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Even if we use different representations of floating point numbers

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Even if we use different ways of encoding characters

Even if we are using different programming languages that encode strings in different ways

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**Exercise** Create a plain text (`txt`) file on MacOS or Linux, and view that file on Windows using Notepad. What is happening?

Addendum May 2018: Microsoft has finally fixed this problem, after only 30 years

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The *American Standard Code for Information Interchange* (ASCII) is one standard for encoding letters, digits and various punctuation marks

However, it is not the only standard and that is precisely the problem

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$$80, 108, 97, 110$$

would be interpreted as "Plan" on an ASCII system, but "&%/ >" on an EBCDIC system

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In ASCII, the value 108 means the character 'l'

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In ASCII, the value 108 means the character 'l'

In EBCDIC, the value 108 means the character '%'

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## Philosophy

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So to make our interpretation consistent we might have to *change the bits*

But not only *how* to change them, but *when*

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Everything depends on the final interpretation of the data: this is a subtle point and is why presentation issues are often ignored or incorrectly implemented

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This means that presentation must be addressed by the programmer in their all their applications

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And programmers are still forgetting this is an issue

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On the other hand, other character sets (Chinese, Russian, Klingon, etc.) are in the ascendant, with the *Universal Coded Character Set* (UCS) plus *Unicode* being the chosen representation

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Unicode takes UCS and adds details like direction of writing (left-to-right or right-to-left or bidirectional), defining alphabetic orders, which are capital letters, and so on

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For example, é is a single character, while é is two code points: e followed by a combining character ’

2,048 code points are excluded (the surrogate values D800–DFFF for backwards compatability with UTF-16, below), so the number of representable characters (more properly: *graphemes*) is just 1,112,064

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## UCS/Unicode

And then there is the *glyph*, the visible rendering of the grapheme in some font: é and é

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Code points can be written as “U+hex”, e.g., U+C2A3 for the index of code point ’£’)

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- break the “one character is one byte” assumption many programs make
- make data files four times as large when the original data were encoded in ASCII, and
- the zero byte is often conventionally used to mean “end of string” so a value such as (hex) 12 34 00 78 is open to misinterpretation

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## UCS/Unicode

So some *encoding systems* are defined: they implement UCS but use differing numbers of bytes to encode the index into its big table of characters

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Some systems are backwardly compatible with ASCII in the sense that values 00 to 7f are the same as their ASCII equivalents

The simplest method, *Unicode Transformation Format* 32 (UTF-32, also called UCS-4), simply uses four bytes per character and embeds ASCII in UCS by merely adding three 0 bytes before every ASCII byte

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But is convenient if we are working with individual characters (rather than strings) as 32 bit values

For example, indexing into an array of characters is very easy: exactly like indexing into an array of 32-bit integers

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Thus the need for UTF-16 which uses *pairs* of UCS-2 values to extend the encoding range

UTF-16 can represent all Unicode values, but at the cost of some complexity

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- Add hex 10000 to get the UCS value

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**Exercise** Compare this to byte stuffing

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UTF-16 is quite popular in use, e.g., Java, C# and various versions of the Windows OS use it for their internal representations of strings

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The most important representation, UTF-8, represents all ASCII (7 bit) values as themselves while still being able to represent the full UCS range

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So, for example, the byte 3F in UTF-8-encoded a file encodes for UCS index 0000003F

UCS values 00000080 to 000007FF become two bytes 110xxxxx 10xxxxxx. The last 11 bits from the UCS values are copied across

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## UCS/Unicode

So '£', UCS 000000A3, binary

$$00000000\ 00000000\ 00000000\ 10100011$$

becomes 11000010 10100011 (C2A3), since

$$00010/100011 \rightarrow 110/0010\ 10/100011$$

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becomes 11000010 10100011 (C2A3), since

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And thus the *two* bytes C2A3 in a file encode the UCS index 000000A3

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## UCS/Unicode

Generally we can encode:

| UCS range (hex) | Encoding (binary) |
|---|---|
| 00000000-0000007F | 0xxxxxxx |
| 00000080-000007FF | 110xxxxx 10xxxxxx |
| 00000800-0000FFFF | 1110xxxx 10xxxxxx 10xxxxxx |
| 00010000-001FFFFF | 11110xxx 10xxxxxx 10xxxxxx 10xxxxxx |
| 00200000-03FFFFFF | 111110xx 10xxxxxx 10xxxxxx 10xxxxxx 10xxxxxx |
| 04000000-7FFFFFFF | 1111110x 10xxxxxx 10xxxxxx 10xxxxxx 10xxxxxx 10xxxxxx |

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So only the first four rows of the table

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## UCS/Unicode

| Unicode range (hex) | Encoding (binary) |
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An ASCII file is already a UTF-8 file and there is no expansion of data when regarding it as UCS

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- All UCS values can be encoded
- The comparison order of UCS is preserved

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- UTF-16 comes in big (UTF-16BE) and little endian (UTF-16LE) variants as well as plain UTF-16, when files can employ a special *byte order mark* (BOM, U+FEFF) at their start to establish order

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## UCS/Unicode

- UTF-16 does not preserve UCS comparison order
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- UTF-16 comes in big (UTF-16BE) and little endian (UTF-16LE) variants as well as plain UTF-16, when files can employ a special *byte order mark* (BOM, U+FEFF) at their start to establish order
- UTF-32 is big endian

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## UCS/Unicode

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- As they are variable length encodings, neither UTF-8 nor UTF-16 allow indexing directly into a string

The advantages of UTF-8 are such that UTF-16 should be retired, but this may take some time

# Presentation

## UCS/Unicode

**Exercise** Have a look at how (or if) your favourite programming language supports UCS or Unicode. E.g., C programmers have `wchar_t`

**Exercise** A typical programming language has variables syntax that “start with a letter, then letters and digits”. How would this work in Unicode?

**Exercise** Read about the *Punycode* encoding

**Exercise** Unicode is split into 17 *planes*. Read about this