libqsearch
A library designed for fast multiple pattern matching

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Outline

- What is libqsearch ?
  - Presentation
  - History
  - Architecture
- Details
  - API
  - Algorithms
  - The whole picture
- Other stuff
  - Test suite
  - Kernel
- Conclusion

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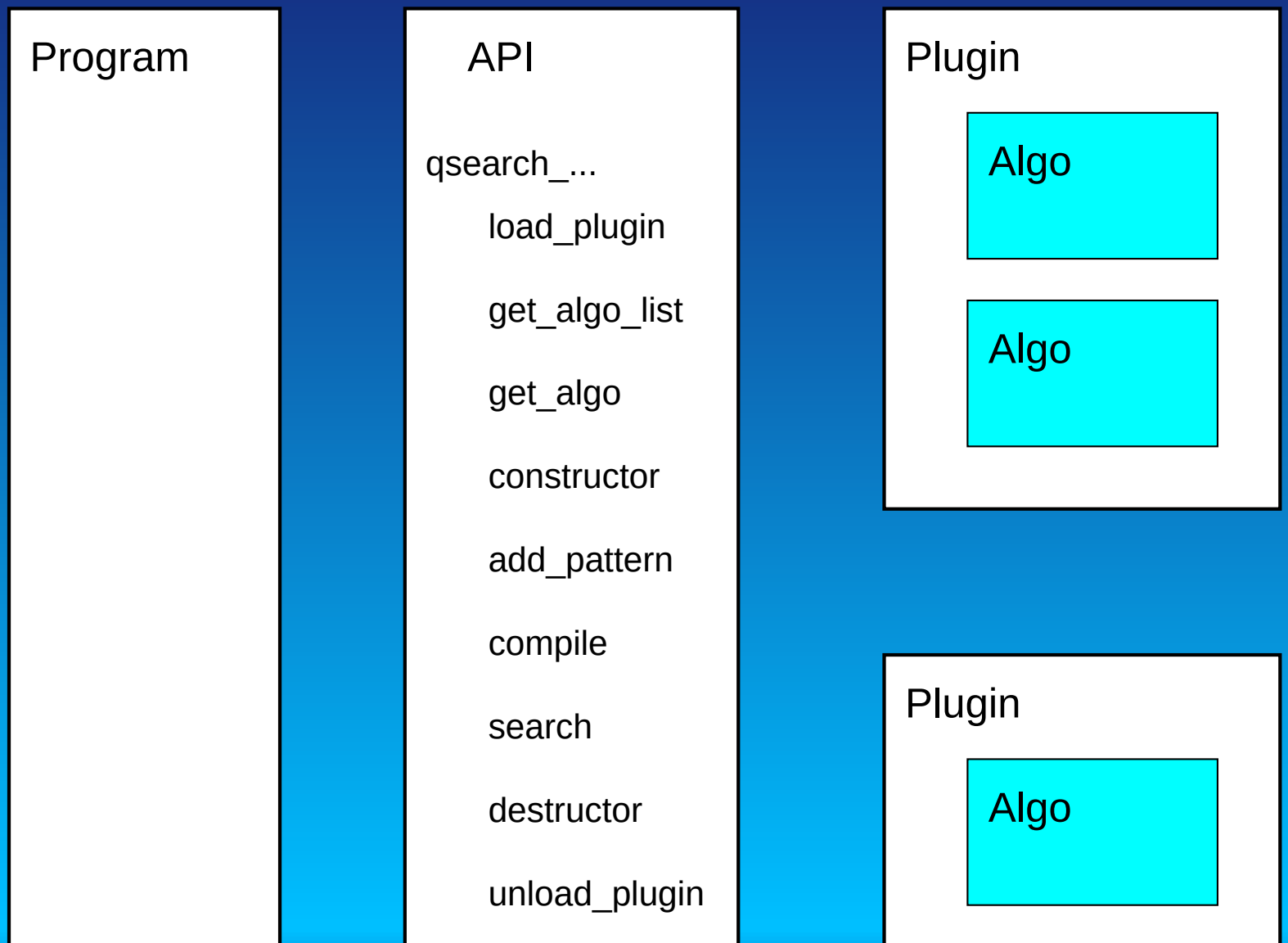
- Lots of programs (IDS, antivirus, . . .) need to
  - search for a lot of patterns at the same time
  - search in a stream splitted in parts (TCP payloads, split in buffers. . .)
  - . . .
- Algorithms exist but one can’t be good at everything (long patterns, lots of patterns, regexps, . . .)

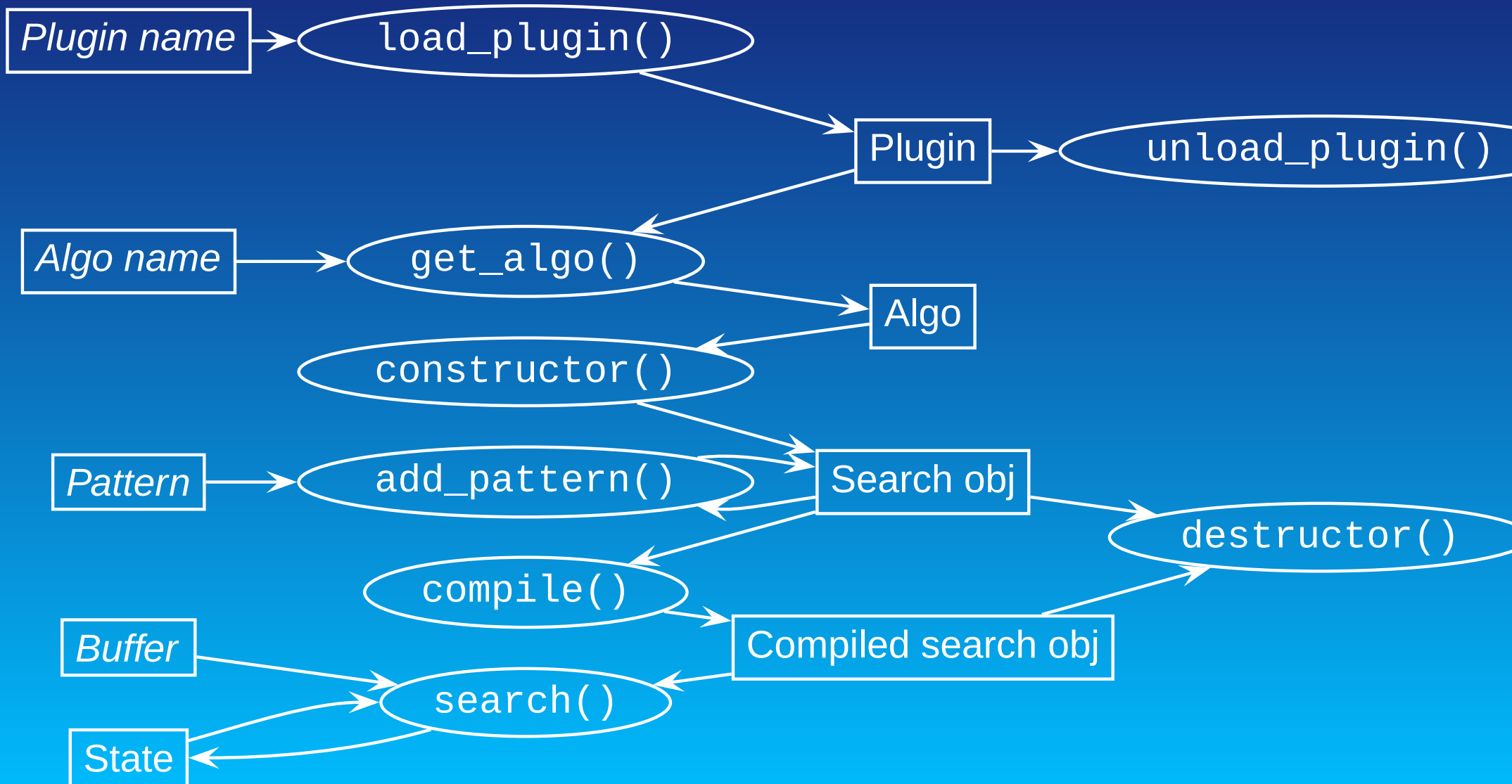
- libqsearch's aim is to provide many algorithms with one interface
- Programmed in C
- Patterns can have a type (case (in)sensitive, use jokers, . . .)
- Search for multiple patterns in one call
- Types of patterns can be mixed in the same search
- Call a callback for each match
- Use states to summarize the past of a stream
  - ↪ patterns splitted between 2, 3,. . . buffers are transparently found
  - ↪ states can be saved to carry on a search at a given point of the stream (rollback, TCP packet scanned but finally cancelled by the target, . . .)

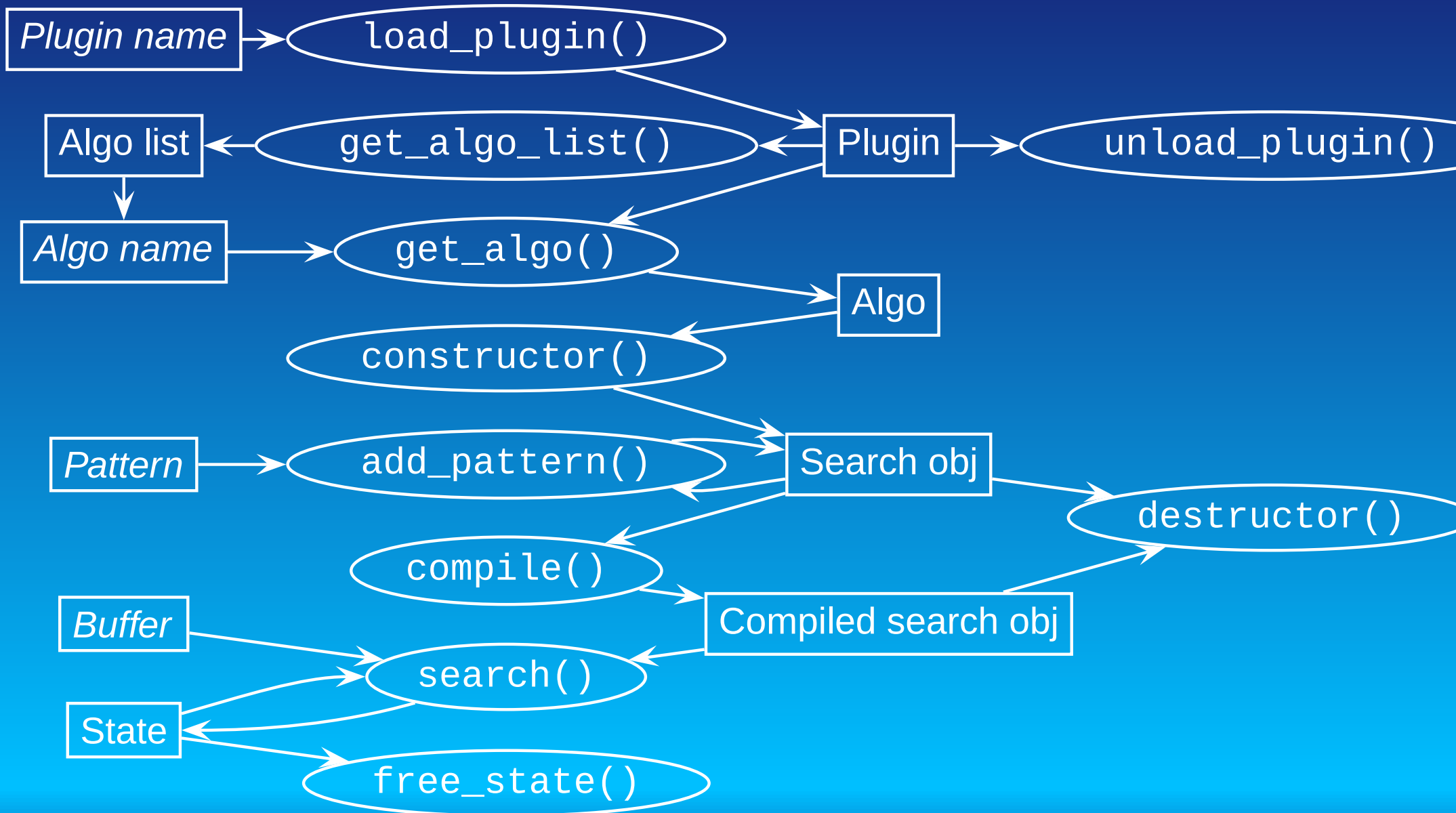
- Nicolas Brulez (<brulez@cartel-securite.fr>) began to write an open source antivirus
- In complement of his heuristic engine, he needed to search lots of signatures
- I wanted to implement a DFA that would recognize multiple patterns at once (phantasm #7)
- The first “fast search experiment” was born : a python program that generated C or ASM code from a list of patterns
- This experiment was submited to Prelude IDS core team
- Yohann Vandoorselaere convinced me to write a quick search library that could be used by Prelude, and help me build libqsearch API specifications.
- libqsearch was born

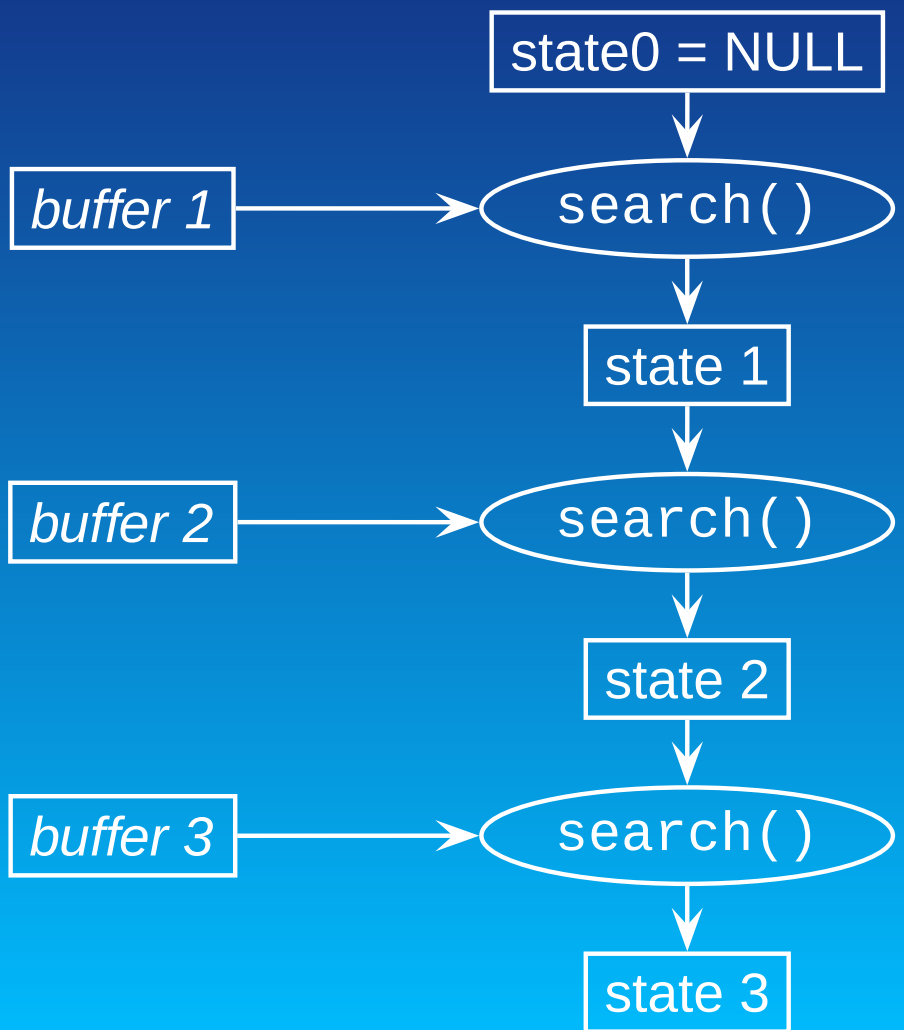
- Romain Françoise from Arkoon asked me about the portability of libqsearch into Linux kernel
- I ported libqsearch API and plugins to the Linux kernel
- libqsearch is waiting to be used, and for plugins to be contributed :-)

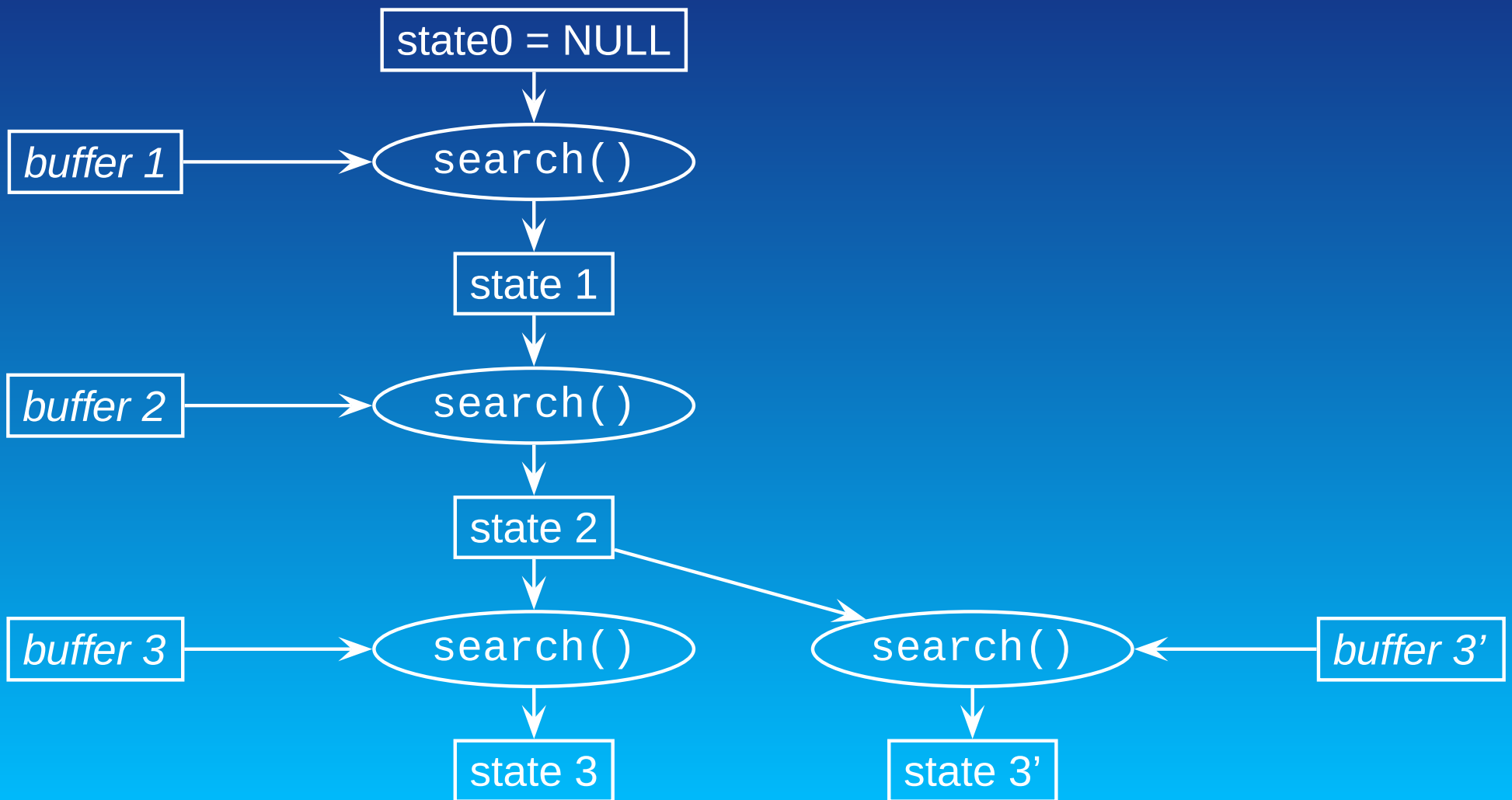

Program
API
qsearch_...
load_plugin
get_algo_list
get_algo
constructor
add_pattern
compile
search
destructor
unload_plugin
Plugin
Algo
Algo
Plugin
Algo

- To use libqsearch, we need to manipulate 4 entities
  - `qsearch_obj_t`: the search object, which we submit patterns to, compile and search
  - `qsearch_algo_t`: the algorithm, which can be instanciated to a search object
  - `qsearch_plugin_t`: the plugin, which can contain many algorithms.
  - `qsearch_state_t`: the state of a search, that summarize the past of a stream


Plugin name
load_plugin()
Plugin
unload_plugin()
Algo name
get_algo()
Algo
constructor()
Pattern
add_pattern()
Search obj
destructor()
compile()
Compiled search obj
Buffer
search()
State


Plugin name
load_plugin()
Algo list
get_algo_list()
Plugin
unload_plugin()
Algo name
get_algo()
Algo
constructor()
Pattern
add_pattern()
Search obj
destructor()
compile()
Buffer
Compiled search obj
search()
State
free_state()


state0 = NULL
buffer 1
search()
state 1
buffer 2
search()
state 2
buffer 3
search()
state 3


state0 = NULL
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search()
state 2
buffer 3
search()
state 3
search()
buffer 3'
state 3'

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- To do a search :
  - Load the plugin, given its name (`qsearch_load_plugin()`)
  - Get an algo from the plugin, given its name (`qsearch_get_algo()`)
  - Instanciate a search object from the algo (`qsearch_constructor()`)
  - Add patterns to the search object (`qsearch_add_pattern()` for each pattern)
  - Compile the set of patterns (`qsearch_compile()`)
  - Look for the patterns in buffers (`qsearch_search()`)
  - Destruct the `search_object` (`qsearch_destructor()`)
  - Unload the plugin (`qsearch_unload_plugin()`)

```
qsearch_plugin_t *qsearch_load_plugin(const char *name);
```

- This function look for a plugin from its name
- user space implementation : search it in the plugin directory if <name> does not contain any '/'
- kernel space implementation : if not already registered, try to load the module `qsearch_`*`name`*
- returns a `(qsearch_plugin_t *)` or NULL if there was an error.

```
int qsearch_unload_plugin(qsearch_plugin_t *plugin);
```

- This function will unload a previously loaded plugin
- Don’t forget to free each search object and state related to algorithm from this plugin

```
qsearch_algo_t **qsearch_get_algo_list(
                                qsearch_plugin_t *plugin);
```

- returns a NULL terminated list of algorithms provided by the plugin

```
qsearch_algo_t *qsearch_get_algo(qsearch_plugin_t *plugin,
                                 char *name);
```

- returns an algorithm provided by the plugin, being given the algorithm name
- returns NULL if the plugin does not contain such an algorithm.

```
qsearch_obj_t *qsearch_constructor(qsearch_algo_t *algo,
                                   qsearch_options_t *options);
```

- instantiate an algorithm.
- you can instantiate as many search objects as you want from the same algorithm
- the options are not used yet
- returns NULL if error

```
int qsearch_destructor(qsearch_obj_t *self);
```

- destructs a previously instantiated search object
- returns non-zero if error

```
int qsearch_add_pattern(qsearch_obj_t *self, char *pattern,
                        int len, void *ptrn_data, int type);
```

- adds a pattern for it to be looked for later
- Each pattern must be given a type
  - There are for the moment 5 types :

```
#define QSEARCH_CS         0 /* normal case sensitive pattern */
#define QSEARCH_CI         1 /* case insensitive pattern */
#define QSEARCH_JOKER_CS   2 /* pattern using '*' for any char */
#define QSEARCH_JOKER_CI   3 /* pattern using '*' for any char */
#define QSEARCH_REGEXP     4 /* regular expression */
```

  - an algorithm may or may not support a given type
  - if not supported, returns `-QEBADTYPE`.
- per-pattern data pointer : each time a pattern matches, a callback will be called with the related `ptrn_data`.
- returns non-zero if error.

```
int qsearch_compile(qsearch_obj_t *self);
```

- patterns can’t be looked for before.
- once every patterns have been added, the search object can be compiled
- no more patterns can be added after that
- Returns non-zero if error.

```
int qsearch_search(qsearch_obj_t *self,
                   qsearch_state_t *state_in,
                   qsearch_state_t **state_out,
                   qsearch_state_t *state_io,
                   qsearch_callback_t cb, void *cb_data,
                   void *buffer, size_t len);
```

- Once every patterns are added and the search object is compiled, we can look for patterns in a buffer.
- If an algo does not implement the states management, `qsearch_search()` will return an error (`-QESTATES`) if `state_in` or `state_out` are not NULL before doing any search.

- The search can be stateful. 2 ways to do that :
  - use `state_in` and `state_out`, `state_io` is always NULL.
    - the function will put a summary of the past search session in `state_out`
    - `state_out` will be used as `state_in` in the next call
    - the very first search will be given NULL as `state_in`.
    - memory used by `state_out` is allocated by `qsearch_search()`, but you have to free it with `qsearch_free_state()`
    - `state_in` is neither modified nor destructed
  - allocate a `state_io` variable with `qsearch_alloc_io_state()`
    - it will be as both `state_in` and `state_out`
    - it can save the time of malloc/free
    - you won't be able to replay searchs

```
typedef int (*qsearch_callback_t)(void *cb_data,
            void *ptrn_data, size_t match_offset);
```

- When a match occurs : the provided callback will be called with
  - the position of the match
  - the per-pattern data pointer (`qsearch_add_pattern()`)
  - the call-back data pointer (`qsearch_search()`).
- If the search is stateful, the match position is absolute
- else, it's relative to the begining of the current buffer
- the position of the match points the end of the pattern.
  position of "abc" in "abcd" will be 3.

- the callback function return
  - 0 $\Longrightarrow$ the search will carry on
  - other $\Longrightarrow$ the search ends, the return value is returned by `qsearch_search()`.
- if `qsearch_search()` raises an error, it will return a negative value.
- to distinguish callback return value and `qsearch_search()` return value, the callback should only return positive values.

```
int qsearch_free_state(qsearch_obj_t *self,
                       qsearch_state_t *state);
```

- free a state allocated by `qsearch_search()`.

```
int qsearch_check_pattern_type(qsearch_obj_t *self,
                               int type);
```

- check if a pattern type is supported by a search object
- return 0 if the pattern type is supported

- To write a new plugin
  - you can start with the skeleton plugin
  - you have to follow some rules

- Rules
  - you SHOULD support both states mechanisms.
    - If `state_io` not supported, `alloc_io_state()` must return `-QESTATES`
    - If supported, position of match MUST be absolute from the begining of the stream
    - If not supported you MUST return `-QESTATES` when searching with non NULL `state_in|out|io`.
  - the position of a match MUST point to the end of the pattern (ex: the position of "`abc`" in "`abcd`" is 3)
  - you SHOULD support as many types as possible
  - you MUST permit to mix the pattern types you support
  - you MUST NOT use `#include` directive
  - you MUST NOT use external libs not allowed by libqsearch

- Kind of object programming
  - Algorithms are classes
  - Search objects are instances of algorithms
  - `add_pattern()`, `compile()`, `search()`, `...`, are methods of search objects

```
int qsearch_compile(qsearch_obj_t *self)
{
        return (*self->statics->compile)(self);
}

int qsearch_alloc_io_state(qsearch_obj_t *self, qsearch_state_t **state)
{
        return (*self->statics->alloc_io_state)(self, state);
}

int qsearch_free_state(qsearch_obj_t *self, qsearch_state_t **state)
{
        return (*self->statics->free_state)(self, state);
}

int qsearch_destructor(qsearch_obj_t *self)
{
        return (*self->statics->destructor)(self);
}
```

```
static skeleton_algo_t algo_skeleton = {
        "skeleton",
        "This is an example",
        1<<QSEARCH_CS | 1<<QSEARCH_CI | 1<<QSEARCH_JOKER_CS | 1<<QSEARCH_JOKER_CI ,
        &skeleton_constructor,
        &skeleton_destructor,
        &skeleton_add_pattern,
        &skeleton_compile,
        &skeleton_search,
        &skeleton_alloc_io_state,
        &skeleton_free_state,
};

skeleton_algo_t *QSEARCH_ALGO_LIST_SYM[] = {
        &algo_skeleton,
        NULL
};
```

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- The test suite program is used to
  - test the accuracy of algorithms
  - in the future : do speed benchmarks
- The test suite program loads the specified plugin, and tests the specified (or all) algo
- Each accuracy test provides
  - patterns to be looked for (with their type)
  - a test sample in which patterns can be looked for
  - for each pattern: where it should have been found in the sample

- The config file contains the list of tests

```
accuracy "ci" {
        info "one pattern case insensitive search";
        patterns "abcd":CI;
        sample  "..abcd..ABCD..AbCd..aBcD..";
        results "00000100000100000100000100";
};

accuracy "mixed" {
        info "mixed pattern types";
        patterns {
                "abc":CS;
                "abcd":CI;
        };
        sample    "..abcd..ABCD..AbCd..abcD..";
        results { "00001000000000000000001000";
                  "00000100000100000100000100";
        };
};
```

- For each accuracy test, the search object is feeded with the sample been splitted up in 1 octet pieces, then in 2 octets, . . . , then with the whole sample at once.
  - ↪ This enables the detection of some hard off-by-one bugs in algorithms implementations

- Kernelize script
  - apply a small patch
    - to modify main Makefile
    - to include new compilation menu options
    - to add an init call in misc devices (for the test module)
  - copy the `qsearch` directory (API kernel implementation) into the kernel dir
  - for each plugin
    - copy the plugin
    - generate a wrapper and a Makefile
    - add a line in the config menu
  - generate the qsearch main Makefile

- Result :

```
<M> Kernel QSearch support
--- Algorithms
<M>   skeleton
<M>   simple
<M>   bm
--- Tools
<M>   QSearch test module
```

```
#define PLUGIN "@PLUGIN_NAME@"

#define malloc(x) kmalloc(x, GFP_KERNEL)
#define free(x) kfree(x)

[...]

#include PLUGIN ".c"
[...]

MODULE_AUTHOR("Philippe Biondi <biondi@cartel_securite.fr>");
MODULE_DESCRIPTION("libqsearch kernel wrapper for " PLUGIN " plugin");
MODULE_LICENSE("GPL");

[...]

#ifdef MODULE
int init_module(void)
[...]
void cleanup_module(void)
[...]
```

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- libqsearch is fully functionnal
- 3 plugins :
  - skeleton (does not find anything)
  - simple one
  - Boyer-Moore-like with CS/CI/JokerCS/JokerCI support
- a test suite
- fully functionnal in kernel space
- a test module and tools to check the API from user space
- very good performances

That's all folks. Thanks for your attention.

You can reach me at **<phil@lids.org>**

These slides are available at
http://www.cartel-securite.fr/pbiondi/

libqsearch is available at
http://www.cartel-securite.fr/pbiondi/libqsearch.html
or

```
cvs
  -d:pserver:anonymous@cvs.prelude-ids.org:/cvsroot/prelude
   co libqsearch
```