Referencing the Unicode Standard

Abstract

We propose to reference the Unicode Standard instead of ISO 10646. This proposal has no impact on implementations.

Revisions

R0

Initial revision

Motivation

Unicode is developed as The Unicode Standard by The Unicode Consortium. From that is derived the ISO 10446 standard. However, Unicode has a much larger scope as it describes algorithms for normalization, clusterization, comparison, case transformation, bi-directional text handling, and more. C++ makes use of these features.

As such, in the current state, we reference ISO 10646 and Unicode, and the Unicode annexes. Care must be taken that the versions referenced are coherent as Unicode algorithms are designed to work with a matching specification and accompanying Unicode data. This is challenging as Unicode and ISO 10646 have different release cycles.

Additionally, there are subtle differences in terminology, the main impact of which is to consume time in study groups. It is also an issue for implementers who usually reference Unicode directly as Unicode delivers the necessary Unicode data in an easily extractible and toolable format (whereas ISO 10646 is just a PDF).

By referring to a single Unicode Standard, we can reduce the number of references that we have to maintain (and thereby the number of dependencies the standard carries), as well as making the standard clearer.

Difference between Unicode and ISO 10646

The Unicode standard explains:
The Unicode Consortium maintains a strong working relationship with ISO/IEC JTC1/SC2/WG2, the working group developing International Standard 10646. Today both organizations are firmly committed to maintaining the synchronization between the Unicode Standard and ISO/IEC 10646. Each standard nevertheless uses its own form of reference and, to some degree, separate terminology.

ISO/IEC 10646:2011 has significantly revised its discussion of encoding forms, compared to earlier editions of that standard. The terminology for encoding forms (and encoding schemes) in 10646 now matches exactly the terminology used in the Unicode Standard. Furthermore, 10646 is now described in terms of a codespace U+0000..U+10FFFF, instead of a 31-bit codespace, as in earlier editions. This convergence in codespace description has eliminated any discrepancies in possible interpretation of the numeric values greater than 0x10FFFF.

As such, the definition of UTF-8, UTF-16, and UTF-32, as well as the set of supported abstract characters and their code point value is the same. Most of the terminology changes operated consist of replacing "UCS" with "Unicode".

There are, however, a few points to mention.

ISO 10646 defines “character” as

member of a set of elements used for the organization, control, or representation of textual data Note 1 to entry – A graphic symbol can be represented by a sequence of one or several coded characters.

Unicode defines instead “abstract character”

A unit of information used for the organization, control, or representation of textual data.

This is a positive change as the term character is both defined by the C++ standard and constantly misused. in the long term, having a term to talk about an abstract character when we mean it is a positive change.

Conformance with Unicode

Unicode specifies a list of conformance requirements (Chapter 3.2)

- C1: A process shall not interpret a high-surrogate code point or a low-surrogate code point as an abstract character.
  C++ satisfies this requirement.
- C2: A process shall not interpret a noncharacter code point as an abstract character
- C3: A process shall not interpret an unassigned code point as an abstract character.
We create characters out of thin air for specifying the translation set. However, we never exchange or materialize, or use these things except for specification purposes.

- **C4:** A process shall interpret a coded character sequence according to the character semantics established by this standard if that process does interpret that coded character sequence.
- **C4:** A process shall not assume that it is required to interpret any particular coded character sequence.
- **C6:** A process shall not assume that the interpretations of two canonical-equivalent character sequences are distinct
- **C7:** When a process purports not to modify the interpretation of a valid coded character sequence, it shall make no change to that coded character sequence other than the possible replacement of character sequences by their canonical-equivalent sequences.

C++ satisfies these requirements.

- **C8:** When a process interprets a code unit sequence which purports to be in a Unicode character encoding form, it shall interpret that code unit sequence according to the corresponding code point sequence.
- **C9:** When a process generates a code unit sequence which purports to be in a Unicode character encoding form, it shall not emit ill-formed code unit sequences.

C++ satisfies these requirements.

- **C10:** When a process interprets a code unit sequence which purports to be in a Unicode character encoding form, it shall treat ill-formed code unit sequences as an error condition and shall not interpret such sequences as characters.

C++ satisfies this requirement, arguably. The C functions do behave weirdly in the presence of invalid code units, but do they actually purports to support Unicode if they don't support multi bytes encodings?

- **C11:** When a process interprets a byte sequence which purports to be in a Unicode character encoding scheme, it shall interpret that byte sequence according to the byte order and specifications for the use of the byte order mark established by this standard for that character encoding scheme.

I think we do.

- **C14:** A process that tests Unicode text to determine whether it is in a Normalization Form shall do so in accordance with the specifications in Section 3.11, Normalization Forms.
- **C16:** Normative references to the Unicode Standard itself, to property aliases, to property value aliases, or to Unicode algorithms shall follow the formats specified in Section 3.1, Versions of the Unicode Standard.

This requirement should be satisfied with the adoption of this paper. Care must be taken when referencing properties.
• C17: Higher-level protocols shall not make normative references to provisional properties. Higher-level protocols may make normative references to informative properties.

• C17: If a process purports to implement a Unicode algorithm, it shall conform to the specification of that algorithm in the standard, including any tailoring by a higher-level protocol as permitted by the specification.

Yes.

Omitted requirements are not applicable.

Terminology

• D4 Character name: A unique string used to identify each abstract character encoded in the standard.

• D5 Character name alias: An additional unique string identifier, other than the character name, associated with an encoded character in the standard.

• D7 Abstract character: A unit of information used for the organization, control, or representation of textual data.

• D10 Code point: Any value in the Unicode codespace.

• D11 Encoded character: An association (or mapping) between an abstract character and a code point.

• D76 Unicode scalar value: Any Unicode code point except high-surrogate and low-surrogate code points.

• D77 Code unit: The minimal bit combination that can represent a unit of encoded text for processing or interchange.

• D78 Code unit sequence: An ordered sequence of one or more code units.

• D79 A Unicode encoding form assigns each Unicode scalar value to a unique code unit sequence.

• D94 Unicode encoding scheme: A specified byte serialization for a Unicode encoding form, including the specification of the handling of a byte order mark (BOM), if allowed.

• D16 Higher-level protocol: Any agreement on the interpretation of Unicode characters that extends beyond the scope of this standard

Character names

Consistently referring to Unicode resolves the observation made by NB comment FR-021-01 that the set of character that can be spelled by named escape sequences \N{ } was, in the standard, a subset of the set of code point with the XID_Continue or XID_Start properties, as the names were derived from ISO and the list of eligible code points from Unicode.
This macro, defined in [cpp] was the most difficult change. Indeed its \texttt{yyyymm} is supposed to refer to the publication date of an ISO1646 revision. Here is the thing though. Past discussions in LLVM and the WG14 reflector have established that the wide execution encoding may depend on the C library, and that macro is therefore defined by the C library. On some platforms, the \texttt{wchar\_t} is actually a runtime property, such that the use of a macro is not suitable.

In addition, its value is not always updated and doesn't indicate much. Indeed, all ISO1646 publications require a 4 bytes \texttt{wchar\_t} for the storing of code points.

Therefore, we change the wording of that macro to state that its value is implementation-defined, such that we do not have to reference ISO10646 and reword it slightly.

Further work is encouraged to maybe deprecate this macro. Inspecting a large amount of open source code, the only use of the value we found was (\texttt{\_STDC\_ISO\_10646\_ \textless\textless 198700L}). Of course, there are numerous uses of the macro for its presence.

Note that we don't expect implementers to change the value of that macro, but it lets us not mention ISO 10646 there

**Removing the reference to ISO1646:2003**

The deprecated \texttt{codecvt\_utf8} and \texttt{codecvt\_utf16} refers to UCS-2. Because this has long been obsoleted and removed from ISO 10646, we carry a dependency on ISO 10646:2003.

But, UCS-2 is a strict subset of UTF-16. So we reword the appropriate paragraph to say "code points in the range U+0000-U+FFFF encoded as UTF-16" instead.

Any code point outside that range doesn't satisfy that requirement, and therefore cannot be encoded and causes the conversion to fail with \texttt{result::error}, preserving the existing behavior.

**Non-Normative reference to UAX #29, Unicode Text Segmentation**

Revision 35 (Unicode 12) -> Revision 41 (Unicode 15)

This is used in [format.string.std] for the purpose of width estimation. The only non-editorial applicable change in that document between that version and the last were

- Moved surrogate code points from Control to XX
- Excluded prepended concatenation marks from Control.

Both are bug fixes. Referencing version 15 ensures that the width of recent code points can be correctly estimated. Some implementations refer to Unicode 15 already.

Once we can use the same version, we can remove the reference entirely, as unicode mentions
This core specification, together with the Unicode code charts, the Unicode Character Database, and the Unicode Standard Annexes, defines the Unicode Standard. The Unicode Standard Annexes form an integral part of the Unicode Standard.

Non-Normative reference to UAX #31

Left untouched, someone needs to go through the UAX31 Annex in the C++ standard to ensure consistency. Given this UAX is changing a lot to support source code spoofing mitigation over the next year, we may consider delaying that work? If we do decided to delay that work, we should make sure UAX31 constantly refer to the referenced version in the annex.

Wording

Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- ISO/IEC 2382, Information technology — Vocabulary
- ISO 8601:2004, Data elements and interchange formats — Information interchange — Representation of dates and times
- ISO/IEC 10646, Information technology — Universal Coded Character Set (UCS)
- ISO/IEC 10646:2003, Information technology — Universal Multiple-Octet Coded Character Set (UCS)
- ISO 80000-2:2009, Quantities and units — Part 2: Mathematical signs and symbols to be used in the natural sciences and technology
The library described in ISO/IEC 9899:2018, Clause 7, is hereinafter called the C standard library.

The operating system interface described in ISO/IEC 9945:2009 is hereinafter called POSIX.

The ECMAScript Language Specification described in Standard Ecma-262 is hereinafter called ECMA-262.

[Note: References to ISO/IEC 10646:2003 are used only to support deprecated features. — end note]

[...]

Phases of translation

The precedence among the syntax rules of translation is specified by the following phases. Implementations behave as if these separate phases occur, although in practice different phases can be folded together.

1. An implementation shall support input files that are a sequence of UTF-8 code units (UTF-8 files). It may also support an implementation-defined set of other kinds of input files, and, if so, the kind of an input file is determined in an implementation-defined manner that includes a means of designating input files as UTF-8 files, independent of their content. [Note: In other words, recognizing the U+feff byte order mark is not sufficient. — end note] If an input file is determined to be a UTF-8 file, then it shall be a well-formed UTF-8 code unit sequence and it is decoded to produce a sequence of UCS Unicode scalar values that constitutes the sequence of elements of the translation character set.

For any other kind of input file supported by the implementation, characters are mapped, in an implementation-defined manner, to a sequence of translation character set elements (introducing new-line characters for end-of-line indicators).
The translation character set consists of the following elements:

- each abstract character named by ISO/IEC 10646, as identified by its unique UCS scalar value assigned a code point in the Unicode codespace, and
- a distinct character for each UCS Unicode scalar value where no named character is assigned not assigned to an abstract character.

[Note: ISO/IEC 10646 Unicode code points are integers in the range \([0, 10FFFF]\) (hexadecimal). A surrogate code point is a value in the range \([\text{D800}, \text{DFFF}]\) (hexadecimal). A UCS Unicode scalar value is any code point that is not a surrogate code point. — end note]

The basic character set is a subset of the translation character set, consisting of 96 characters as specified in . [Note: Unicode short names are given only as a means to identifying the character; the numerical value has no other meaning in this context. — end note]

The universal-character-name construct provides a way to name other characters.

\[
n\text{-char: one of } \quad \text{A B C D E F G H I J K L M N O P Q R S T U V W X Y Z} \quad 0 1 2 3 4 5 6 7 8 9 \\
\text{u}\text{+002} \quad \text{u}\text{+0020}
\]

\[
n\text{-char-sequence:} \\
n\text{-char} \\
n\text{-char-sequence } n\text{-char}
\]

\[
n\text{named-universal-character:} \\
\text{\N{ }n\text{-char-sequence } }
\]

\[
\text{hex-quad:} \\
\text{hexadecimal-digit hexadecimal-digit hexadecimal-digit hexadecimal-digit}
\]

\[
\text{simple-hexadecimal-digit-sequence:} \\
\text{hexadecimal-digit} \\
\text{simple-hexadecimal-digit-sequence } \text{hexadecimal-digit}
\]

\[
\text{universal-character-name:} \\
\text{\u } \text{hex-quad} \\
\text{\U } \text{hex-quad hex-quad} \\
\text{\u{ }simple-hexadecimal-digit-sequence } \\
\text{named-universal-character}
\]

A universal-character-name of the form \(\text{\u } \text{hex-quad}, \text{\U } \text{hex-quad hex-quad}, \text{or } \text{\u{ }simple-hexadecimal-digit-sequence } \) designates the character in the translation character set whose UCS Unicode scalar value is the hexadecimal number represented by the sequence of hexadecimal-digits in the universal-character-name. The program is ill-formed if that number is not a UCS Unicode scalar value.

A universal-character-name that is a named-universal-character designates the character named by its n-char-sequence. A character is so named if the n-char-sequence is equal to
Table 1: Basic character set

<table>
<thead>
<tr>
<th>character</th>
<th>glyph</th>
</tr>
</thead>
<tbody>
<tr>
<td>u+0009</td>
<td>character tabulation</td>
</tr>
<tr>
<td>u+000b</td>
<td>line tabulation</td>
</tr>
<tr>
<td>u+000c</td>
<td>form feed</td>
</tr>
<tr>
<td>u+0020</td>
<td>space</td>
</tr>
<tr>
<td>u+002a</td>
<td>line feed</td>
</tr>
<tr>
<td>u+0021</td>
<td>exclamation mark</td>
</tr>
<tr>
<td>u+0022</td>
<td>quotation mark</td>
</tr>
<tr>
<td>u+0023</td>
<td>number sign</td>
</tr>
<tr>
<td>u+0024</td>
<td>percent sign</td>
</tr>
<tr>
<td>u+0026</td>
<td>ampersand</td>
</tr>
<tr>
<td>u+0027</td>
<td>apostrophe</td>
</tr>
<tr>
<td>u+0028</td>
<td>left parenthesis</td>
</tr>
<tr>
<td>u+0029</td>
<td>right parenthesis</td>
</tr>
<tr>
<td>u+002a</td>
<td>asterisk</td>
</tr>
<tr>
<td>u+002b</td>
<td>plus sign</td>
</tr>
<tr>
<td>u+002c</td>
<td>comma</td>
</tr>
<tr>
<td>u+002d</td>
<td>hyphen-minus</td>
</tr>
<tr>
<td>u+002e</td>
<td>full stop</td>
</tr>
<tr>
<td>u+002f</td>
<td>solidus</td>
</tr>
<tr>
<td>u+0030 ..</td>
<td>digit zero .. nine</td>
</tr>
<tr>
<td>u+0031</td>
<td>colon</td>
</tr>
<tr>
<td>u+0032</td>
<td>semicolon</td>
</tr>
<tr>
<td>u+0033</td>
<td>less-than sign</td>
</tr>
<tr>
<td>u+0034</td>
<td>equals sign</td>
</tr>
<tr>
<td>u+0035</td>
<td>greater-than sign</td>
</tr>
<tr>
<td>u+0036</td>
<td>question mark</td>
</tr>
<tr>
<td>u+0041 ..</td>
<td>latin capital letter a .. z</td>
</tr>
<tr>
<td>u+0042</td>
<td>left square bracket</td>
</tr>
<tr>
<td>u+0043</td>
<td>reverse solidus</td>
</tr>
<tr>
<td>u+0044</td>
<td>right square bracket</td>
</tr>
<tr>
<td>u+0045</td>
<td>circumflex accent</td>
</tr>
<tr>
<td>u+0046</td>
<td>low line</td>
</tr>
<tr>
<td>u+0061 ..</td>
<td>latin small letter a .. z</td>
</tr>
<tr>
<td>u+0062</td>
<td>left curly bracket</td>
</tr>
<tr>
<td>u+0063</td>
<td>vertical line</td>
</tr>
<tr>
<td>u+0064</td>
<td>right curly bracket</td>
</tr>
<tr>
<td>u+0065</td>
<td>tilde</td>
</tr>
</tbody>
</table>
• the associated character name or associated character name alias its character name, as specified in The Unicode Standard (chapter 4.8 Name) specified in ISO/IEC 10646 subclause ‘Code charts and lists of character names’ or

• the control code alias given in [lex.charset.ucn]. [Note: The aliases in [lex.charset.ucn] are provided for control characters which otherwise have no associated character name or character name alias. These names are derived from the Unicode Character Database’s NameAliases.txt. For historical reasons, control characters are formally unnamed. — end note]

one of its character name aliases as specified in The Unicode Standard (chapter 4.8 Name), if that character name alias is of type “control”, “correction”, or “alternate”.

[Note: None of the associated Unicode character names, associated Unicode character name aliases, or control code aliases have leading or trailing spaces. — end note]

[Editor’s note: Remove the table “Table 2: Control code aliases [tab:lex.charset.ucn]”]

If a universal-character-name outside the c-char-sequence, s-char-sequence, or r-char-sequence of a character-literal or string-literal (in either case, including within a user-defined-literal) corresponds to a control character or to a character in the basic character set, the program is ill-formed. [Note: A sequence of characters resembling a universal-character-name in an r-char-sequence does not form a universal-character-name. — end note]

The basic literal character set consists of all characters of the basic character set, plus the control characters specified in . [Note: The alias bell for u+0007 shown in ISO 10646 the Unicode Standard is ambiguous with u+1f514 bell. — end note]

Table 2: Additional control characters in the basic literal character set

<table>
<thead>
<tr>
<th>character</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>u+0000</td>
<td>null</td>
</tr>
<tr>
<td>u+0007</td>
<td>alert</td>
</tr>
<tr>
<td>u+0008</td>
<td>backspace</td>
</tr>
<tr>
<td>u+000d</td>
<td>carriage return</td>
</tr>
</tbody>
</table>

A code unit is an integer value of character type. Characters in a character-literal other than a multicharacter or non-encodable character literal or in a string-literal are encoded as a sequence of one or more code units, as determined by the encoding-prefix; this is termed the respective literal encoding. The ordinary literal encoding is the encoding applied to an ordinary character or string literal. The wide literal encoding is the encoding applied to a wide character or string literal.

A literal encoding or a locale-specific encoding of one of the execution character sets encodes each element of the basic literal character set as a single code unit with non-negative value, distinct from the code unit for any other such element. [Note: A character not in the basic literal character set can be encoded with more than one code unit; the value of such a code unit can be the same as that of a code unit for an element of the basic literal character set. — end note] The u+0000 null character is encoded as the value 0. No other element of the translation character set is encoded with a code unit of value 0. The code unit value of each
The character classes XID_Start and XID_Continue are Derived Core Properties as described by UAX #44. The program is ill-formed if an identifier does not conform to Normalization Form C as specified in ISO/IEC 10646 The Unicode Standard. [Note: Identifiers are case-sensitive. — end note] [Note: In translation phase 4, identifier also includes those preprocessing-token s differentiated as keywords in the later translation phase 7. — end note]

Evaluating a string-literal results in a string literal object with static storage duration. Whether all string-literal s are distinct (that is, are stored in nonoverlapping objects) and whether successive evaluations of a string-literal yield the same or a different object is unspecified. [Note: The effect of attempting to modify a string literal object is undefined. — end note]
String literal objects are initialized with the sequence of code unit values corresponding to the string-literal's sequence of s-char s (originally from non-raw string literals) and r-char s (originally from raw string literals), plus a terminating u+0000 null character, in order as follows:

- The sequence of characters denoted by each contiguous sequence of basic-s-char s, r-char s, simple-escape-sequence s, and universal-character-name s is encoded to a code unit sequence using the string-literal's associated character encoding. If a character lacks representation in the associated character encoding, then the string-literal is conditionally-supported and an implementation-defined code unit sequence is encoded. [Note: No character lacks representation in any of the \textit{UCS} Unicode encoding forms. — end note] When encoding a stateful character encoding, implementations should encode the first such sequence beginning with the initial encoding state and encode subsequent sequences beginning with the final encoding state of the prior sequence. [Note: The encoded code unit sequence can differ from the sequence of code units that would be obtained by encoding each character independently. — end note]

⚠️ Predefined macro names [cpp.predefined]

- \texttt{__STDC\_VERSION\_}
  Whether \texttt{__STDC\_VERSION\_} is predefined and if so, what its value is, are implementation-defined.

- \texttt{__STDC\_ISO\_10646\_}
  An integer literal of the form $yyyymmL$ (for example, 199712L). If this symbol is defined, then every character in the Unicode required set, when stored in an object of type \texttt{wchar\_t}, has the same value as the code point of that character. The \textit{Unicode required set} consists of all the characters that are defined by ISO/IEC 10646, along with all amendments and technical corrigenda as of the specified year and month. Unicode code point can be stored as a single object of type \texttt{wchar\_t}.
  The specified year and month are implementation-defined.

[Editor's note: —— Library wording below ——]

⚠️ Formatting escaped characters and strings [format.string.escaped]

A character or string can be formatted as escaped to make it more suitable for debugging or for logging.

The escaped string $E$ representation of a string $S$ is constructed by encoding a sequence of characters as follows. The associated character encoding $CE$ for $\texttt{char\_T()}$ is used to both interpret $S$ and construct $E$.

- $u+0022$ quotation mark (") is appended to $E$.
- For each code unit sequence $X$ in $S$ that either encodes a single character, is a shift sequence, or is a sequence of ill-formed code units, processing is in order as follows:
- If \( X \) encodes a single character \( C \), then:
  
  ★ If \( C \) is one of the characters in \( \), then the two characters shown as the corresponding escape sequence are appended to \( E \).
  
  ★ Otherwise, if \( C \) is not \( \text{u+0020} \) space and

  - \( CE \) is a Unicode encoding and \( C \) corresponds to either a UCS scalar value whose Unicode property General_Category has a value in the groups Separator (\( Z \)) or Other (\( C \)) or to a UCS scalar value whose Unicode property Grapheme_Extend=Yes, as described by table 12 of UAX #44, or

  - \( CE \) is not a Unicode encoding and \( C \) is one of an implementation-defined set of separator or non-printable characters

    then the sequence \( \backslash u\{\text{hex-digit-sequence}\} \) is appended to \( E \), where \( \text{hex-digit-sequence} \) is the shortest hexadecimal representation of \( C \) using lower-case hexadecimal digits.

  ★ Otherwise, \( C \) is appended to \( E \).

- Otherwise, if \( X \) is a shift sequence, the effect on \( E \) and further decoding of \( S \) is unspecified.

  *Recommended practice*: A shift sequence should be represented in \( E \) such that the original code unit sequence of \( S \) can be reconstructed.

- Otherwise (\( X \) is a sequence of ill-formed code units), each code unit \( U \) is appended to \( E \) in order as the sequence \( \backslash x\{\text{hex-digit-sequence}\} \), where \( \text{hex-digit-sequence} \) is the shortest hexadecimal representation of \( U \) using lower-case hexadecimal digits.

  - Finally, \( \text{u+0022} \) quotation mark (" ) is appended to \( E \).

[...]

\* Print

[ostream.formatted.print]

[...]

```cpp
void vprint_unicode(ostream& os, string_view fmt, format_args args);
void vprint_nonunicode(ostream& os, string_view fmt, format_args args);
```

*Effects*: Behaves as a formatted output function of \( os \), except that:

- failure to generate output is reported as specified below, and

- any exception thrown by the call to \( vformat \) is propagated without regard to the value of \( os \).exceptions() and without turning on \( \text{ios_base::badbit} \) in the error state of \( os \).

After constructing a \( \text{sentry} \) object, the function initializes an automatic variable via
string out = vformat(os.getloc(), fmt, args);

If the function is vprint_unicode and os is a stream that refers to a terminal capable of displaying Unicode which is determined in an implementation-defined manner, writes out to the terminal using the native Unicode API; if out contains invalid code units, the behavior is undefined and implementations are encouraged to diagnose it. Otherwise (if os is not such a stream or the function is vprint_nonunicode), inserts the character sequence [out.begin(), out.end()] into os. If writing to the terminal or inserting into os fails, calls os.setstate(ios_base::badbit) (which may throw ios_base::failure).

**Recommended practice:** For vprint_unicode, if invoking the native Unicode API requires transcoding, implementations should substitute invalid code units with u+fffd replacement character per The Unicode Standard *Version 14.0—Core Specification*, Chapter 3.9 U+FFFD Substitution in Conversion.

```cpp
void vprint_unicode(FILE* stream, string_view fmt, format_args args);
```

**Preconditions:** stream is a valid pointer to an output C stream.

**Effects:** The function initializes an automatic variable via

```cpp
string out = vformat(fmt, args);
```

If stream refers to a terminal capable of displaying Unicode, writes out to the terminal using the native Unicode API; if out contains invalid code units, the behavior is undefined and implementations are encouraged to diagnose it. Otherwise writes out to stream unchanged. [*Note:* On POSIX and Windows, stream referring to a terminal means that, respectively, `isatty(fileno(stream))` and `GetConsoleMode(_get_osfhandle(_fileno(stream)), ...) return nonzero. — end note*] [*Note:* On Windows, the native Unicode API is `WriteConsoleW`. — end note]

**Throws:** Any exception thrown by the call to vformat. system_error if writing to the terminal or stream fails. May throw bad_alloc.

**Recommended practice:** If invoking the native Unicode API requires transcoding, implementations should substitute invalid code units with u+fffd replacement character per The Unicode Standard *Version 14.0—Core Specification*, Chapter 3.9 U+FFFD Substitution in Conversion.
- `Elem` is the wide-character type, such as `wchar_t`, `char16_t`, or `char32_t`.

- `Maxcode` is the largest wide-character code that the facet will read or write without reporting a conversion error.

- If `(Mode & consume_header)`, the facet shall consume an initial header sequence, if present, when reading a multibyte sequence to determine the endianness of the subsequent multibyte sequence to be read.

- If `(Mode & generate_header)`, the facet shall generate an initial header sequence when writing a multibyte sequence to advertise the endianness of the subsequent multibyte sequence to be written.

- If `(Mode & little_endian)`, the facet shall generate a multibyte sequence in little-endian order, as opposed to the default big-endian order.

For the facet `codecvt_utf8`:

- The facet shall convert between UTF-8 multibyte sequences and `UCS-2` or `UTF-32` (depending on the size of `Elem`) within the program.
  - Code points in the range U+0000-U+FFFF (Basic Multilingual Plane) encoded as UTF-16 or,
  - UTF-32.

- Endianness shall not affect how multibyte sequences are read or written.

- The multibyte sequences may be written as either a text or a binary file.

For the facet `codecvt_utf16`:

- The facet shall convert between UTF-16 multibyte sequences and `UCS-2` or `UTF-32` (depending on the size of `Elem`) within the program.
  - Code points in the range U+0000-U+FFFF (Basic Multilingual Plane) encoded as UTF-16 or,
  - UTF-32.

- Multibyte sequences shall be read or written according to the `Mode` flag, as set out above.

- The multibyte sequences may be written only as a binary file. Attempting to write to a text file produces undefined behavior.

For the facet `codecvt_utf8_utf16`:

- The facet shall convert between UTF-8 multibyte sequences and UTF-16 (one or two 16-bit codes) within the program.

- Endianness shall not affect how multibyte sequences are read or written.

- The multibyte sequences may be written as either a text or a binary file.

The encoding forms UTF-8, UTF-16, and UTF-32 are specified in ISO/IEC 10646. The encoding form UCS-2 is specified in ISO/IEC 10646:2003.
Bibliography

— ISO 4217:2015, Codes for the representation of currencies


[Editor's note: Referencing Unicode encompasses the annexes and the motivation explains that we can and should reference the version of the annex that correspond to the Unicode Standard]


— IANA Time Zone Database. Available from: https://www.iana.org/time-zones


The arithmetic specification described in ISO/IEC 10967-1:2012 is called LIA-1 in this document.

References

[N4892] Thomas Köppe Working Draft, Standard for Programming Language C++
https://wg21.link/N4892