Proposal for C2Y
WG14 N3731

Title:	Range bounds for math functions
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Background

In email to CFP, Trevor Gross asked whether library functions are allowed to produce values outside the range of the corresponding mathematical function. In follow-up email, Paul Zimmermann pointed out that rounding is an issue, and that even correct rounding can yield a result that is outside the range of the mathematical function in cases where the range has an endpoint that is not representable in the format. However, specification of some functions in C 7.12 state that the function returns a value in such an interval. For example, 7.12.5.2 #3 says

> The `asin` functions return arcsin *x* in the interval [−π/2, +π/2] radians.

This issue also pertains in

> 7.12.5.1 The `acos` functions
> 7.12.5.3 The `atan` functions
> 7.12.5.4 The `atan2` functions

We know of no other cases where a C requirement is incompatible with correct rounding.

ISO/IEC 60559 https://wiki.edg.com/pub/CFP/WebHome/754-2019.pdf requires its operations to be correctly rounded, and does not require mathematical properties that correct rounding would violate. Regarding its operations **atan** and **atan2** whose unrounded ranges are [−π/2, +π/2] and [−π, +π] it notes (9.2.1):

> For some formats under some rounding attributes the rounded magnitude range of **atan** (**atan2**) might exceed the unrounded magnitude of π/2 (π). A programmer must then take care to properly handle any anomalous manifold jump that might occur under the inverse operation.

This all argues for removing the range requirements, which is the purpose of the suggested changes below.

The suggested changes do not invalidate any implementations. Correct rounding for the relevant functions remains not required and implementations are still allowed to adhere to the range requirements removed by the changes.

Suggested Changes

In 7.12.5.1 #2 and #3 change:

> **Description**
> The `acos` functions compute the principal value of the arc cosine of *x*. …
>
> **Returns**
> The `acos` functions return arccos *x* ~~in the interval [0, π] radians~~.

to:

> **Description**
> The `acos` functions compute the principal value of the arc cosine of *x*, which is in the interval [0, π] radians. …
>
> **Returns**
> The `acos` functions return the principal value of arcos *x*.
>
> NOTE The `acos` functions, and similarly the `asin`, `atan` and `atan2` functions, can return a value outside the principal value range for the computed mathematical function. Because the principal value range has endpoints that are not representable as floating-point numbers, even correct rounding can yield values outside the mathematical range, depending on the return type and rounding direction.

In 7.12.5.2 #2 and #3 change:

> **Description**
> The `asin` functions compute the principal value of the arc sine of *x*. …
>
> **Returns**
> The `asin` functions return arcsin *x* ~~in the interval [−π/2, +π/2] radians~~.

to:

> **Description**
> The `asin` functions compute the principal value of the arc sine of *x*, which is in the interval [−π/2, +π/2] radians. …
>
> **Returns**
> The `asin` functions return the principal value of arcsin *x*.

In 7.12.5.3 #2 and #3 change:

> **Description**
> The `atan` functions compute the principal value of the arc tangent of *x*. …
>
> **Returns**
> The `atan` functions return arctan *x* ~~in the interval [−π/2, +π/2] radians~~.

to:

Description
The `atan` functions compute the principal value of the arc tangent of *x*, which is in the interval [−π/2, +π/2] radians. …

Returns
The `atan` functions return the principal value of arctan *x*.

In 7.12.5.4 #2 and #3 change:

Description
The `atan2` functions compute the value of the arc tangent of *y*/*x*, using the signs of both arguments to determine the quadrant of the return value. …

Returns
The `atan2` functions return arctan(*y*/*x*) ~~in the interval [−π, +π] radians~~.

to:

Description
The `atan2` functions compute the value of the arc tangent of *y*/*x* in the interval [−π, +π] radians, using the signs of both arguments to determine the quadrant of the return value. …

Returns
The `atan2` functions return arctan(*y*/*x*).