primesieve

12.0

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Chapter 1

primesieve

1.1 About

primesieve is a C/C++ library for quickly generating prime numbers. It generates the primes below 10^9 in just 0.2 seconds on a single core of an Intel Core i7-6700 3.4GHz CPU from 2015. primesieve can generate primes and prime k-tuplets up to 2^64. primesieve's memory requirement is about pi(sqrt(n)) ∗ 8 bytes per thread, its run-time complexity is O(n log log n) operations. The recommended way to get started is to first have a look at a few C or C++ example programs. The most common use cases are iterating over primes using next_prime() or prev_prime() and storing primes in a vector or an array.

For more information please visit `https://github.com/kimwalisch/primesieve`.

1.2 Installation

- **`Install libprimesieve using package manager.`**
- **`Build libprimesieve from source.`**

1.3 C API

- primesieve.h - primesieve C header.
- primesieve_iterator - Provides the primesieve_next_prime() and primesieve_prev_prime() functions.
- **`C examples`** - Example programs that show how to use libprimesieve.
- **`C error handling`** - How to detect and handle errors.
- **`Link against libprimesieve.`**

1.4 C++ API

- primesieve.hpp - primesieve C++ header.
- primesieve::iterator - Provides the next_prime() and prev_prime() methods.
- **`C++ examples`** - Example programs that show how to use libprimesieve.
- **`C++ error handling`** - How to detect and handle errors.
- **`Link against libprimesieve.`**

1.5 Performance tips

- `libprimesieve performance tips`
- `Multi-threading`
- `SIMD (vectorization)`

Chapter 2

Hierarchical Index

2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

primesieve::iterator 9
primesieve_iterator 14
std::runtime_error
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Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

primesieve::iterator
Primesieve::iterator allows to easily iterate over primes both forwards and backwards 9
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primesieve_iterator
C prime iterator, please refer to iterator.h for more information 14

Chapter 4

File Index

4.1 File List

Here is a list of all documented files with brief descriptions:

primesieve.h
Primesieve C API 15
primesieve.hpp
Primesieve C++ API 21
iterator.h
Primesieve_iterator allows to easily iterate over primes both forwards and backwards 26
iterator.hpp
Primesieve::iterator allows to easily iterate (forwards and backwards) over prime numbers . . . 30
primesieve_error.hpp
The primesieve_error class is used for all exceptions within primesieve 31

Chapter 5

Class Documentation

5.1 primesieve::iterator Struct Reference

primesieve::iterator allows to easily iterate over primes both forwards and backwards.

```
#include <iterator.hpp>
```

Public Member Functions

- iterator () noexcept

  Create a new iterator object.
- iterator (uint64_t start, uint64_t stop_hint=std::numeric_limits< uint64_t >::max()) noexcept

  Create a new iterator object.
- void jump_to (uint64_t start, uint64_t stop_hint=std::numeric_limits< uint64_t >::max()) noexcept

  Reset the primesieve iterator to start.
- **iterator** (const iterator &)=delete

  primesieve::iterator objects cannot be copied.
- iterator & **operator=** (const iterator &)=delete
- **iterator** (iterator &&) noexcept

  primesieve::iterator objects support move semantics.
- iterator & **operator=** (iterator &&) noexcept
- ∼**iterator** ()

  Frees all memory.
- void clear () noexcept

  Reset the start number to 0 and free most memory.
- void generate_next_primes ()

  Used internally by next_prime().
- void generate_prev_primes ()

  Used internally by prev_prime().
- uint64_t next_prime ()

  Get the next prime.
- uint64_t prev_prime ()

  Get the previous prime.

Public Attributes

- std::size_t **i_**

  Current index of the primes array.
- std::size_t **size_**

  Current number of primes in the primes array.
- uint64_t **start_**

  Generate primes >= start.
- uint64_t **stop_hint_**

  Generate primes <= stop_hint.
- uint64_t ∗ primes_

  The primes array.
- void ∗ **memory_**

  Pointer to internal IteratorData data structure.

5.1.1 Detailed Description

primesieve::iterator allows to easily iterate over primes both forwards and backwards.

Generating the first prime has a complexity of O(r log log r) operations with r = n^0.5, after that any additional prime is generated in amortized O(log n log log n) operations. The memory usage is PrimePi(n^0.5) ∗ 8 bytes.

Examples

prev_prime.cpp, and primesieve_iterator.cpp.

5.1.2 Constructor & Destructor Documentation

5.1.2.1 iterator() [1/2]

```
primesieve::iterator::iterator ( ) [noexcept]
```

Create a new iterator object.

Generate primes >= 0. The start number is default initialized to 0 and the stop_hint is default initialized UINT64_↩
MAX.

5.1.2.2 iterator() [2/2]

```
primesieve::iterator::iterator (
            uint64_t start,
            uint64_t stop_hint = std::numeric_limits< uint64_t >::max() ) [noexcept]
```

Create a new iterator object.

Parameters

start	Generate primes >= start (or <= start).
stop_hint	Stop number optimization hint, gives significant speed up if few primes are generated. E.g. if you want to generate the primes <= 1000 use stop_hint = 1000.

5.1.3 Member Function Documentation

5.1.3.1 clear()

```
void primesieve::iterator::clear ( )  [noexcept]
```

Reset the start number to 0 and free most memory.

Keeps some smaller data structures in memory (e.g. the PreSieve object) that are useful if the primesieve::iterator is reused. The remaining memory uses at most 200 kilobytes.

5.1.3.2 generate_next_primes()

```
void primesieve::iterator::generate_next_primes ( )
```

Used internally by next_prime().

generate_next_primes() fills (overwrites) the primes array with the next few primes ($\sim$ 2^10) that are larger than the current largest prime in the primes array or with the primes >= start if the primes array is empty. Note that this method also updates the i & size member variables of this primesieve::iterator struct. The size of the primes array varies, but it is > 0 and usually close to 2^10.

5.1.3.3 generate_prev_primes()

```
void primesieve::iterator::generate_prev_primes ( )
```

Used internally by prev_prime().

generate_prev_primes() fills (overwrites) the primes array with the next few primes $\sim$ O(sqrt(n)) that are smaller than the current smallest prime in the primes array or with the primes <= start if the primes array is empty. Note that this method also updates the i & size member variables of this primesieve::iterator struct. The size of the primes array varies, but it is > 0 and $\sim$ O(sqrt(n)).

5.1.3.4 jump_to()

```
void primesieve::iterator::jump_to (
            uint64_t start,
            uint64_t stop_hint = std::numeric_limits< uint64_t >::max() )  [noexcept]
```

Reset the primesieve iterator to start.

Parameters

start	Generate primes >= start (or <= start).
stop_hint	Stop number optimization hint, gives significant speed up if few primes are generated. E.g. if you want to generate the primes <= 1000 use stop_hint = 1000.

Examples

prev_prime.cpp.

5.1.3.5 next_prime()

```
uint64_t primesieve::iterator::next_prime ( )  [inline]
```

Get the next prime.

Throws a primesieve::primesieve_error exception (derived from std::runtime_error) if any error occurs.

Examples

primesieve_iterator.cpp.

5.1.3.6 prev_prime()

```
uint64_t primesieve::iterator::prev_prime ( )  [inline]
```

Get the previous prime.

prev_prime(n) returns 0 for n <= 2. Note that next_prime() runs up to 2x faster than prev_prime(). Hence if the same algorithm can be written using either prev_prime() or next_prime() it is preferable to use next_prime().

Examples

prev_prime.cpp.

5.1.4 Member Data Documentation

5.1.4.1 primes_

```
uint64_t* primesieve::iterator::primes_
```

The primes array.

The current smallest prime can be accessed using primes[0]. The current largest prime can be accessed using primes[size-1].

The documentation for this struct was generated from the following file:

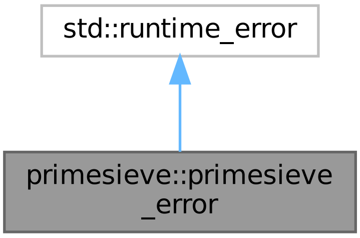
- iterator.hpp

5.2 primesieve::primesieve_error Class Reference

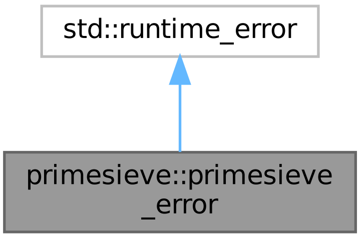
primesieve throws a primesieve_error exception if an error occurs e.g.

`#include <primesieve_error.hpp>`

Inheritance diagram for primesieve::primesieve_error:



Collaboration diagram for primesieve::primesieve_error:



Public Member Functions

- **primesieve_error** (const std::string &msg)

5.2.1 Detailed Description

primesieve throws a primesieve_error exception if an error occurs e.g.

prime $>$ 2^64.

The documentation for this class was generated from the following file:

- primesieve_error.hpp

5.3 primesieve_iterator Struct Reference

C prime iterator, please refer to iterator.h for more information.

```
#include <iterator.h>
```

Public Attributes

- size_t **i**

  Current index of the primes array.
- size_t **size**

  Current number of primes in the primes array.
- uint64_t **start**

  Generate primes >= start.
- uint64_t **stop_hint**

  Generate primes <= stop_hint.
- uint64_t * primes

  The primes array.
- void * **memory**

  Pointer to internal IteratorData data structure.
- int **is_error**

  Initialized to 0, set to 1 if any error occurs.

5.3.1 Detailed Description

C prime iterator, please refer to iterator.h for more information.

Examples

prev_prime.c, and primesieve_iterator.c.

5.3.2 Member Data Documentation

5.3.2.1 primes

```
uint64_t* primesieve_iterator::primes
```

The primes array.

The current smallest prime can be accessed using primes[0]. The current largest prime can be accessed using primes[size-1].

The documentation for this struct was generated from the following file:

- iterator.h

Chapter 6

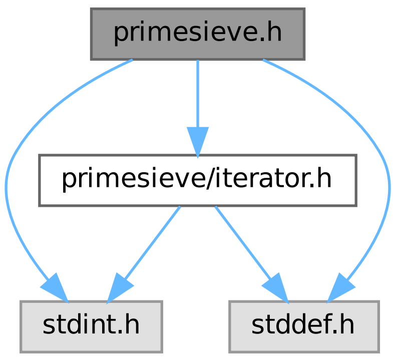
File Documentation

6.1 primesieve.h File Reference

primesieve C API.

```
#include <primesieve/iterator.h>
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for primesieve.h:



Macros

- #define **PRIMESIEVE_VERSION** "12.0"
- #define **PRIMESIEVE_VERSION_MAJOR** 12
- #define **PRIMESIEVE_VERSION_MINOR** 0
- #define **PRIMESIEVE_ERROR** ((uint64_t) ∼((uint64_t) 0))

  primesieve functions return PRIMESIEVE_ERROR (UINT64_MAX) if any error occurs.

Enumerations

- enum {
  SHORT_PRIMES , USHORT_PRIMES , INT_PRIMES , UINT_PRIMES ,
  LONG_PRIMES , ULONG_PRIMES , LONGLONG_PRIMES , ULONGLONG_PRIMES ,
  INT16_PRIMES , UINT16_PRIMES , INT32_PRIMES , UINT32_PRIMES ,
  INT64_PRIMES , UINT64_PRIMES }

Functions

- void ∗ primesieve_generate_primes (uint64_t start, uint64_t stop, size_t ∗size, int type)

  Get an array with the primes inside the interval [start, stop].
- void ∗ primesieve_generate_n_primes (uint64_t n, uint64_t start, int type)

  Get an array with the first n primes >= start.
- uint64_t primesieve_nth_prime (int64_t n, uint64_t start)

  Find the nth prime.
- uint64_t primesieve_count_primes (uint64_t start, uint64_t stop)

  Count the primes within the interval [start, stop].
- uint64_t primesieve_count_twins (uint64_t start, uint64_t stop)

  Count the twin primes within the interval [start, stop].
- uint64_t primesieve_count_triplets (uint64_t start, uint64_t stop)

  Count the prime triplets within the interval [start, stop].
- uint64_t primesieve_count_quadruplets (uint64_t start, uint64_t stop)

  Count the prime quadruplets within the interval [start, stop].
- uint64_t primesieve_count_quintuplets (uint64_t start, uint64_t stop)

  Count the prime quintuplets within the interval [start, stop].
- uint64_t primesieve_count_sextuplets (uint64_t start, uint64_t stop)

  Count the prime sextuplets within the interval [start, stop].
- void **primesieve_print_primes** (uint64_t start, uint64_t stop)

  Print the primes within the interval [start, stop] to the standard output.
- void **primesieve_print_twins** (uint64_t start, uint64_t stop)

  Print the twin primes within the interval [start, stop] to the standard output.
- void **primesieve_print_triplets** (uint64_t start, uint64_t stop)

  Print the prime triplets within the interval [start, stop] to the standard output.
- void **primesieve_print_quadruplets** (uint64_t start, uint64_t stop)

  Print the prime quadruplets within the interval [start, stop] to the standard output.
- void **primesieve_print_quintuplets** (uint64_t start, uint64_t stop)

  Print the prime quintuplets within the interval [start, stop] to the standard output.
- void **primesieve_print_sextuplets** (uint64_t start, uint64_t stop)

  Print the prime sextuplets within the interval [start, stop] to the standard output.
- uint64_t primesieve_get_max_stop (void)

  Returns the largest valid stop number for primesieve.
- int **primesieve_get_sieve_size** (void)

  Get the current set sieve size in KiB.
- int **primesieve_get_num_threads** (void)

  Get the current set number of threads.
- void primesieve_set_sieve_size (int sieve_size)

  Set the sieve size in KiB (kibibyte).
- void primesieve_set_num_threads (int num_threads)

  Set the number of threads for use in primesieve_count_∗() and primesieve_nth_prime().
- void **primesieve_free** (void ∗primes)

  Deallocate a primes array created using the primesieve_generate_primes() or primesieve_generate_n_primes() functions.
- const char ∗ **primesieve_version** (void)

  Get the primesieve version number, in the form "i.j"

6.1.1 Detailed Description

primesieve C API.

primesieve is a library for quickly generating prime numbers. If an error occurs, primesieve functions with a uint64_t return type return PRIMESIEVE_ERROR and the corresponding error message is printed to the standard error stream. libprimesieve also sets the C errno variable to EDOM if an error occurs.

6.1.2 Enumeration Type Documentation

6.1.2.1 anonymous enum

```
anonymous enum
```

Enumerator

SHORT_PRIMES	Generate primes of short type.
USHORT_PRIMES	Generate primes of unsigned short type.
INT_PRIMES	Generate primes of int type.
UINT_PRIMES	Generate primes of unsigned int type.
LONG_PRIMES	Generate primes of long type.
ULONG_PRIMES	Generate primes of unsigned long type.
LONGLONG_PRIMES	Generate primes of long long type.
ULONGLONG_PRIMES	Generate primes of unsigned long long type.
INT16_PRIMES	Generate primes of int16_t type.
UINT16_PRIMES	Generate primes of uint16_t type.
INT32_PRIMES	Generate primes of int32_t type.
UINT32_PRIMES	Generate primes of uint32_t type.
INT64_PRIMES	Generate primes of int64_t type.
UINT64_PRIMES	Generate primes of uint64_t type.

6.1.3 Function Documentation

6.1.3.1 primesieve_count_primes()

```
uint64_t primesieve_count_primes (
            uint64_t start,
            uint64_t stop )
```

Count the primes within the interval [start, stop].

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

Note that each call to primesieve_count_primes() incurs an initialization overhead of O(sqrt(stop)) even if the interval [start, stop] is tiny. Hence if you have written an algorithm that makes many calls to primesieve_count_primes() it may be preferable to use a primesieve::iterator which needs to be initialized only once.

Examples

count_primes.c.

6.1.3.2 primesieve_count_quadruplets()

```
uint64_t primesieve_count_quadruplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime quadruplets within the interval [start, stop].

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

6.1.3.3 primesieve_count_quintuplets()

```
uint64_t primesieve_count_quintuplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime quintuplets within the interval [start, stop].

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

6.1.3.4 primesieve_count_sextuplets()

```
uint64_t primesieve_count_sextuplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime sextuplets within the interval [start, stop].

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

6.1.3.5 primesieve_count_triplets()

```
uint64_t primesieve_count_triplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime triplets within the interval [start, stop].

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

6.1.3.6 primesieve_count_twins()

```
uint64_t primesieve_count_twins (
            uint64_t start,
            uint64_t stop )
```

Count the twin primes within the interval [start, stop].

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

6.1.3.7 primesieve_generate_n_primes()

```
void * primesieve_generate_n_primes (
            uint64_t n,
            uint64_t start,
            int type )
```

Get an array with the first n primes >= start.

Parameters

type	The type of the primes to generate, e.g. INT_PRIMES.

In case an error occurs the error message is printed to the standard error stream and a NULL pointer is returned. libprimesieve also sets the C errno variable (from <errno.h>) to EDOM if any error occurs. The only advantage which checking errno (after primesieve_generate_n_primes()) has over checking if a NULL pointer has been returned, is that errno is not set when calling primesieve_generate_n_primes(0, start, type) which is valid (but useless) and which returns a NULL pointer.

Examples

primes_array.c.

6.1.3.8 primesieve_generate_primes()

```
void * primesieve_generate_primes (
            uint64_t start,
            uint64_t stop,
            size_t * size,
            int type )
```

Get an array with the primes inside the interval [start, stop].

Parameters

size	The size of the returned primes array.
type	The type of the primes to generate, e.g. INT_PRIMES.

In case an error occurs the error message is printed to the standard error stream, the size is set to 0 and a

NULL pointer is returned. In order to distinguish an "error" from "no primes found within [start, stop]" libprimesieve also sets the C errno variable (from <errno.h>) to EDOM if any error occurs. By checking errno after calling primesieve_generate_primes() users can reliably detect errors.

Examples

primes_array.c.

6.1.3.9 primesieve_get_max_stop()

```
uint64_t primesieve_get_max_stop (
            void )
```

Returns the largest valid stop number for primesieve.

Returns

2^64-1 (UINT64_MAX).

6.1.3.10 primesieve_nth_prime()

```
uint64_t primesieve_nth_prime (
            int64_t n,
            uint64_t start )
```

Find the nth prime.

By default all CPU cores are used, use primesieve_set_num_threads(int threads) to change the number of threads.

Note that each call to primesieve_nth_prime(n, start) incurs an initialization overhead of O(sqrt(start)) even if n is tiny. Hence it is not a good idea to use primesieve_nth_prime() repeatedly in a loop to get the next (or previous) prime. For this use case it is better to use a primesieve::iterator which needs to be initialized only once.

Parameters

n	if n = 0 finds the 1st prime >= start, if n > 0 finds the nth prime > start, if n < 0 finds the nth prime < start (backwards).

Examples

nth_prime.c.

6.1.3.11 primesieve_set_num_threads()

```
void primesieve_set_num_threads (
            int num_threads )
```

Set the number of threads for use in primesieve_count_*() and primesieve_nth_prime().

By default all CPU cores are used.

6.1.3.12 primesieve_set_sieve_size()

```
void primesieve_set_sieve_size (
            int sieve_size )
```

Set the sieve size in KiB (kibibyte).

The best sieving performance is achieved with a sieve size of your CPU's L1 or L2 cache size (per core).

Precondition

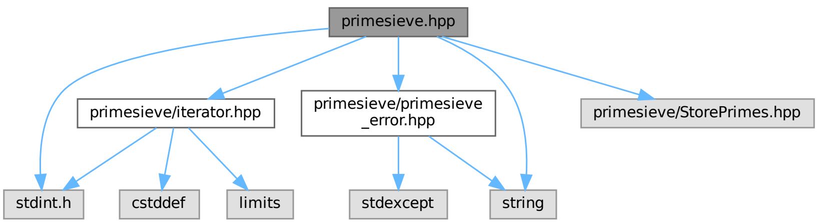
sieve_size >= 16 && <= 8192.

6.2 primesieve.hpp File Reference

primesieve C++ API.

```
#include <primesieve/iterator.hpp>
#include <primesieve/primesieve_error.hpp>
#include <primesieve/StorePrimes.hpp>
#include <stdint.h>
#include <string>
```

Include dependency graph for primesieve.hpp:



Macros

- #define **PRIMESIEVE_VERSION** "12.0"
- #define **PRIMESIEVE_VERSION_MAJOR** 12
- #define **PRIMESIEVE_VERSION_MINOR** 0

Functions

- template<typename vect >
  void primesieve::generate_primes (uint64_t stop, vect ∗primes)

  Appends the primes <= stop to the end of the primes vector.
- template<typename vect >
  void primesieve::generate_primes (uint64_t start, uint64_t stop, vect ∗primes)

  Appends the primes inside [start, stop] to the end of the primes vector.
- template<typename vect >
  void primesieve::generate_n_primes (uint64_t n, vect ∗primes)

Appends the first n primes to the end of the primes vector.

- template<typename vect >
  void primesieve::generate_n_primes (uint64_t n, uint64_t start, vect *primes)

  Appends the first n primes >= start to the end of the primes vector.
- uint64_t primesieve::nth_prime (int64_t n, uint64_t start=0)

  Find the nth prime.
- uint64_t primesieve::count_primes (uint64_t start, uint64_t stop)

  Count the primes within the interval [start, stop].
- uint64_t primesieve::count_twins (uint64_t start, uint64_t stop)

  Count the twin primes within the interval [start, stop].
- uint64_t primesieve::count_triplets (uint64_t start, uint64_t stop)

  Count the prime triplets within the interval [start, stop].
- uint64_t primesieve::count_quadruplets (uint64_t start, uint64_t stop)

  Count the prime quadruplets within the interval [start, stop].
- uint64_t primesieve::count_quintuplets (uint64_t start, uint64_t stop)

  Count the prime quintuplets within the interval [start, stop].
- uint64_t primesieve::count_sextuplets (uint64_t start, uint64_t stop)

  Count the prime sextuplets within the interval [start, stop].
- void **primesieve::print_primes** (uint64_t start, uint64_t stop)

  Print the primes within the interval [start, stop] to the standard output.
- void **primesieve::print_twins** (uint64_t start, uint64_t stop)

  Print the twin primes within the interval [start, stop] to the standard output.
- void **primesieve::print_triplets** (uint64_t start, uint64_t stop)

  Print the prime triplets within the interval [start, stop] to the standard output.
- void **primesieve::print_quadruplets** (uint64_t start, uint64_t stop)

  Print the prime quadruplets within the interval [start, stop] to the standard output.
- void **primesieve::print_quintuplets** (uint64_t start, uint64_t stop)

  Print the prime quintuplets within the interval [start, stop] to the standard output.
- void **primesieve::print_sextuplets** (uint64_t start, uint64_t stop)

  Print the prime sextuplets within the interval [start, stop] to the standard output.
- uint64_t primesieve::get_max_stop ()

  Returns the largest valid stop number for primesieve.
- int **primesieve::get_sieve_size** ()

  Get the current set sieve size in KiB.
- int **primesieve::get_num_threads** ()

  Get the current set number of threads.
- void primesieve::set_sieve_size (int sieve_size)

  Set the sieve size in KiB (kibibyte).
- void primesieve::set_num_threads (int num_threads)

  Set the number of threads for use in primesieve::count_*() and primesieve::nth_prime().
- std::string **primesieve::primesieve_version** ()

  Get the primesieve version number, in the form "i.j".

6.2.1 Detailed Description

primesieve C++ API.

primesieve is a library for fast prime number generation, in case an error occurs a primesieve::primesieve_error exception (derived form std::runtime_error) is thrown.

6.2.2 Function Documentation

6.2.2.1 count_primes()

```
uint64_t primesieve::count_primes (
            uint64_t start,
            uint64_t stop )
```

Count the primes within the interval [start, stop].

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

Note that each call to count_primes() incurs an initialization overhead of O(sqrt(stop)) even if the interval [start, stop] is tiny. Hence if you have written an algorithm that makes many calls to count_primes() it may be preferable to use a primesieve::iterator which needs to be initialized only once.

Examples

count_primes.cpp.

6.2.2.2 count_quadruplets()

```
uint64_t primesieve::count_quadruplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime quadruplets within the interval [start, stop].

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

6.2.2.3 count_quintuplets()

```
uint64_t primesieve::count_quintuplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime quintuplets within the interval [start, stop].

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

6.2.2.4 count_sextuplets()

```
uint64_t primesieve::count_sextuplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime sextuplets within the interval [start, stop].

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

6.2.2.5 count_triplets()

```
uint64_t primesieve::count_triplets (
            uint64_t start,
            uint64_t stop )
```

Count the prime triplets within the interval [start, stop].

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

6.2.2.6 count_twins()

```
uint64_t primesieve::count_twins (
            uint64_t start,
            uint64_t stop )
```

Count the twin primes within the interval [start, stop].

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

6.2.2.7 generate_n_primes() [1/2]

```
template<typename vect >
void primesieve::generate_n_primes (
            uint64_t n,
            uint64_t start,
            vect * primes )  [inline]
```

Appends the first n primes >= start to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

6.2.2.8 generate_n_primes() [2/2]

```
template<typename vect >
void primesieve::generate_n_primes (
            uint64_t n,
            vect * primes )  [inline]
```

Appends the first n primes to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

Examples

primes_vector.cpp.

6.2.2.9 generate_primes() [1/2]

```
template<typename vect >
void primesieve::generate_primes (
            uint64_t start,
            uint64_t stop,
            vect * primes ) [inline]
```

Appends the primes inside [start, stop] to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

6.2.2.10 generate_primes() [2/2]

```
template<typename vect >
void primesieve::generate_primes (
            uint64_t stop,
            vect * primes ) [inline]
```

Appends the primes <= stop to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

Examples

primes_vector.cpp.

6.2.2.11 get_max_stop()

```
uint64_t primesieve::get_max_stop ( )
```

Returns the largest valid stop number for primesieve.

Returns

2^64-1 (UINT64_MAX).

6.2.2.12 nth_prime()

```
uint64_t primesieve::nth_prime (
            int64_t n,
            uint64_t start = 0 )
```

Find the nth prime.

By default all CPU cores are used, use primesieve::set_num_threads(int threads) to change the number of threads.

Note that each call to nth_prime(n, start) incurs an initialization overhead of O(sqrt(start)) even if n is tiny. Hence it is not a good idea to use nth_prime() repeatedly in a loop to get the next (or previous) prime. For this use case it is better to use a primesieve::iterator which needs to be initialized only once.

Parameters

n	if n = 0 finds the 1st prime >= start, if n > 0 finds the nth prime > start, if n < 0 finds the nth prime < start (backwards).

Examples

nth_prime.cpp.

6.2.2.13 set_num_threads()

```
void primesieve::set_num_threads (
            int num_threads )
```

Set the number of threads for use in primesieve::count_*() and primesieve::nth_prime().

By default all CPU cores are used.

6.2.2.14 set_sieve_size()

```
void primesieve::set_sieve_size (
            int sieve_size )
```

Set the sieve size in KiB (kibibyte).

The best sieving performance is achieved with a sieve size of your CPU's L1 or L2 cache size (per core).

Precondition

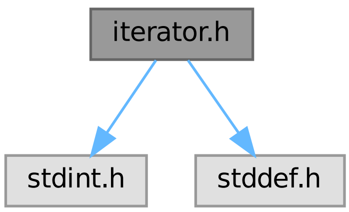
sieve_size >= 16 && <= 8192.

6.3 iterator.h File Reference

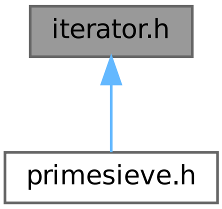
primesieve_iterator allows to easily iterate over primes both forwards and backwards.

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for iterator.h:



This graph shows which files directly or indirectly include this file:



Classes

- struct primesieve_iterator

  C prime iterator, please refer to iterator.h for more information.

Macros

- #define **IF_UNLIKELY_PRIMESIEVE**(x) if (x)

Functions

- void **primesieve_init** (primesieve_iterator ∗it)

  Initialize the primesieve iterator before first using it.
- void **primesieve_free_iterator** (primesieve_iterator ∗it)

  Free all memory.
- void primesieve_clear (primesieve_iterator ∗it)

  Reset the start number to 0 and free most memory.
- void primesieve_jump_to (primesieve_iterator ∗it, uint64_t start, uint64_t stop_hint)

  Reset the primesieve iterator to start.
- void primesieve_skipto (primesieve_iterator ∗it, uint64_t start, uint64_t stop_hint)

  Reset the primesieve iterator to start.
- void primesieve_generate_next_primes (primesieve_iterator ∗)

  Used internally by primesieve_next_prime().
- void primesieve_generate_prev_primes (primesieve_iterator ∗)

  Used internally by primesieve_prev_prime().
- static uint64_t primesieve_next_prime (primesieve_iterator ∗it)

  Get the next prime.
- static uint64_t primesieve_prev_prime (primesieve_iterator ∗it)

  Get the previous prime.

6.3.1 Detailed Description

primesieve_iterator allows to easily iterate over primes both forwards and backwards.

Generating the first prime has a complexity of O(r log log r) operations with r = n^0.5, after that any additional prime is generated in amortized O(log n log log n) operations. The memory usage is about PrimePi(n^0.5) * 8 bytes.

The primesieve_iterator.c example shows how to use primesieve_iterator. If any error occurs primesieve_next_prime() and primesieve_prev_prime() return PRIMESIEVE_ERROR. Furthermore primesieve_iterator.is_error is initialized to 0 and set to 1 if any error occurs.

6.3.2 Function Documentation

6.3.2.1 primesieve_clear()

```
void primesieve_clear (
            primesieve_iterator * it )
```

Reset the start number to 0 and free most memory.

Keeps some smaller data structures in memory (e.g. the PreSieve object) that are useful if the primesieve_iterator is reused. The remaining memory uses at most 200 kilobytes.

6.3.2.2 primesieve_generate_next_primes()

```
void primesieve_generate_next_primes (
            primesieve_iterator * )
```

Used internally by primesieve_next_prime().

primesieve_generate_next_primes() fills (overwrites) the primes array with the next few primes (∼ 2^10) that are larger than the current largest prime in the primes array or with the primes >= start if the primes array is empty. Note that this function also updates the i & size member variables of the primesieve_iterator struct. The size of the primes array varies, but it is > 0 and usually close to 2^10. If an error occurs primesieve_iterator.is_error is set to 1 and the primes array will contain PRIMESIEVE_ERROR.

6.3.2.3 primesieve_generate_prev_primes()

```
void primesieve_generate_prev_primes (
            primesieve_iterator * )
```

Used internally by primesieve_prev_prime().

primesieve_generate_prev_primes() fills (overwrites) the primes array with the next few primes ∼ O(sqrt(n)) that are smaller than the current smallest prime in the primes array or with the primes <= start if the primes array is empty. Note that this function also updates the i & size member variables of the primesieve_iterator struct. The size of the primes array varies, but it is > 0 and ∼ O(sqrt(n)). If an error occurs primesieve_iterator.is_error is set to 1 and the primes array will contain PRIMESIEVE_ERROR.

6.3.2.4 primesieve_jump_to()

```
void primesieve_jump_to (
            primesieve_iterator * it,
            uint64_t start,
            uint64_t stop_hint )
```

Reset the primesieve iterator to start.

Parameters

start	Generate primes >= start (or <= start).
stop_hint	Stop number optimization hint. E.g. if you want to generate the primes <= 1000 use stop_hint = 1000, if you don't know use UINT64_MAX.

Examples

prev_prime.c, and primesieve_iterator.c.

6.3.2.5 primesieve_next_prime()

```
static uint64_t primesieve_next_prime (
            primesieve_iterator * it )  [inline], [static]
```

Get the next prime.

Returns PRIMESIEVE_ERROR (UINT64_MAX) if any error occrus.

Examples

primesieve_iterator.c.

6.3.2.6 primesieve_prev_prime()

```
static uint64_t primesieve_prev_prime (
            primesieve_iterator * it )  [inline], [static]
```

Get the previous prime.

primesieve_prev_prime(n) returns 0 for n <= 2. Note that primesieve_next_prime() runs up to 2x faster than primesieve_prev_prime(). Hence if the same algorithm can be written using either primesieve_prev_prime() or primesieve_next_prime() it is preferable to use primesieve_next_prime().

Examples

prev_prime.c.

6.3.2.7 primesieve_skipto()

```
void primesieve_skipto (
            primesieve_iterator * it,
            uint64_t start,
            uint64_t stop_hint )
```

Reset the primesieve iterator to start.

Parameters

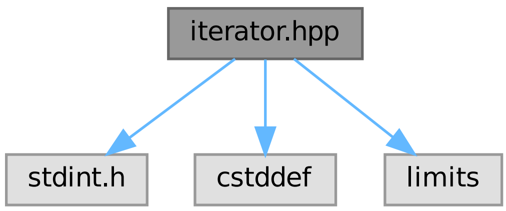
start	Generate primes > start (or < start).
stop_hint	Stop number optimization hint. E.g. if you want to generate the primes <= 1000 use stop_hint = 1000, if you don't know use UINT64_MAX.

6.4 iterator.hpp File Reference

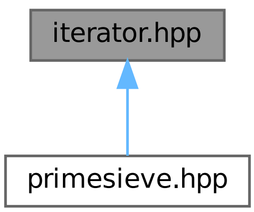
primesieve::iterator allows to easily iterate (forwards and backwards) over prime numbers.

```
#include <stdint.h>
#include <cstddef>
#include <limits>
```

Include dependency graph for iterator.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- struct primesieve::iterator

    primesieve::iterator allows to easily iterate over primes both forwards and backwards.

Macros

- #define **IF_UNLIKELY_PRIMESIEVE**(x) if (x)

6.4.1 Detailed Description

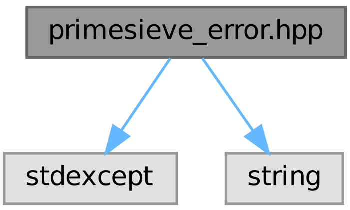
primesieve::iterator allows to easily iterate (forwards and backwards) over prime numbers.

6.5 primesieve_error.hpp File Reference

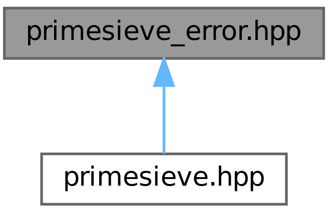
The primesieve_error class is used for all exceptions within primesieve.

```
#include <stdexcept>
#include <string>
```

Include dependency graph for primesieve_error.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class primesieve::primesieve_error
  primesieve throws a primesieve_error exception if an error occurs e.g.

6.5.1 Detailed Description

The primesieve_error class is used for all exceptions within primesieve.

Chapter 7

Examples

7.1 count_primes.cpp

This example shows how to count primes.

This example shows how to count primes.

```
#include <primesieve.hpp>
#include <stdint.h>
#include <iostream>

int main()
{
  uint64_t count = primesieve::count_primes(0, 1000);
  std::cout « "Primes <= 1000: " « count « std::endl;

  return 0;
}
```

7.2 primesieve_iterator.cpp

Iterate over primes using primesieve::iterator.

Iterate over primes using primesieve::iterator.

```
#include <primesieve.hpp>
#include <cstdlib>
#include <iostream>

int main(int argc, char** argv)
{
  uint64_t limit = 10000000000ull;

  if (argc > 1)
    limit = std::atol(argv[1]);

  primesieve::iterator it(0, limit);
  uint64_t prime = it.next_prime();
  uint64_t sum = 0;

  // Iterate over the primes <= 10^9
  for (; prime <= limit; prime = it.next_prime())
    sum += prime;

  std::cout « "Sum of primes <= " « limit « ": " « sum « std::endl;

  // Note that since sum is a 64-bit variable the result
  // will be incorrect (due to integer overflow) if
  // limit > 10^10. However we do allow limits > 10^10
  // since this is useful for benchmarking.
  if (limit > 10000000000ull)
    std::cerr « "Warning: sum is likely incorrect due to 64-bit integer overflow!" « std::endl;

  return 0;
}
```

7.3 nth_prime.cpp

Find the nth prime.

Find the nth prime.

```
#include <primesieve.hpp>
#include <stdint.h>
#include <iostream>
#include <cstdlib>

int main(int, char** argv)
{
  uint64_t n = 1000;

  if (argv[1])
    n = std::atol(argv[1]);

  uint64_t nth_prime = primesieve::nth_prime(n);
  std::cout « n « "th prime = " « nth_prime « std::endl;

  return 0;
}
```

7.4 prev_prime.cpp

Iterate backwards over primes using primesieve::iterator.

Iterate backwards over primes using primesieve::iterator.

```
#include <primesieve.hpp>
#include <cstdlib>
#include <iostream>

int main(int argc, char** argv)
{
  uint64_t limit = 10000000000ull;

  if (argc > 1)
    limit = std::atol(argv[1]);

  primesieve::iterator it;
  it.jump_to(limit);
  uint64_t prime = it.prev_prime();
  uint64_t sum = 0;

  // Backwards iterate over the primes <= 10^9
  for (; prime > 0; prime = it.prev_prime())
    sum += prime;

  std::cout « "Sum of primes <= " « limit « ": " « sum « std::endl;

  // Note that since sum is a 64-bit variable the result
  // will be incorrect (due to integer overflow) if
  // limit > 10^10. However we do allow limits > 10^10
  // since this is useful for benchmarking.
  if (limit > 10000000000ull)
    std::cerr « "Warning: sum is likely incorrect due to 64-bit integer overflow!" « std::endl;

  return 0;
}
```

7.5 primes_vector.cpp

Fill a std::vector with primes.

Fill a std::vector with primes.

```
#include <primesieve.hpp>
```

```
#include <vector>

int main()
{
  std::vector<int> primes;

  // Fill the primes vector with the primes <= 1000
  primesieve::generate_primes(1000, &primes);

  primes.clear();

  // Fill the primes vector with the primes inside [1000, 2000]
  primesieve::generate_primes(1000, 2000, &primes);

  primes.clear();

  // Fill the primes vector with the first 1000 primes
  primesieve::generate_n_primes(1000, &primes);

  primes.clear();

  // Fill the primes vector with the first 10 primes >= 1000
  primesieve::generate_n_primes(10, 1000, &primes);

  return 0;
}
```

7.6 count_primes.c

C program that shows how to count primes.

C program that shows how to count primes.

```
#include <primesieve.h>
#include <inttypes.h>
#include <stdio.h>

int main(void)
{
  uint64_t count = primesieve_count_primes(0, 1000);
  printf("Primes <= 1000: %" PRIu64 "\n", count);

  return 0;
}
```

7.7 prev_prime.c

Iterate backwards over primes using primesieve_iterator.

Iterate backwards over primes using primesieve_iterator.Note that primesieve_next_prime() runs up to 2x faster and uses only half as much memory as primesieve_prev_prime(). Hence if it is possible to write the same algorithm using either primesieve_prev_prime() or primesieve_next_prime() then it is preferable to use primesieve_next_prime().

```
#include <primesieve.h>
#include <inttypes.h>
#include <stdlib.h>
#include <stdio.h>

int main(int argc, char** argv)
{
  uint64_t limit = 10000000000ull;

  if (argc > 1)
    limit = atol(argv[1]);

  primesieve_iterator it;
  primesieve_init(&it);

  /* primesieve_jump_to(&it, start_number, stop_hint) */
  primesieve_jump_to(&it, limit, 0);
  uint64_t prime;
```

```
  uint64_t sum = 0;

  /* Backwards iterate over the primes <= limit */
  while ((prime = primesieve_prev_prime(&it)) > 0)
    sum += prime;

  primesieve_free_iterator(&it);
  printf("Sum of the primes: %" PRIu64 "\n", sum);

  /* Note that since sum is a 64-bit variable the result
   * will be incorrect (due to integer overflow) if
   * limit > 10^10. However we do allow limits > 10^10
   * since this is useful for benchmarking. */
  if (limit > 10000000000ull)
    printf("Warning: sum is likely incorrect due to 64-bit integer overflow!");

  return 0;
}
```

7.8 primesieve_iterator.c

Iterate over primes using C primesieve_iterator.

Iterate over primes using C primesieve_iterator.

```
#include <primesieve.h>
#include <inttypes.h>
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char** argv)
{
  uint64_t limit = 10000000000ull;

  if (argc > 1)
    limit = atol(argv[1]);

  primesieve_iterator it;
  primesieve_init(&it);

  /* Indicate exact bounds to improve performance */
  primesieve_jump_to(&it, 0, limit);

  uint64_t sum = 0;
  uint64_t prime = 0;

  /* Iterate over the primes <= 10^9 */
  while ((prime = primesieve_next_prime(&it)) <= limit)
    sum += prime;

  printf("Sum of the primes <= %" PRIu64 ": %" PRIu64 "\n", limit, sum);

  primesieve_free_iterator(&it);

  return 0;
}
```

7.9 nth_prime.c

C program that finds the nth prime.

C program that finds the nth prime.

```
#include <primesieve.h>
#include <stdlib.h>
#include <inttypes.h>
#include <stdio.h>

int main(int argc, char** argv)
{
  uint64_t n = 1000;

  if (argc > 1 && argv[1])
```

```
    n = atol(argv[1]);

  uint64_t prime = primesieve_nth_prime(n, 0);
  printf("%" PRIu64 "th prime = %" PRIu64 "\n", n, prime);

  return 0;
}
```

7.10 primes_array.c

Generate an array of primes.

Generate an array of primes.

```
#include <primesieve.h>
#include <stdio.h>

int main(void)
{
  uint64_t start = 0;
  uint64_t stop = 1000;
  size_t i;
  size_t size;

  /* Get an array with the primes <= 1000 */
  int* primes = (int*) primesieve_generate_primes(start, stop, &size, INT_PRIMES);

  for (i = 0; i < size; i++)
    printf("%i\n", primes[i]);

  primesieve_free(primes);
  uint64_t n = 1000;

  /* Get an array with the first 1000 primes */
  primes = (int*) primesieve_generate_n_primes(n, start, INT_PRIMES);

  for (i = 0; i < n; i++)
    printf("%i\n", primes[i]);

  primesieve_free(primes);
  return 0;
}
```

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