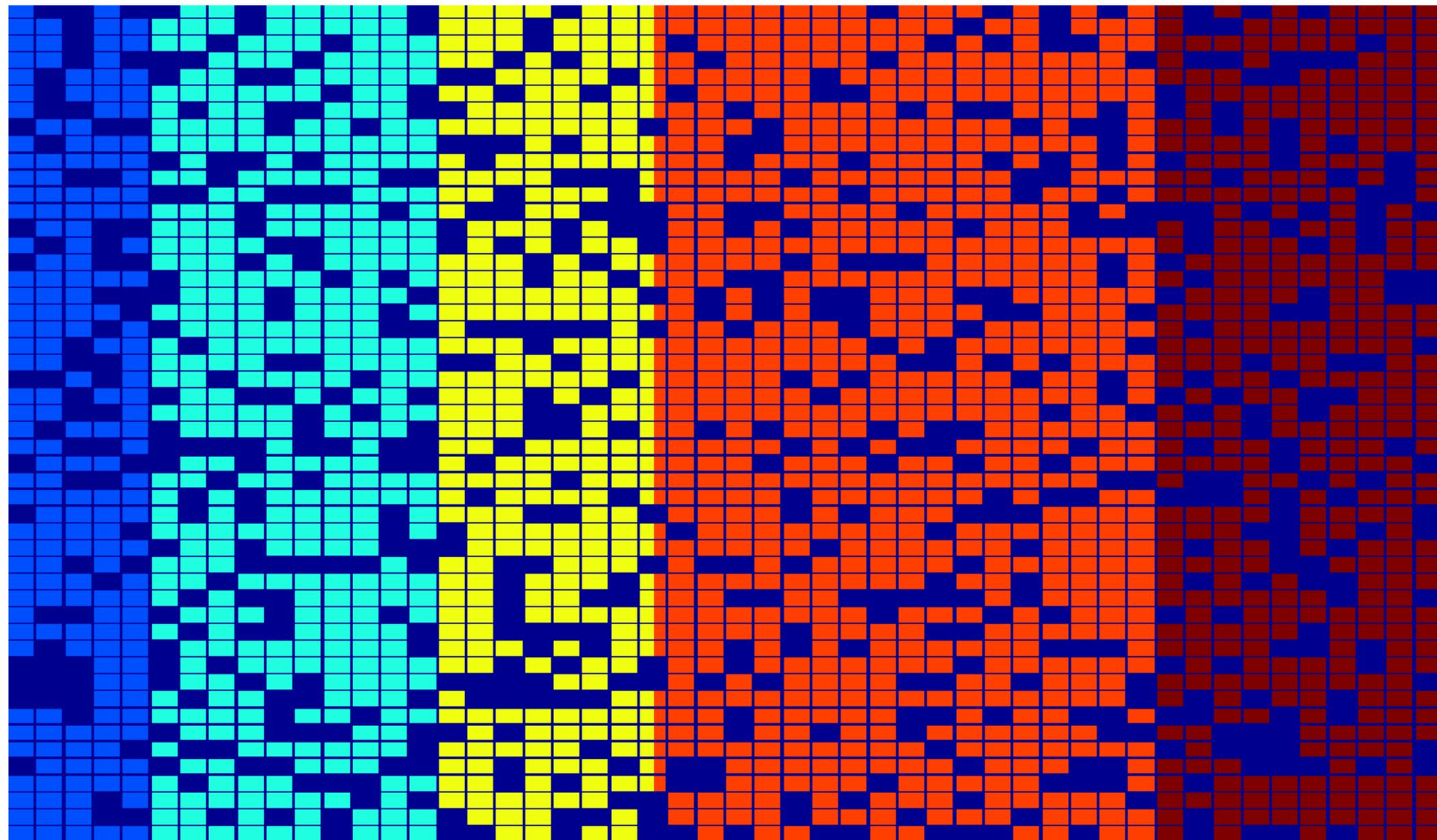
≈



≈



# Incomplete information in recommendation systems



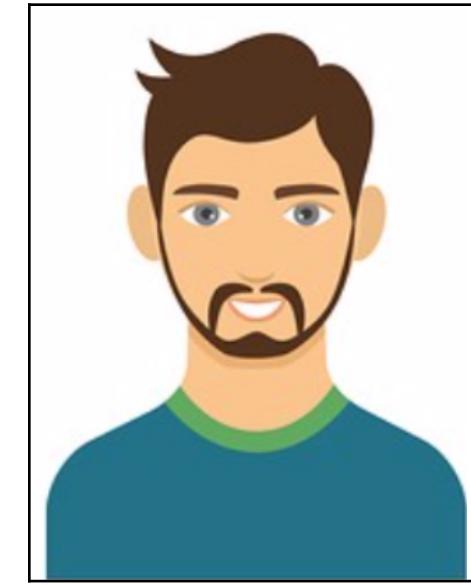
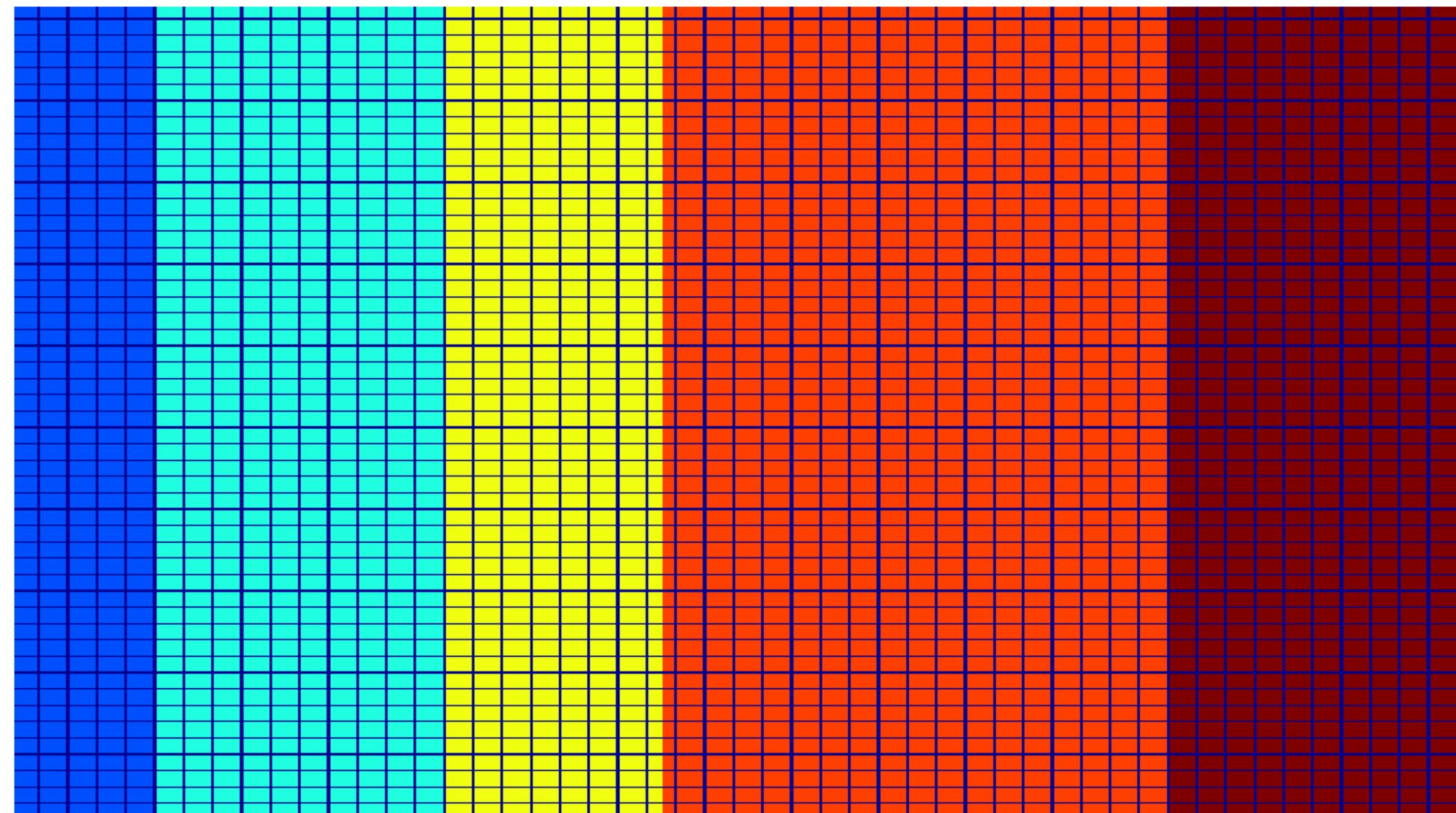
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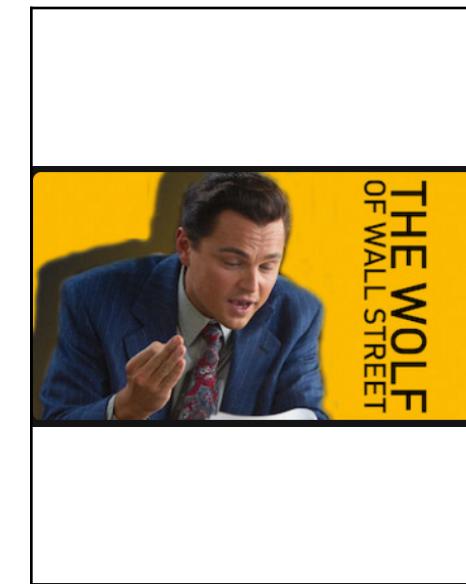
# Incomplete information in recommendation systems



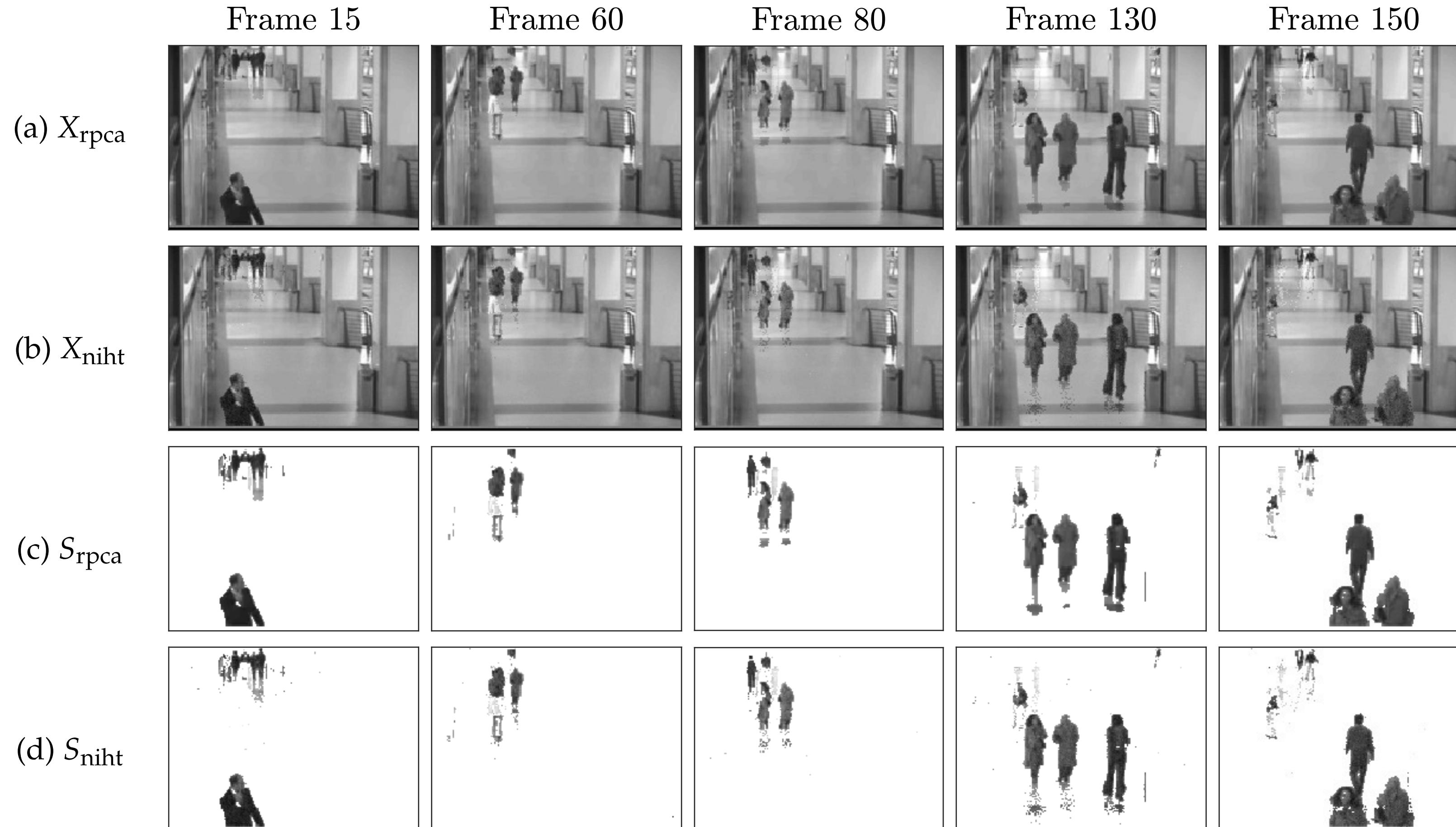
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# Topic of my DPhil: Combining the two structures



Dynamic-foreground/static-background separation from 1/3 information.

**Thank you for your attention.**

[simonvary.github.io/talk-exeter.pdf](https://simonvary.github.io/talk-exeter.pdf)