Lecture 21: Compression; Error detection and correction

- **compression: squeeze out redundancy**
  - to use less memory and/or use less network bandwidth,
  - encode the same information in fewer bits
    - some bits carry no information
    - some bits can be computed or inferred from others
    - some bits don't matter to the recipient and can be dropped entirely

- **error detection & correction: add redundancy**
  - to detect and fix up loss or damage
  - add carefully defined, systematic redundancy
  - with enough of the right redundancy,

    can detect damaged bits

    can correct errors

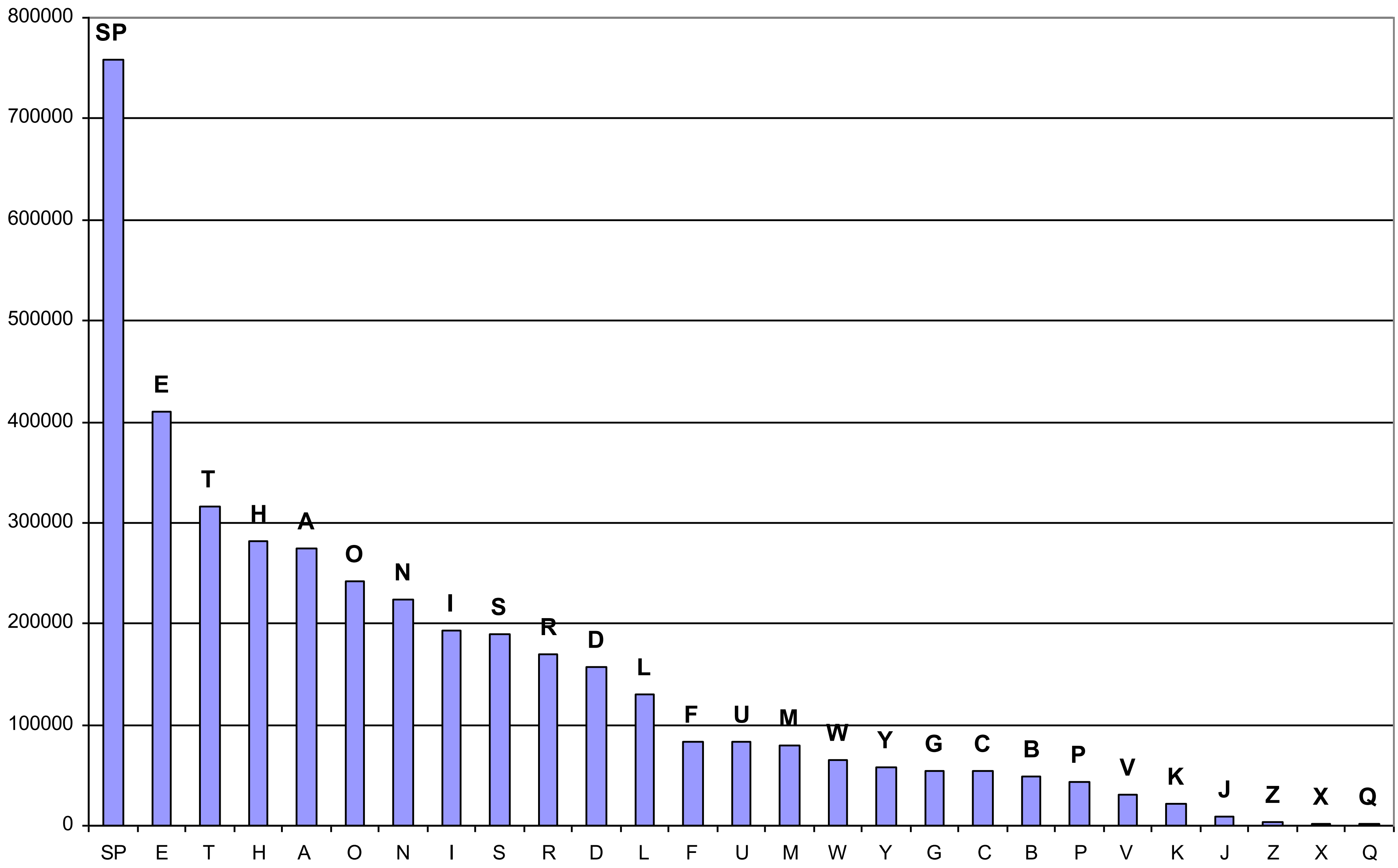
Compressing English text

- **letters do not occur equally often**
- **encode frequent letters with fewer bits,**
- **encode less frequent letters with more bits**
- **trades complexity against space**
  - e.g., Morse code, Huffman code, ...

- **run-length encoding**
  - encode runs of identical things with a count
  - e.g., World Wide Web Consortium => WWWC => W3C

- **words do not occur equally often**
- **encode whole words or phrases, not just letters**
  - e.g., abbreviations for frequent words or sequences
  - acronyms, shorthands, ...

Letter frequencies in King James bible (4.1M chars)



Lempel-Ziv coding; adaptive compression algorithms

- **build a dictionary of recently occurring data**
- **replace subsequent occurrences by (shorter) reference to the dictionary entry**
- **dictionary <u>adapts</u> as more input is seen**
  - compression adapts to properties of particular input
  - algorithm is independent of nature of input
- **dictionary is included in the compressed data**

- **Lempel-Ziv is the basis of PKZip, Winzip, gzip, GIF**
  - compresses Bible from 4.1 MB to 1.2 MB (typical for English text)

- **Lempel-Ziv is a <u>lossless</u> compression scheme**
  - compression followed by decompression reproduces the input exactly

- **lossy compression: may do better if can discard some information**
  - commonly used for pictures, sounds, movies

JPEG (Joint Photographic Experts Group) picture compression

- **a lossy compression scheme, based on how our eyes work**
- **digitize picture into pixels**
- **discard some color information (use fewer distinct colors)**
  - eye is less sensitive to color variation than to brightness
- **discard some fine detail**
  - decompressed image is not quite as sharp as original

- **use Huffman code, run-length encoding, etc., to compress resulting stream of numeric values**

- **compression is usually 10:1 to 20:1 for pictures**
- **used in web pages, digital cameras, ...**

PNG (Portable Network Graphics) compression

- **PNG is lossless**
- **PNG was always an open algorithm – no patent issues**

- **PNG versus JPG?**
  – JPG is "designed for photographic image data, which is typically dominated by soft, low-contrast transitions, and an amount of noise or similar irregular structures."
  – "Using PNG instead of a high-quality JPEG for such images would result in a large increase in filesize with negligible gain in quality."
  – "In comparison, when storing images that contain text, line art, or graphics – images with sharp transitions and large areas of solid color – the PNG format can compress image data more than JPEG can. Additionally, PNG is lossless, while JPEG produces visual artifacts around high-contrast areas."
- **"Where an image contains both sharp transitions and photographic parts, a choice must be made between the two effects."**

MPEG (Moving Picture Experts Group) movie compression

- **MPEG-4: lossy compression scheme, based on human perceptions**

- **uses JPEG for individual frames (spatial redundancy)**

- **adds compression of temporal redundancy**
  - look at image in blocks
  - if a block hasn't changed, just transmit that fact, not the content
  - if a block has moved, transmit amount of motion
  - motion prediction (encode expected differences plus correction)
  - separate moving parts from static background
  - ...

- **used in phones, DVD, TV, Internet video, video games, ...**
- **rate depends on resolution, frame rate, ...**

MP3 (MPEG Audio Layer-3) sound compression

- **movies have sound as well as motion; this is the audio part**
- **3 levels, with increasing compression, increasing complexity**
- **based on "perceptual noise shaping":**
  use characteristics of the human ear to compress better:
  - human ear can't hear some sounds (e.g., very high frequencies)
  - human ear hears some sounds better than others
  - louder sounds mask softer sounds
- **break sound into different frequency bands**
- **encode each band separately**
- **encode 2 stereo channels as 1 plus difference**

- **gives about 10:1 compression over CD-quality audio**
  - 1 MB/minute instead of 10 MB/minute
  - can trade quality against compression

Summary of compression

- **eliminate / reduce redundancy**
  - more frequent things encoded with fewer bits
  - use a dictionary of encoded things, and refer to it (Lempel-Ziv)
  - encode repetitions with a count
- **not everything can be compressed**
  - something will be bigger
- **lossless vs lossy compression**
  - lossy discards something that is not needed by recipient
- **tradeoffs**
  - encoding time and complexity vs decoding time and complexity
  - encoding is usually slower and more complicated (done once)
  - parameters in lossy compressions

    size, speed, quality

Error detection and correction

- **systematic use of redundancy to defend against errors**
- **some common numbers have no redundancy**
  - and thus can't detect when an error might have occurred
  - e.g., SSN -- any 9-digit number is potentially valid
- **if some extra data is added or if some possible values are excluded, this can be used to detect and even correct errors**
- **common examples include**
  - ATM & credit card numbers
  - ISBN for books
  - bar codes for products, mail, ...

ATM card checksum

- **credit card / ATM card checksum:**
  starting at rightmost digit:
  multiply digit alternately by 1 or 2
  if result is > 9 subtract 9
  add the resulting digits
  sum should be divisible by 10

  e.g., 12345678 is invalid
  8 + (14-9) + 6 + (10-9) + 4 + 6 + 2 + 2 = 34
  but 42345678 is valid
  8 + (14-9) + 6 + (10-9) + 4 + 6 + 2 + 8 = 40

- **defends against transpositions and many single digit errors**
  - these are the most common errors

Parity & other binary codes

- **parity bit: use one extra bit so total number of 1-bits is even**

```
0110100 => 01101001
0110101 => 01101010
```

  - detects any single-bit error

- **more elaborate codes can detect and even correct errors**

- **basic idea is to add extra bits systematically so that legal values are uniformly spread out, so any small error converts a legal value into an illegal one**
  - some schemes correct random isolated errors
  - some schemes correct bursts of errors (used in CD-ROM and DVD)

- **no error correcting code can detect/correct all errors**
  - a big enough error can convert one legal pattern into another one