libfswatch

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Cross-platform file change monitor C/C++ library with multiple backends
for `libfswatch` version 1.7.0, 10 November 2015

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This manual is for `libfswatch` (version 1.7.0, 10 November 2015), a cross-platform C/C++ file change monitor library with multiple backends: Apple OS X *File System Events*, *BSD *kqueue*, Solaris/Illumos *File Events Notification*, Linux *inotify*, Microsoft Windows `ReadDirectoryChangesW` and a `stat()`-based backend.

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1.1.1 Feature Changes

The changes introduced in `5:0:2` are the following:

- A monitor based on the Solaris/Illumos File Events Notification API has been added.
- The possibility of watching for directories only during a recursive scan. This feature helps reducing the number of open file descriptors if a generic change event for a directory is acceptable instead of events on directory children.

1.1.2 C++ Interface Changes

- Added the `fsw::fen_monitor` class has been added to provide a monitor based on the Solaris/Illumos File Events Notification API.
- Added the `monitor::set_directory_only` method to set a flag to only watch directories during a recursive scan.

1.1.3 C Interface Changes

- Added the `fsw_set_directory_only` function to set a flag to only watch directories during a recursive scan.
- Added the `fsw_logf_perror` function to log a `printf`-compatible message using `perror`.

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1.2.1 Feature Changes

The changes introducted in `4:0:1` are the following:

- A monitor for Microsoft Windows was added.
- A logging function has been added to the library to log verbose messages.

1.2.2 C++ Interface Changes

- The `windows_monitor` class has been added to provide a monitor that uses the Windows API.

1.2.3 C Interface Changes

- A family of functions and macros have been added to log diagnostic messages and conditionally print them only in verbose mode:
  - `fsw_log`

- `fsw_flog`
- `fsw_logf`
- `fsw_flogf`
- `fsw_log_perror`
- `FSW_LOG`
- `FSW_ELOG`
- `FSW_LOGF`
- `FSW_ELOGF`
- `FSW_FLOGF`

1.3 3:0:0

1.3.1 Feature Changes

The changes introduced in `3:0:0` are the following:

- The possibility of filtering events by *event type* was added.
- All the monitors were refactored and the callback invocation logic was moved to the base `monitor` class.
- All the monitors were refactored and the filtering logic (both by path and event type) was moved to the base `monitor` class.

1.3.2 C++ Interface Changes

- Added the `monitor::add_event_type_filter` method to add an event type filter.
- Added the `monitor::set_event_type_filters` method to set the event type filters.
- Added the `monitor::notify_events` method to centralize event filtering and dispatching into the base monitor class.
- Added the `event::get_event_flag_by_name` method to lookup an event type by name.
- Added the `event::get_event_flag_name` method to get the name of an event type.
- Added the overloaded `ostream& operator<<(ostream& out, const fsw_event_flag flag)` operator to simplify printing the name of an event type on a stream.

1.3.3 C Interface Changes

- Added the `fsw_event_type_filter` structure to represent a event type filter.
- Added the `FSW_ERR_UNKNOWN_VALUE` exit code.

- Added the `fsw_add_event_type_filter` function to add an event type filter.
- Added the `fsw_get_event_flag_by_name` function to lookup an event type by name.
- Added the `fsw_get_event_flag_name` function to get the name of an event type.

2 Introduction

`fswatch` is a cross-platform file change monitor currently supporting the following backends:

- A monitor based on the *FSEvents* API of Apple OS X.
- A monitor based on *kqueue*, an event notification interface introduced in FreeBSD 4.1 and supported on most *BSD systems (including OS X).
- A monitor based on *File Events Notification*, an event notification API of the Solaris/Illumos kernel.
- A monitor based on *inotify*, a Linux kernel subsystem that reports file system changes to applications.
- A monitor based on the Microsoft Windows' `ReadDirectoryChangesW` function and reads change events asynchronously.
- A monitor which periodically stats the file system, saves file modification times in memory and manually calculates file system changes, which can work on any operating system where `stat` can be used.

The first releases of `fswatch` were monolithic, self-contained binaries whose output was typically piped to other applications for processing. Given the nature of the features provided by `fswatch`, however, we recognized the need to expose this functionality through a library and the `libfswatch` package was born. `fswatch` is now built upon it and all its functionality is provided by the `libfswatch` library, with the exception perhaps of some formatting routines printing results to the standard output.

The biggest issue we have faced while developing `fswatch` was abstracting the behaviour of different backends behind a common interface and `libfswatch` is the result of that effort. Instead of using different APIs, a programmer can use just one: the API of `libfswatch`. The advantages of using `libfswatch` are many:

- Portability: `libfswatch` supports many backends, effectively giving support to a great number of operating systems, including Solaris, *BSD Unix and Linux.
- Ease of use: using `libfswatch` should be easier than using any of the APIs it supports.

2.1 Available Bindings

`libfswatch` is a C++ library with C bindings which makes it available to a wide range of programming languages. If a programming language has C bindings, then `libfswatch` can be used from it. The C binding provides all the functionality provided by the C++ implementation and it can be used as a fallback solution when the C++ API cannot be used.

2.2 Relation between `fswatch` and `libfswatch`

Although `fswatch` uses functionality provided by `libfswatch` and depends on it, `libfswatch` is currently a package nested into `fswatch`. If either component is updated, the whole package is, as well as their version numbers are. From the GNU Build System point of view, the package version of `libfswatch` is always kept in sync with `fswatch`'s.

The library API version, however, *is not*, and it is the only piece of information that should be kept into account when linking against `libfswatch`. Since we use `libtool` to build `libfswatch`, we adopt `libtool`'s versioning scheme for library interface versions.

2.3 `libtool`'s versioning scheme

`libtool`'s versioning scheme is described by three integers:

```
current:revision:age
```

where:

- `current` is the most recent interface number implemented by the library.
- `revision` is the implementation number of the current interface.
- `age` is the difference between the newest and the oldest interface that the library implements.

2.4 The C and the C++ API

The C API is built on top of the C++ API but the two are very different, to reflect the fundamental differences between the two languages.

The C++ API centres on the concept of *monitor*, a class of objects modelling the functionality of the file monitoring API. Different monitor types are modelled as different classes inheriting from the `fsw::monitor` abstract class, that is the type that defines the core monitoring API. API clients can pick the current platform's default monitor, or choose a specific implementation amongst the available ones, configure it and *run* it. When running, a monitor gathers file system change events and communicates them back to the caller using a *callback*.

The C API, on the other hand, centres on the concept of *monitoring session*. A session internally wraps a monitor instance and represents an opaque C bridge to the C++ monitor API. Sessions are identified by a *session handle* and they can be thought as a sort of C 'façade' of the C++ monitor class. In fact there is an evident similarity between the C library functions operating on a monitoring session and the methods of the `monitor` class.

2.5 Thread Safety

The C++ API does not deal with thread safety explicitly. Rather, it leaves the responsibility of implementing a thread-safe use of the library to the callers. The C++ implementation has been designed in order to:

- Encapsulate all the state of a monitor into its class fields.
- Perform no concurrent access control in methods or class fields.
- Guarantee that functions and *static* methods are thread safe.

As a consequence, it is *not* thread-safe to access a monitor's member, be it a method or a field, from different threads concurrently. The easiest way to implement thread-safety when using `libfswatch`, therefore, is segregating access to each monitor instance from a different thread.

The C API, a layer above the C++ API, has been designed in order to provide the same basic guarantee:

- Concurrently manipulating different monitoring sessions is thread safe.
- Concurrently manipulating the same monitoring session is *not* thread safe.

There is an additional limitation which affects the C library only: the C binding implementation internally uses C++11 classes and keywords to provide the aforementioned guarantees. If compiler or library support is not found when building `libfswatch` the library will still build, but those guarantees will *not* be honoured. A warning such as the following will appear in `configure`'s output to inform the user:

```
configure: WARNING: libfswatch is not thread-safe because the current
combination of compiler and libraries do not support the thread_local
storage specifier.
```

2.6 Reporting Bugs and Suggestions

If you find problems or have suggestions about this program or this manual, please report them as new issues in the official GitHub repository of `fswatch` at https://github.com/emcrisostomo/fswatch. Please, read the `CONTRIBUTING.md` file for detailed instructions on how to contribute to `fswatch`.

3 The C++ API

The C++ API provides users an easy to use, object-oriented interface to a wide range of file monitoring APIs. This API provides a common facade to a set of heterogeneous APIs that not only greatly simplifies their usage, but provides an indirection layer that makes applications more portable: as far as there is an available monitor in another platform, an existing application will *just* work.

In reality, a monitor may have platform-specific behaviours that should be taken into account when writing portable applications using this library. This differences complicate the task of writing portable applications that are truly independent of the file monitoring API they may be using. However, monitors try to 'compensate' for any behavioural difference across implementations.

The typical usage pattern of this API is similar to the following:

- An instance of a `monitor` is either created directly or through the factory (see [Monitor Discovery], page 9).
- The monitor is configured according to the user needs (see [Monitors], page 10).
- The monitor is *run* and change events are waited for.

3.1 Monitor Discovery

Since multiple monitor implementations exist and the caller potentially ignores which monitors will be available at run time, there must exist a way to query the API for the list of available monitor and request a particular instance. The `monitor_factory` is an object factory class that provides basic monitor *registration* and *discovery* functionality: API clients can query the monitor registry to get a list of available monitors and get an instance of a monitor either by *type* or by *name*.

The `monitor_factory` class provides the following methods:

`static monitor * create_monitor`

Creates a monitor of the specified type with the specified constructor parameters (see [Monitors], page 10). A monitor of the platform default type can be created if `fsw_monitor_type::system_default_monitor_type`. If the named monitor is not available, then return `nullptr`.

`static monitor * create_monitor_by_name`

Creates a monitor of the specified type (by *name*) and constructor parameters (see [Monitors], page 10). If the named monitor is not available, then return `nullptr`.

`static std::vector<std::string> get_types()`
: Get the list of available monitor types. The type name can then be used to get a monitor instance by name using `create_monitor_by_name`.

`static bool exists_type(const std::string& name)`
: Query whether the specified monitor exists.

`static void register_type(const std::string& name, fsw_monitor_type type)`
: Register a monitor type in the list of available implementations.

3.2 Monitor Registration

In order for monitor types to be visible to the factory they have to be registered. Currently they can be registered using two helper macros, defined in `monitor.h`:

`REGISTER_MONITOR(classname, monitor_type)`
: This macro must be invoked into a class' header file and must be passed the class name and the monitor type.

`REGISTER_MONITOR_IMPL(classname, monitor_type)`
: This macro must be invoked into a class' source file and must be passed the class name and the monitor type.

The same monitor type cannot be used to register multiple monitor implementations. No checks are in place to detect this situation and the registration will succeed; however, the registration process of multiple monitor implementations for the same monitor type is not deterministic.

3.3 Monitors

The `monitor` class is the fundamental type of the C++ API: it defines the interface of every monitor and provides common functionality to inheritors of this class.

The public interface of a monitor is the following:

```
class monitor
{
public:
  monitor(std::vector<std::string> paths,
          FSW_EVENT_CALLBACK * callback,
          void * context = nullptr);
  virtual ~monitor();

  monitor(const monitor& orig) = delete;
  monitor& operator=(const monitor & that) = delete;

  void set_properties(
```

```
      std::map<std::string, std::string> options);
    std::string get_property(std::string name);
    void set_latency(double latency);
    void set_allow_overflow(bool overflow);
    void set_recursive(bool recursive);
    void set_directory_only(bool directory_only);
    void add_filter(const monitor_filter &filter);
    void set_filters(
      const std::vector<monitor_filter> &filters);
    void set_follow_symlinks(bool follow);
    void * get_context() const;
    void set_context(void * context);
    void start();
    void add_event_type_filter(
      const fsw_event_type_filter &filter);
    void set_event_type_filters(
      const std::vector<fsw_event_type_filter> &filters);
  }
```

A monitor is thus a type with the following characteristics:

- It cannot be copied.
- It cannot be assigned.
- It is disegned for extension.

3.3.1 Business Interface

The business interface of the `monitor` class is the following:

`void set_properties(std::map<std::string, std::string> options);`
: This function sets a map of monitor-specific properties.

`std::string get_property(std::string name);`
: This function returns the property named `name`.

`void set_allow_overflow(bool allow_overflow);`
: This function sets the allow overflow flag to the specified value. If this flag is set, then the monitor will report a monitor buffer overflow as a change event of type `fsw_event_flag::Overflow`.

`void set_latency(double latency);`
: This function sets the latency of the monitor in seconds. This method only sets the latency value. The exact meaning of latency and how it is enforced depends on a monitor implementation.

`void set_recursive(bool recursive);`
: This function sets the `recursive` flag of the monitor to indicate whether the monitor should recursively observe the contents of directories.

`void set_directory_only(bool directory_only);`
: This function sets the directory only flag to the specified value. If this flag is set, then the monitor will only watch directories during a recursive scan. This functionality is only supported by monitors whose backend fires change events on a directory when one its children is changed. If a monitor backend does not support this functionality, the flag is ignored.

`void add_filter(const monitor_filter &filter);`
: This function adds a `monitor_filter` instance to the filter list of the current monitor.

`void set_filters(const std::vector<monitor_filter> &filters);`
: This function sets the filter list of the current monitor, substituting existing filter if any.

`void set_follow_symlinks(bool follow);`
: This function sets the `follow_symlinks` flag of the monitor to indicate whether the monitor should follow observed symbolic links or observe the links themselves.

`void * get_context() const;`
: This function gest the pointer to the context data that is passed to the callback by the monitor.

`void set_context(void * context);`
: This function sets the pointer to the context data that is passed to the callback by the monitor.

`void start();`
: This function starts the monitor so that it begins listening to file system change events.

`void add_event_type_filter(const fsw_event_type_filter &filter);`
: This function adds a `fsw_event_type_filter` instance to the event type filter list of the current monitor.

`void set_event_type_filters(const std::vector<fsw_event_type_filter> &filters);`
: This function sets the event type filter list of the current monitor, substituting existing filters if any.

3.3.2 Implementing Monitors

`monitor` is a class that declares the following protected functions:

`bool accept_event_type(fsw_event_flag event_type) const`
: This function checks whether the specified `event_type` can be accepted according to the list of event type filters of the monitor.

`bool accept_path(const std::string &path) const`
: This function checks whether the specified `path` can be accepted according to the list of filters of the monitor.

`bool accept_path(const char *path) const`
: This function checks whether the specified `path` can be accepted according to the list of filters of the monitor.

`void notify_events(const std::vector<event> &events) const`
: This function notifies that detection of the specified `events`.

`void notify_overflow(const std::string & path) const`
: This function notifies that the monitor has overflowed. *Overflowing* is a monitor-specific concept and not all monitors experience this behaviour.

`std::vector<fsw_event_flag> filter_flags(const event &evt) const`
: This function filters the list of flags of an event `evt` using the list of event type filters of the monitor. If no filters are set, all the flags are returned.

`virtual void run() = 0`
: This pure virtual function shall contain the logic of a monitor implementation. This function will be invoked by the monitor's `start` API function.

Since it contains a pure virtual function, `run()`, the `monitor` class is abstract. Inheritors are required to provide an implementation of the `run()` function containing the monitor logic and its 'event loop'.

3.3.3 The Anatomy of a Typical Monitor

The anatomy of monitors is typically very similar and it can be illustrated with the following algorithm (written in pseudo-code):

```
void run()
{
  initialize_api();

  while (true)
  {
    scan_paths();
    wait_for_events(latency);

    vector<change_events> evts = get_changes();
    vector<event> events;

    for (auto & evt : evts)
    {
      if (accept(evt.get_path))
      {
```

```
          events.push_back({event from evt});
        }
      }

      if (events.size())
      {
        notify_events(events);
      }
    }
  }
```

Despite being a minimal implementation, this algorithm exemplifies the common tasks performed by a monitor:

- It initializes the API it uses to detect file system change events.
- It enters a loop, often infinite, where change events are waited for.
- It scans the paths that must be observed: this step might be necessary for example because some path may not have existed during the loop's previous iteration, or because some API may require the user to re-register a watch on a path after events are retrieved.
- Events are waited for and the wait should last approximately the *latency* configured into the monitor.
- Events are filtered to exclude those that refer to paths that do not satisfy the filters of the monitor.
- The `notify_events` method is called on the base class to filter the events and notify the caller.

3.4 Events

Events are modeled by the `fsw::event` class, defined in the `event.h` header:

```
class event
{
public:
  event(std::string path,
        time_t evt_time,
        std::vector<fsw_event_flag> flags);
  virtual ~event();

  std::string get_path() const;
  time_t get_time() const;
  std::vector<fsw_event_flag> get_flags() const;

  static fsw_event_flag
    get_event_flag_by_name(const std::string &name);
  static std::string
    get_event_flag_name(const fsw_event_flag &flag);
```

```
  private:
    std::string path;
    time_t evt_time;
    std::vector<fsw_event_flag> evt_flags;
  };
```

The `event` class provides a simple and uniform representation of an event to all the API. An event has got the following characteristics:

- The *path* it relates to.
- The timestamp *evt_time* of the moment the event was raised.
- The list event *flags* (see [Event Flags], page 22).

Currently the API provides no way for monitor implementors to provide additional, monitor-dependent fields to an event. Since the API stores events by value into collections (such as `vector`), an extended event would be *sliced* and additional fields would be lost.

3.4.1 Looking Up Event Types by Name

Event types can be looked up by *name* using the following function:

`fsw_event_flag get_event_flag_by_name(const std::string &name);`

Returns the `fsw_event_flag` instance whose name is *name*. If no instance is found with the specified *name*, this function will throw a `libfsw_exception`.

3.4.2 Getting the Name of an Event Type

The name of an event type can be obtained using the following function:

`static std::string get_event_flag_name(const fsw_event_flag &flag);`

This function returns the name of the specified event type.

Most of the times, the name of an event type is used when writing user output: to ease this task, the `event.h` header defines the following operator overload:

`ostream& operator<<(ostream& out, const fsw_event_flag flag);`

This operator writes the name of the specified `fsw_event_flag` to the stream.

3.5 Path Filters

Path filters are regular expression used to accept or reject file change events based on the value of their path. A filter is represented by the `fsw::monitor_filter` type, defined in the `filter.h` header:

```
  typedef struct monitor_filter
  {
```

```
    std::string text;
    fsw_filter_type type;
    bool case_sensitive;
    bool extended;
  } monitor_filter;
```

and has the following characteristics:

`text` The regular expression used to match paths.

`type` The filter type can either be an *inclusion* or *exclusion* filter.

`case_sensitive`
A flag indicating the filter case sensitivitiy.

`extended` A flag indicating whether `text` is an extended regular expression.

3.5.1 Filter Types

A filter type determine whether the filter regular expression is used to include and exclude paths from the list of the events processed by the library. `libfswatch` processes filters this way:

- If a path matches an including filter, the path is accepted no matter any other filter.
- If a path matches an excluding filter, the path is rejected.
- If a path matches no filters, the path is accepted.

Said another way:

- All paths are accepted by default, unless an exclusion filter says otherwise.
- Inclusion filters may override any other exclusion filter.
- The order in the definition of filters has no effect.

The `fswatch` Info documentation has a user-oriented discussion of how filters are used.

3.6 Event Type Filters

Event type filters let callers filter the events using a specified set of event types. An event type filter is represented by the `fsw_event_type_filter` type, defined in the `cfilter.h` header:

```
typedef struct fsw_event_type_filter
{
  fsw_event_flag flag;
} fsw_event_type_filter;
```

4 The C API

4.1 Overview

The C API, whose main header file is `libfswatch.h`, is a C-compatible lightweight wrapper around the C++ API that provides an easy to use binding to C clients. The central type in the C API is the *monitoring session*, an opaque type identified by a handle of type `FSW_HANDLE` that can be manipulated using the C functions of this library.

Session-modifying API calls (such as `fsw_add_path`) will take effect the next time a monitor is started with `fsw_start_monitor`. Currently not all monitors supports being stopped, in which case `fsw_start_monitor` is a non-returning API call.

4.1.1 Translating the C++ API

The conventions used to translate C++ types into C types are rather common:

- `std::string` is represented as a '`NUL`'-terminated `char *`.
- Lists are represented as arrays whose length is specified in a separate field: `flags_num` indicates how many elements are stored in the array pointed by `flags`.
- More complex types are usually translated as a `struct` containing data fields and a set of functions to operate on it.

4.1.2 Thread Safety

If the compiler and the C++ library used to build `libfswatch` support the `thread_local` storage specified then this API is thread safe and a different state is maintained on a per-thread basis (see [Thread Safety], page 6).

Even when `thread_local` is not available, manipulating different monitoring sessions in different threads concurrently is thread safe, since they share no data.

4.2 Library Initialization

Before calling any library method, the library must be initialized by calling the `fsw_init_library()` function:

```
// Initialize the library
FSW_STATUS ret = fsw_init_library();

if (ret != FSW_OK)
{
  exit(1);
}
```

4.3 Status Codes and Errors

Most API functions return a status code of type `FSW_STATUS` (`error.h` header) which can take any value specified in the `error.h` header. A successful API call returns `FSW_OK` and the last error can be obtained calling the `fsw_last_error()` function. Currently, the following status codes are defined:

`FSW_OK`
`0` The operation completed successfully.

`FSW_ERR_UNKNOWN_ERROR`
`(1 << 0)` An error occurred.

`FSW_ERR_SESSION_UNKNOWN`
`(1 << 1)` The session identified by the specified handle does not exist.

`FSW_ERR_MONITOR_ALREADY_EXISTS`
`(1 << 2)` The session already contains a monitor.

`FSW_ERR_MEMORY`
`(1 << 3)` An error occurred while using a memory management routine.

`FSW_ERR_UNKNOWN_MONITOR_TYPE`
`(1 << 4)` The specified monitor type does not exist.

`FSW_ERR_CALLBACK_NOT_SET`
`(1 << 5)` The callback is not set.

`FSW_ERR_PATHS_NOT_SET`
`(1 << 6)` The paths are not set.

`FSW_ERR_UNKNOWN_MONITOR`
`(1 << 7)` Unused.

`FSW_ERR_MISSING_CONTEXT`
`(1 << 8)` The callback context is missing.

`FSW_ERR_INVALID_PATH`
`(1 << 9)` The path is invalid.

`FSW_ERR_INVALID_CALLBACK`
`(1 << 10)` The callback is invalid.

`FSW_ERR_INVALID_LATENCY`
`(1 << 11)` The latency is invalid.

`FSW_ERR_INVALID_REGEX`
`(1 << 12)` The regular expression is invalid.

`FSW_ERR_MONITOR_ALREADY_RUNNING`
`(1 << 13)` A monitor is already running in the specified session.

`FSW_ERR_STALE_MONITOR_THREAD`
`(1 << 14)` Unused.

`FSW_ERR_THREAD_FAULT`
`(1 << 15)` Unused.

`FSW_ERR_UNSUPPORTED_OPERATION`
`(1 << 16)` Unused.

`FSW_ERR_UNKNOWN_VALUE`
`(1 << 17)` Unused.

`FSW_ERR_INVALID_PROPERTY`
`(1 << 18)` The specified property is invalid.

4.4 Functions

The library `libfswatch.h` header file defines the functions listed in the following table. As seen in See [Status Codes and Errors], page 18, functions return `FSW_OK` if they succeed, otherwise they return an error code. Functions that modify an existing monitoring sessions accept the session handle of type `FSW_HANDLE`.

`FSW_STATUS`
`fsw_init_library()`
: This function initializes the libfswatch library and must be invoked before any other calls to the C or C++ API. If the function succeeds, it returns `FSW_OK`, otherwise the initialization routine failed and the library will not be usable.

`FSW_HANDLE`
`fsw_init_session(const fsw_monitor_type type = system_default_monitor_type)`
: This function creates a new monitor session using the specified monitor and returns an handle to it. This function is the libfswatch API entry point.

`FSW_STATUS`
`fsw_add_path(const FSW_HANDLE handle, const char * path)`
: Adds a path to watch to the specified session. At least one path must be added to the current session in order for it to be valid.

`FSW_STATUS`
`fsw_add_property(const FSW_HANDLE handle, const char * name, const char * value)`
: This function adds a new key-value pair `(name, value)` in the monitor's property map.

`FSW_STATUS`
`fsw_set_allow_overflow(const FSW_HANDLE handle, const bool allow_overflow)`
: Sets the allow overflow flag to the specified value. If this flag is set, monitor buffer overflows will be reported as change events of type `fsw_event_flag::Overflow`.

`FSW_STATUS`
`fsw_set_callback(const FSW_HANDLE handle, const FSW_CEVENT_CALLBACK callback, void * data)`

Sets the callback the monitor invokes when some events are received (see [Callbacks], page 21) and an optional pointer to context data (see [Context Data], page 21). The callback must be set in the current session in order for it to be valid.

`FSW_STATUS`
`fsw_set_latency(const FSW_HANDLE handle, const double latency);`

Sets the latency of the monitor. By default, the latency is set to 1 second.

`FSW_STATUS`
`fsw_set_recursive(const FSW_HANDLE handle, const bool recursive)`

Determines whether the monitor recursively scans each watched path or not. Recursive scanning is an optional feature which could not be implemented by all the monitors. By default, recursive scanning is disabled.

`FSW_STATUS`
`fsw_set_directory_only(const FSW_HANDLE handle, const bool directory_only)`

Sets the directory only flag to the specified value. If this flag is set, then the monitor will only watch directories during a recursive scan. This functionality is only supported by monitors whose backend fires change events on a directory when one its children is changed. If a monitor backend does not support this functionality, the flag is ignored.

`FSW_STATUS`
`fsw_set_follow_symlinks(const FSW_HANDLE handle, const bool follow_symlinks)`

Determines whether a symbolic link is followed or not. By default, symbolic links are not followed.

`FSW_STATUS`
`fsw_add_filter(const FSW_HANDLE handle,const fsw_cmonitor_filter filter)`

Adds a filter to the current session. A filter (see [Filters], page 15) is a regular expression that, depending on whether the filter type is exclusion or not, must or must not be matched for an event path for the event to be accepted.

`FSW_STATUS`
`fsw_add_event_type_filter(const FSW_HANDLE handle, const fsw_event_type_filter event_type)`

Adds an event type filter to the current session. A filter (see [Event Type Filters], page 16) contains the *name* of the event type to include into the output. A session may contain multiple event type filters.

`FSW_STATUS`
`fsw_start_monitor(const FSW_HANDLE handle)`
Starts the monitor if it is properly configured. Depending on the type of monitor this call might return when a monitor is stopped or not.

`FSW_STATUS`
`fsw_destroy_session(const FSW_HANDLE handle)`
Destroys an existing session and invalidates its handle.

`FSW_STATUS`
`fsw_last_error()`
Gets the last error code.

`bool`
`fsw_is_verbose()`
Check whether the verbose mode is active.

4.5 Callbacks

When a monitor receives change events satisfying all the session criteria, a callback provided by the user is invoked and passed a copy of the events; a function pointer of type `FSW_CEVENT_CALLBACK` is used by the API as a callback:

```
typedef void (*FSW_CEVENT_CALLBACK)(
  fsw_cevent const * const events,
  const unsigned int event_num,
  void * data);
```

The callback is passed the following arguments:

- `events`, a const pointer to an array of events of type `const fsw_cevent`.
- `event_num`, the size of the `*events` array.
- `data`, a pointer to an optional user-provided context.

The memory used by the `fsw_cevent` objects will be freed at the end of the callback invocation. A callback should copy such data instead of storing a pointer to it.

4.5.1 Context Data

A *context* may be passed to the callback when events are received. Context data may be useful to easily associate a 'state' to each monitoring session. A monitoring session does *not* acquire ownership of the context data pointer; therefore, the following are responsibilities of the caller:

- To keep the pointer valid throughout the life of a monitoring session that shares this pointer.

- To free the pointed memory *after* when the pointer is not shared with any monitoring session any longer.

4.6 Memory Management Functions

The C API published by the `libfswatch` library contains some memory management routines. These functions, defined in the `libfswatch_mem.h` header file, are the following:

`void * fsw_alloc(size_t size)`
: This function allocates a chunk of memory of the specified *size* and returns a pointer to it. If the memory could not be allocated, `nullptr` is returned instead.

`void fsw_free(void * ptr)`
: This function frees the memory pointed by *ptr*.

`fsw_free`

4.7 Events in the C API

The C API represents events as instances of the `fsw_cevent` structure (`cevent.h`) which is an exact translation of the `fsw:event` type (see [Events], page 14) where C++ types and collections are represented by C friendly equivalent types:

```
typedef struct fsw_cevent
{
  char * path;
  time_t evt_time;
  fsw_event_flag * flags;
  unsigned int flags_num;
} fsw_cevent;
```

4.8 Event Flags

Events flags are `enum` values shared by both the C++ and the C API and they are defined in the `cevent.h` header. The values of event flags are power of 2, that is numbers f in the form $f = 2^n$ where n is an integer. This representation makes it easy to combine flags into a bit mask and encode multiple events flags into a single integer. The `fsw_event_flag` enumeration currently includes the following values:

`NoOp`
`0`
: This event flag is used as a marker.

`PlatformSpecific`
`1 << 0`
: This event flag represents a platform-specific flag that is not encoded as any other event flag by the API.

`Created`
`1 << 1` This event flag represents a file creation creation event.

`Updated`
`1 << 2` This event flag represents a file update update event.

`Removed`
`1 << 3` This event flag represents a file removal event.

`Renamed`
`1 << 4` This event flag represents a file rename event.

`OwnerModified`
`1 << 5` This event flag represents a file owner modification event.

`AttributeModified`
`1 << 6` This event flag represents a file attribute modification event.

`MovedFrom`
`1 << 7` This event flag represents a file rename event.

`MovedTo`
`1 << 8` This event flag represents a file rename event.

`IsFile`
`1 << 9` This event flag indicates that the modified object is a regular file.

`IsDir`
`1 << 10` This event flag indicates that the modified object is a directory.

`IsSymLink`
`1 << 11` This event flag indicates that the modified object is a symbolic link.

`Link`
`1 << 12` This event flag represents a file link event.

`Overflow`
`1 << 13` This event flag represents a monitor buffer overflow.

A monitor implementation is required to map implementation-specific flags into API flags. Sometimes, though, a perfect match is not possible and the following situation may arise:

- One platform-specific flags must be mapped into multiple API flags.
- Multiple platform-specific flags must be mapped into a single API flag.
- A mapping is not possible for some flags, in which case they should be mapped to the `PlatformSpecific` API flags. The API currently offers no way to retain a platform-specific event flag value in this case.

The `cevent.h` header also defines the following utility functions:

`fsw_event_flag fsw_get_event_flag_by_name(const char * name);`

This function looks for a `fsw_event_flag` instace with the specified *name*. If a matching event type is not found, this function will return a negative number.

`char * fsw_get_event_flag_name(const fsw_event_flag flag);`

This function returns a `char *` pointer to the name of the specified event type, *flag*, or `nullptr` if an error occurs. The memory pointed by the return value of this function should be freed with a call to `fsw_free` (see [Memory Management Functions], page 22).

4.9 Filters in the C API

The C API represents filters (see [Filters], page 15) as instances of the `fsw_cmonitor_filter` structure, defined in the `cfilter.h` header. This structure is a translation of the `monitor_filter` class using C equivalent types:

```
enum fsw_filter_type
{
  filter_include,
  filter_exclude
};

typedef struct fsw_cmonitor_filter
{
  char * text;
  fsw_filter_type type;
  bool case_sensitive;
  bool extended;
} fsw_cmonitor_filter;
```

4.10 Monitor Types

The `fsw_monitor_type` enumeration, defined in the `cmonitor.h` header, contains a list of monitor types built into the `libfswatch` library:

```
enum fsw_monitor_type
{
  system_default_monitor_type = 0,
  fsevents_monitor_type,
  kqueue_monitor_type,
  inotify_monitor_type,
  windows_monitor_type,
  poll_monitor_type
};
```

Members of this enumeration may be used with factory methods (see [Monitor Discovery], page 9 provided by the API to request a monitor of a specific type. The members of this enumeration must be known at compile time.

4.11 Logging

The `libfswatch` library never writes any output to the standard streams, unless the *verbose* mode is set: in this mode, diagnostic information is written to standard error. The library offers a set of logging functions to ease the task of conditionally writing both literal and formatted messages to the output, when the verbose flag is set.

4.11.1 Logging functions

`void fsw_log(const char * msg)`
: This function prints the specified message `msg` literally to the standard output.

`void fsw_flog(FILE * f, const char * msg)`
: This function prints the specified message `msg` literally to the file `f`.

`void fsw_logf(const char * format, ...);`
: This function prints and formats the specified message `format` to the standard output.

`void fsw_flogf(FILE * f, const char * format, ...)`
: This function prints and formats the specified message `format` to the file `f`.

`void fsw_log_perror(const char * msg)`
: This function prints the specified message `msg` using `perror`.

`void fsw_logf_perror(const char * format, ...)`
: This function prints the `printf`-compatible message using `perror`.

4.11.2 Logging macros

The `libfswatch` library provides a set of macros that can be used to print diagnostic messages containing the name of the method where the macro is called from. The format of a message `msg` printed using one of these macros from inside a function called `func` will be similar to:

```
func: msg
```

`FSW_LOG(msg)`
: This macro prints to standard output the name of the function this macro is called from followed by the message `msg`.

`FSW_ELOG(msg)`
: This macro prints to standard error the name of the function this macro is called from followed by the message `msg`.

`FSW_LOGF(msg, ...)`
: This macro prints to standard output the name of the function this macro is called from followed by the message `msg`, formatted using the specified arguments.

`FSW_ELOGF(msg, ...)`
: This macro prints to standard error the name of the function this macro is called from followed by the message `msg`, formatted using the specified arguments.

`FSW_FLOGF(f, msg, ...)`
: This macro prints to the specified file the name of the function this macro is called from followed by the message `msg`, formatted using the specified arguments.

4.12 Example

This is a basic example of how a monitor session can be constructed and run using the C API. To be valid, a session needs at least the following information:

- A *path* to watch.
- A *callback* to process the events sent by the monitor.

The next code fragment shows how to create and start a basic monitoring session (error checking code was omitted):

```
// Initialize the library
fsw_init_library();

// Use the default monitor.
const FSW_HANDLE handle = fsw_init_session();
fsw_add_path(handle, "my/path");
fsw_set_callback(handle, my_callback);

fsw_start_monitor(handle);
```

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Appendix B Index of Functions

The `fsw::` and `std::` prefixes have been dropped by function names in the following index.

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Appendix C Index of Data Types

The `fsw::` prefix has been dropped by function names in the following index.

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