Error Correction through Language Processing

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Another title for the talk ...

Is There A New Way To Correct Errors

Two fundamental approaches for correcting errors:

- Add external redundancy
- Use internal redundancy

- APPROACH I: Add External Redundancy.

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  That is Wonderful!

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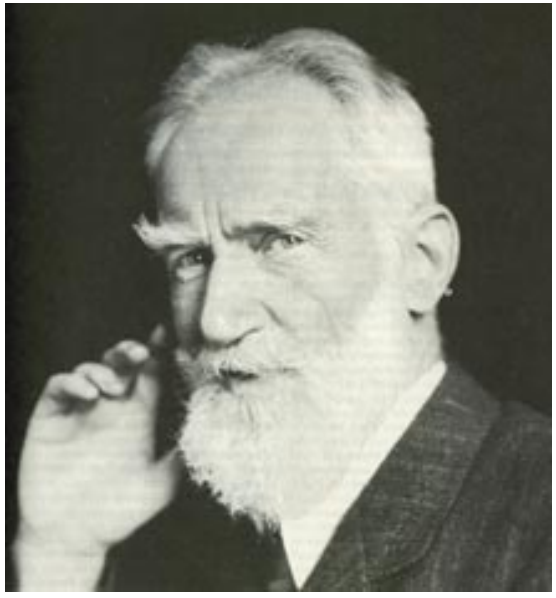
  That is Wonderful!

No No No...

"There are two tragedies in life:
One is dream lost,
The other is dream realized."



George Bernard Shaw

- It is time to consider APPROACH II: Use internal redundancy.

Open Problem:

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Suggestion: Focus on "intelligent information", such as languages, images, videos...

Reason: Such data have plenty of redundancy, even after data compression.

It is related to: Joint Source-Channel Coding

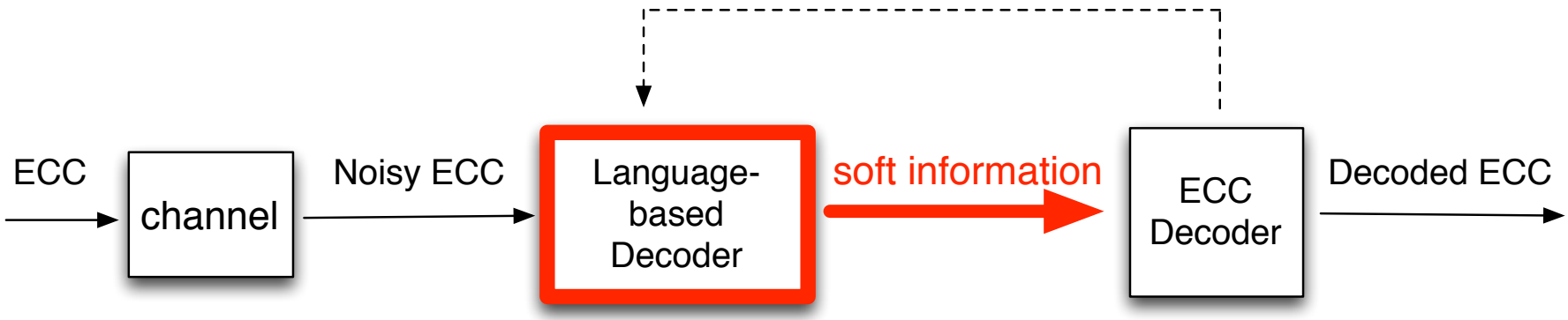
Distinct Features:

- No joint work: Focus on error correction
- No change to ECC data: Compatible with existing systems

It is related to: Denoising

Tsachy Weissman, Erik Ordentlich, Gadiel Seroussi, Sergio Verdu, and Marcelo J. Weinberger,
Universal Discrete Denoising: Known Channel,
in *IEEE Trans. Information Theory*, vol. 51, no. 1, pp. 5–28, January 2005. (IEEE Communications Society and Information Theory Society Joint Paper Award, 2006.)

Error-Correction Framework



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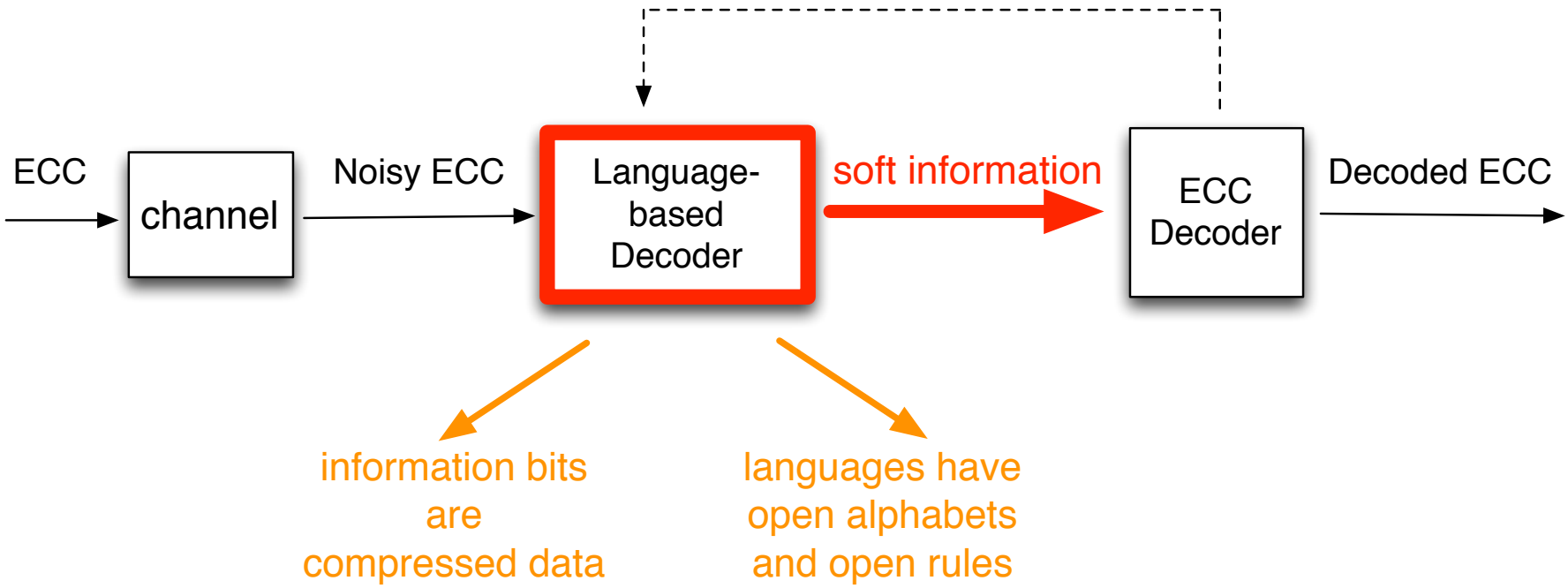
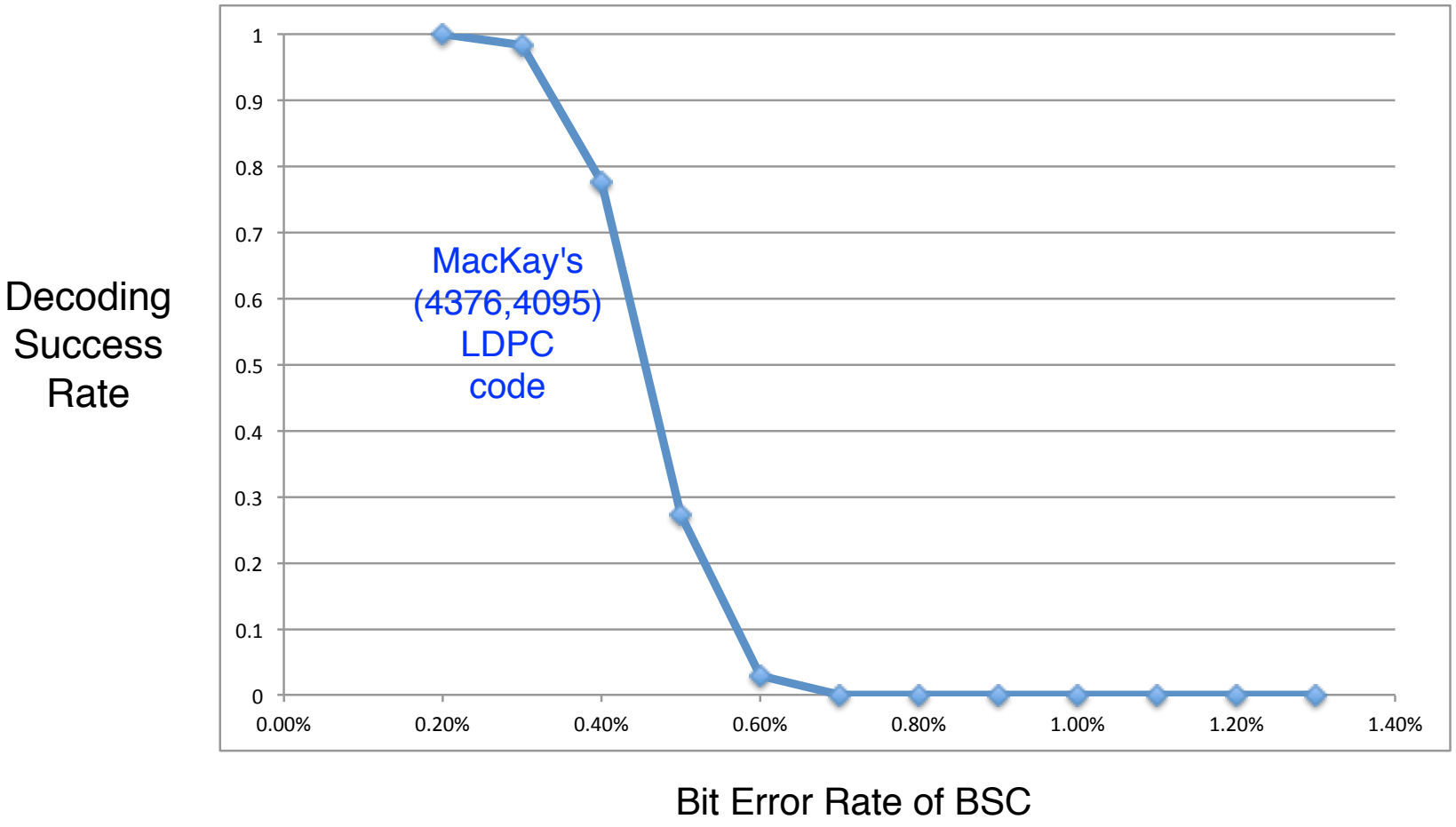


Does it work?


Decoding Success Rate
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MacKay's (4376,4095) LDPC code
0.00%
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Bit Error Rate of BSC

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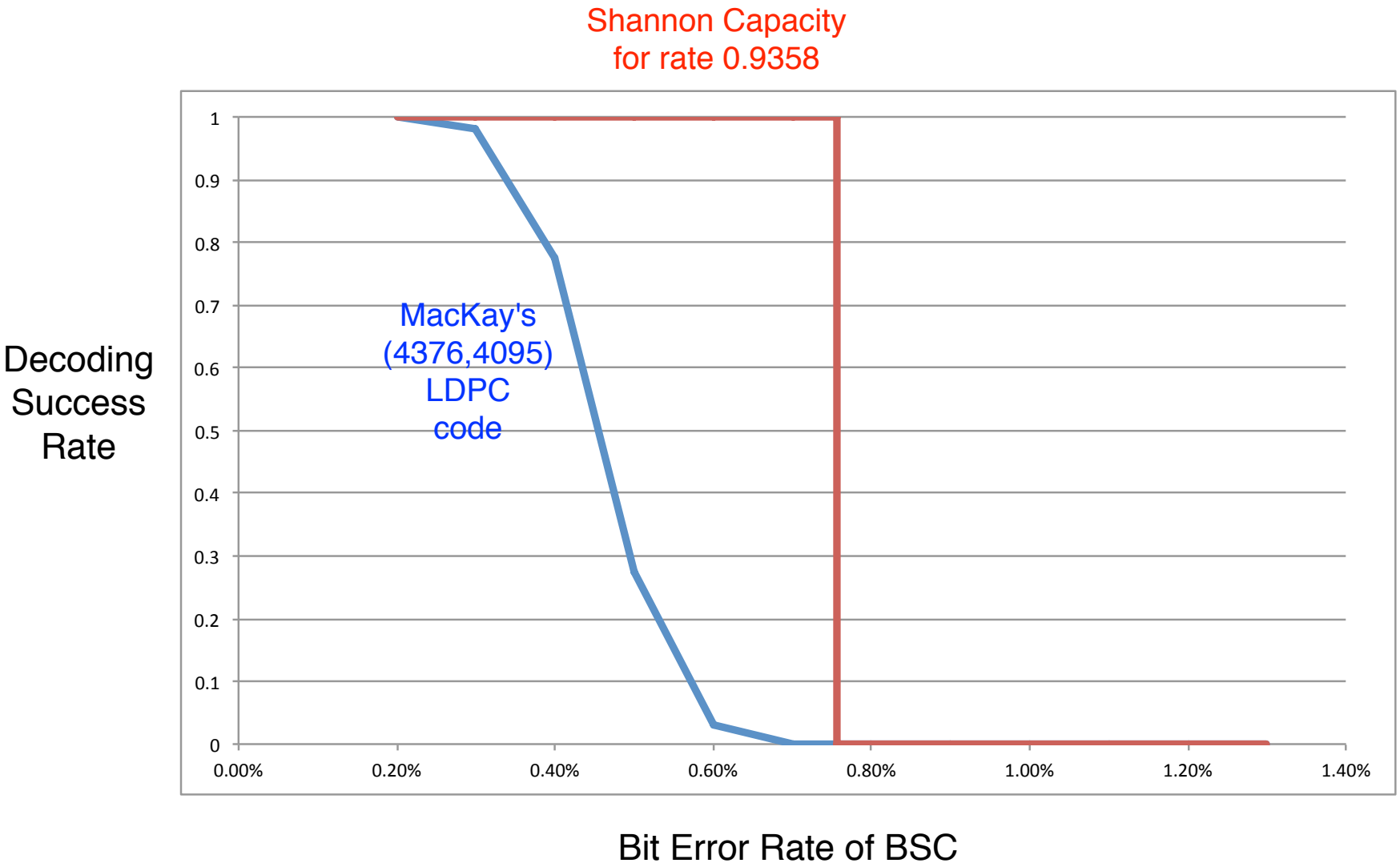
Shannon Capacity
for rate 0.9358
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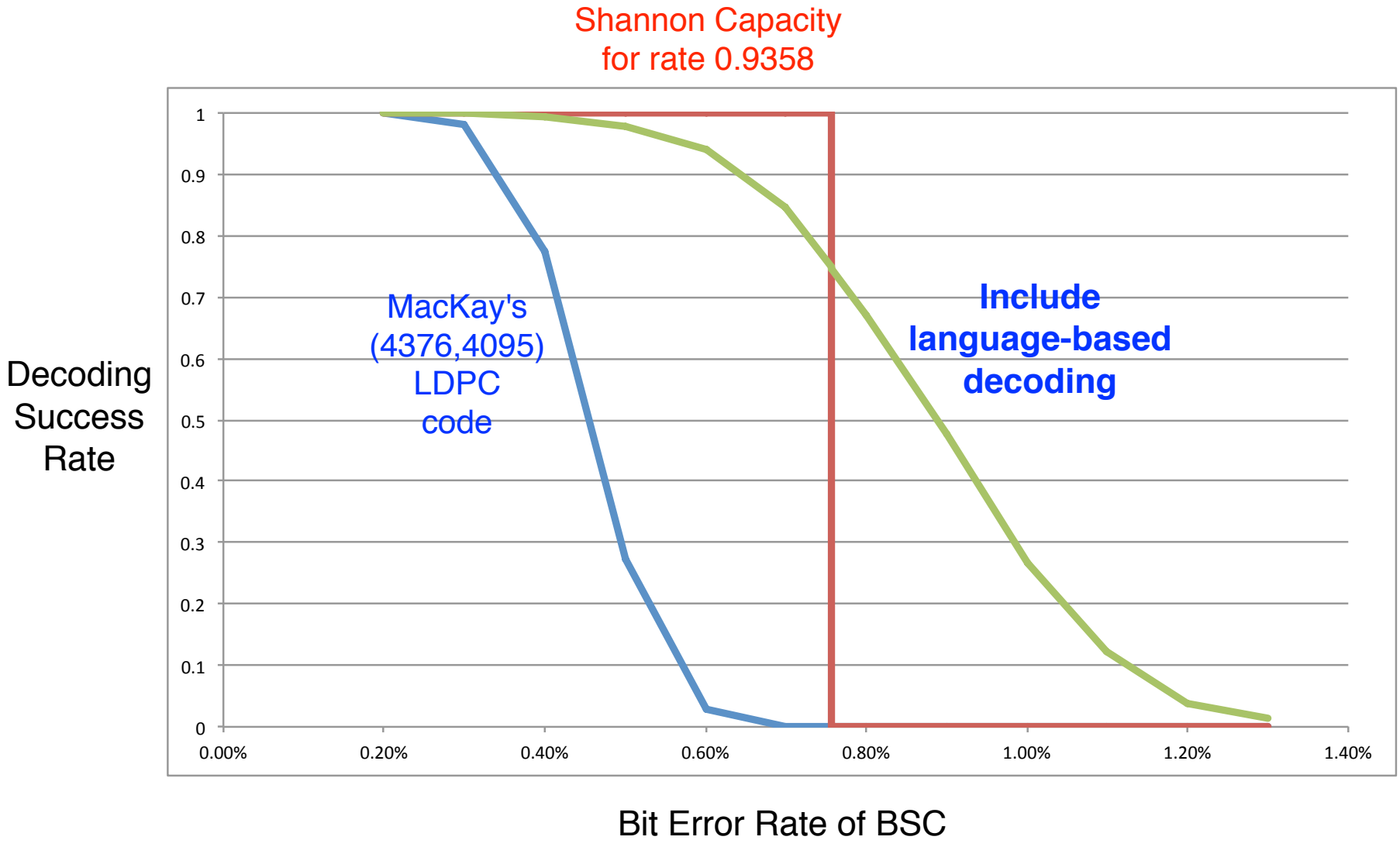
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Include
language-based
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Bit Error Rate of BSC

Does it work?

- It can be proved: If optimal codes (codes that reach Shannon capacity) are used, the required redundancy will be 3.52 times the redundancy used by the shown code.

The above decoding algorithm is based on word recognition.

Key observation:

- Valid texts are **extremely sparse**.

A Manual Example

Consider the well known paragraph by Shannon:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design.

A Manual Example

Compress it with an optimized Huffman code (for characters):

101101100001111100101101000001110010111101000001001111001010101000110000101110111001010000010001100111.....000

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Comment: 1% is a large BER for storage systems.

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Decode with Huffman code:

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Comment: Error propagation is not too bad.

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Comment: Red segments are "recognizable", black segments are "noisy segments".

A Manual Example

Number of bits	Number of errors	Number of all solutions	Number of decodable solutions	Number of "valid" solutions	"Valid" solutions
138	3	438128	373033	4	(1) th actual message is on selected (2) th actual message is one selected (3) the actual message is on selected (4) the actual message is one selected

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A Manual Example

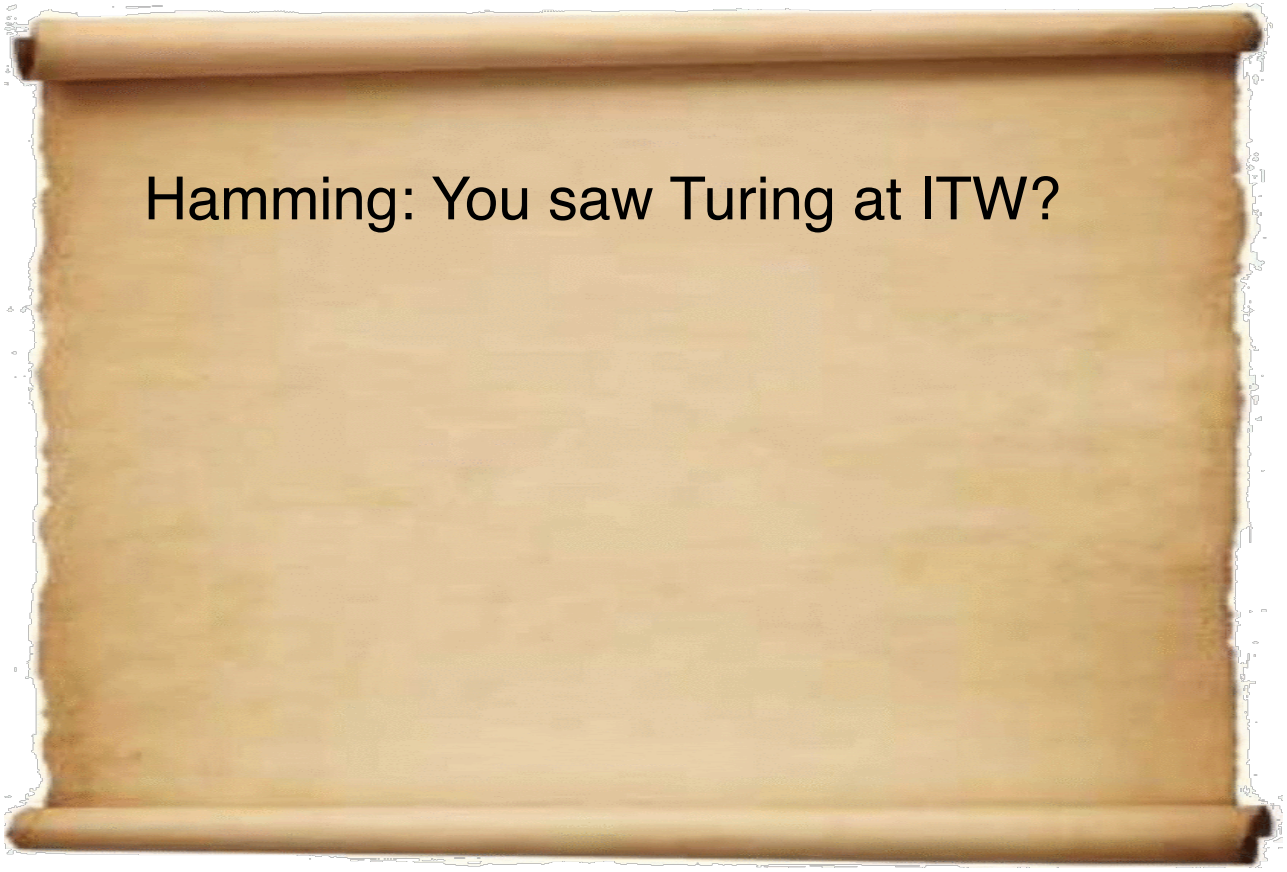
Observations:

- It is easy to recognize the correct answer for all 15 "noisy segments".
- Note that 1% is a large BER for storage systems. (Many storage systems use error-correcting codes designed for BER of 0.4% or less.) However, the noisy paragraph here has been corrected completely via human scanning without using any additional redundancy (as ECCs do).

The above decoding algorithm is based on word recognition.

More techniques at many levels:

- Grammar
- Context
- Topic
- Meaning
- Knowledge
- Logic
- ...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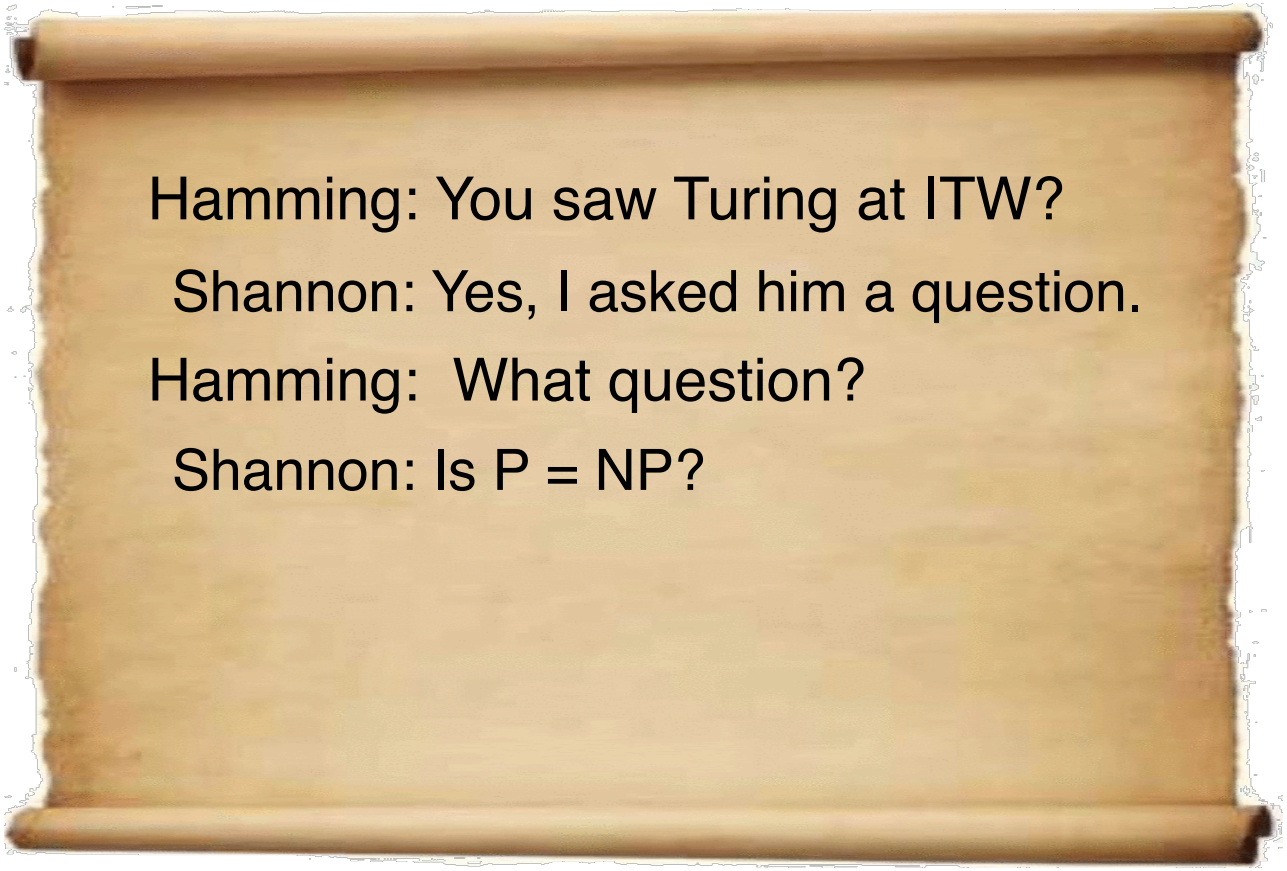
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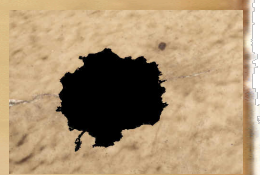

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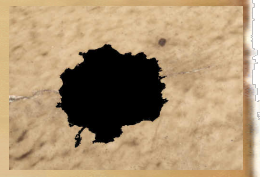
Shannon: He said the answer is 

Hint for the erasure:

1. **yes**
2. **no**