

# State Machine Generator

## User Manual

System Documentation

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# 1 Overview

This tool generates a safety-critical Hierarchical State Machine (HSM) from a YAML/SMB definition file. It supports three output languages — **Rust**, **C**, and **Python** — and includes advanced features such as orthogonal regions (parallelism), history patterns, decision trees, and fork transitions.

The generator also produces a **Graphviz DOT** file for visualizing the state machine diagram.

## 2 Generating the Code

The generator is a Python script (`sm-compiler.py`) that validates your model and produces code in the selected target language.

```
# Language is read from the 'language:' key in the .smb file
uv run python sm-compiler.py model.smb

# Override the language
uv run python sm-compiler.py model.smb --lang rust
uv run python sm-compiler.py model.smb --lang c

# Custom output base path (extensions added automatically)
# Produces build/myfsm.rs and build/myfsm.dot
uv run python sm-compiler.py model.smb -o build/myfsm
```

Listing 1: Command Line Usage

### 2.1 Command Line Options

Option	Default	Description
<code>file</code>	(required)	Path to the input <code>.smb</code> file.
<code>--lang</code>	from file	Output language: <code>rust</code> , <code>c</code> , or <code>python</code> . If omitted, reads the <code>language:</code> key from the SMB file (defaults to <code>rust</code> if absent). The <code>language:</code> key may be a list, in which case code is generated for all listed languages.
<code>-o, --output</code>	<code>./statemachine</code>	Output base path without extension. Language-specific extensions ( <code>.rs</code> , <code>.c</code> , <code>.h</code> , <code>.py</code> , <code>.dot</code> ) are appended automatically. Parent directories are created if needed.

### 2.2 Outputs

Given `-o path/to/name`, the following files are produced:

Language	Output Files	Description
Rust	<code>name.rs</code>	Complete Rust implementation (single file).
C	<code>name.h, name.c</code>	Header with struct/function declarations and source with implementation. The <code>.c</code> file includes <code>name.h</code> automatically.
Python	<code>name.py</code>	Complete Python implementation (single file). Import with <code>from name import StateMachine</code> .

Language	Output Files	Description
All	name.dot	Graphviz visualization of the state machine.

### 3 SMB File Structure

The input file uses YAML syntax with the extension `.smb`. A complete model has this top-level structure:

```

language: rust          # Target language (rust, c, or python)

includes: |           # Code placed before the Context struct
    // imports, helper functions, etc.

context: |             # User-defined fields for the Context struct
    pub counter: i32,   # (Rust syntax)
    pub flag: bool,

context_init: |         # Initialization code for context fields
    counter: 0,        # (Rust: struct init syntax)
    flag: true,

hooks:                 # Global code injected into all states
    entry: |
        // runs on every state entry
    exit: |
        // runs on every state exit
    do: |
        // runs on every state tick
    transition: |
        // runs on every transition

initial: first_state   # Name of the initial child state

states:
    first_state:
        # ... state definition ...

```

Listing 2: Top-level SMB structure

#### 3.1 Language-Specific Syntax

Since `includes`, `context`, `context_init`, guards, and actions contain raw target-language code, they must use the syntax of the selected output language:

Element	Rust	C	Python
Context access	<code>ctx.field</code>	<code>ctx-&gt;field</code>	<code>ctx.field</code>
Context fields	<code>pub field: Type,</code>	<code>Type field;</code>	<code>field: Type (annotation)</code>
Context init	<code>field: value,</code>	<code>sm-&gt;ctx.field = value;</code>	<code>ctx.field = value</code>
Print	<code>println!("...")</code>	<code>printf("...\n")</code>	<code>print("...")</code>
String type	<code>&amp;str</code>	<code>const char*</code>	<code>str</code>
Boolean	<code>bool</code>	<code>bool (via stdbool.h)</code>	<code>bool</code>
True/False	<code>true/false</code>	<code>true/false</code>	<code>True/False</code>
Logical OR	<code>  </code>	<code>  </code>	<code>or</code>

Element	Rust	C	Python
Logical AND	<code>&amp;&amp;</code>	<code>&amp;&amp;</code>	<code>and</code>

## 4 Integration & API

### 4.1 Rust Integration

The generated code provides a `StateMachine` struct. You must initialize it and call `tick()` cyclically.

```
mod statemachine;
use statemachine::StateMachine;

fn main() {
    let mut sm = StateMachine::new();

    while sm.is_running() {
        sm.ctx.now += 0.1; // Advance logical time
        sm.tick();
        println!("State: {}", sm.get_state_str());
        std::thread::sleep(std::time::Duration::from_millis(100));
    }
}
```

Listing 3: Example Rust driver (main.rs)

### Rust API

Function	Location	Description
<code>StateMachine::new()</code>	constructor	Creates and starts the state machine.
<code>sm.tick()</code>	<code>sm</code>	Executes one cycle of logic (do-activities & transitions).
<code>sm.is_running()</code>	<code>sm</code>	Returns <code>false</code> if the machine has terminated.
<code>sm.get_state_str()</code>	<code>sm</code>	Returns a string like <code>/run/active</code> or <code>/p/[a/x,b/y]</code> .
<code>ctx.in_state_X()</code>	<code>ctx</code>	Returns <code>true</code> if state X is currently active.

### 4.2 C Integration

The generated code provides a `StateMachine` struct with an `SM_Context` inside. Use the provided API functions.

Listing 4: Example C driver (main.c)

```
#include "statemachine.h"
#include <stdio.h>
#include <unistd.h>

int main(void) {
    StateMachine sm;
    sm_init(&sm);
```

```

char state_buf[256];

while (sm_is_running(&sm)) {
    sm_tick(&sm);
    sm_get_state_str(&sm, state_buf, sizeof(state_buf));
    printf("State: %s\n", state_buf);
    usleep(100000);
}

return 0;
}

```

Compile with:

```
gcc main.c statemachine.c -o my_program
```

## C API

Function	Description
<code>sm_init(StateMachine* sm)</code>	Initializes context (zeroes memory, applies initial state).
<code>sm_tick(StateMachine* sm)</code>	Executes one cycle of logic.
<code>sm_is_running(StateMachine* sm)</code>	Returns <code>true</code> if the machine has not terminated.
<code>sm_get_state_str(StateMachine* sm, char* buf, size_t max)</code>	Writes the current state path into <code>buf</code> .
<code>IN_STATE_X</code>	Macro: evaluates to <code>true</code> if state X is current inside guards and actions where <code>ctx</code> is in.

## 4.3 Python Integration

The generated code provides a `StateMachine` class. No compilation needed — run directly with Python 3.

Listing 5: Example Python driver

```

from statemachine import StateMachine

sm = StateMachine()
print(sm.get_state_str())

while sm.is_running():
    sm.tick()
    sm.ctx.counter += 1
    print(f"{sm.ctx.counter:02d}:{sm.get_state_str()}")

```

Run with:

```
python3 driver.py
```

## Python API

Method / Attribute	Description
<code>StateMachine()</code>	Creates and initializes the state machine. Enters the initial state.
<code>sm.tick()</code>	Executes one cycle of logic.
<code>sm.is_running()</code>	Returns <code>True</code> if the machine has not terminated.
<code>sm.get_state_str()</code>	Returns the current state path as a string.
<code>sm.ctx</code>	Direct access to the <code>Context</code> object (read/write fields).
<code>ctx.in_state_X()</code>	Returns <code>True</code> if state X is currently active.

**Note:** Python uses `None` for empty function pointers and first-class functions for state callbacks. The `context_init` code uses `ctx.field = value` syntax, where `ctx` is an alias for `self` inside the `Context.__init__` method.

## 4.4 Context Struct

All backends generate a `Context` struct or class (Rust: `Context`, C: `SM_Context`, Python: `Context`) containing:

- `now`: Logical time (`f64/double`). You update this before each tick.
- `state_timers[]`: Per-state entry timestamps (set automatically on entry).
- `transition_fired`: Safety flag for orthogonal regions (managed automatically).
- `terminated`: Set when a `null` transition fires (managed automatically).
- Hierarchy pointers: Function pointers tracking the active state at each level (managed automatically).
- User fields: Whatever you declare in the `context:` block.

## 5 Writing Logic: Handlers vs. Hooks

### 5.1 Local Handlers (Per State/Transition)

These are defined inside specific states or transitions in the YAML. They apply only to that specific element.

- `entry`: Runs once when entering the specific state.
- `do`: Runs every tick while in the specific state.
- `exit`: Runs once when leaving the specific state.
- `action`: Runs during a specific transition (see Section 6).

### 5.2 Global Hooks (System-wide)

Hooks are defined at the root level under the `hooks:` key. They inject code into **every** occurrence of an event type across the entire machine (e.g., for logging).

Hook Key	Trigger Event
<code>hooks: entry</code>	Injected into <b>all</b> states' entry handlers.

Hook Key	Trigger Event
hooks: do	Injected into <b>all</b> states' do handlers.
hooks: exit	Injected into <b>all</b> states' exit handlers.
hooks: transition	Injected into <b>all</b> transitions (equivalent to a global action).

**Note:** There is no hooks: action. Use hooks: transition instead.

### 5.3 Available Variables in Code Blocks

The following variables are injected into the scope of your code snippets. Use the appropriate syntax for your target language.

Variable	Scope	Description
ctx	All	The shared context struct. Rust: <code>&amp;mut Context</code> . C: <code>SM_Context*</code> . Python: <code>Context</code> instance.
time	All	Time elapsed (seconds) since entering the current state ( <code>f64/double</code> ).
state_name	All	Short name of the current state (e.g., "idle").
state_full_name	All	Full path of the current state (e.g., "/run/idle").
t_src	Transitions	The full path of the source state.
t_dst	Transitions	The full path/description of the target.

## 6 Transitions

A transition determines how the machine moves between states.

### 6.1 Basic Transition Syntax

```
transitions:
- guard: ctx.counter == 5      # Condition (target language expression)
  action: |                      # Code executed during the transition
    // runs BEFORE exit/entry sequence
  to: target_state               # Where to go
```

Listing 6: Transition syntax

All three fields are optional:

- Omitting `guard` makes the transition unconditional (`true`).
- Omitting `action` means no transition-time code.
- `to: null` triggers machine termination.

### 6.2 Transition Execution Order

When a transition fires:

1. Evaluate the `guard` condition.

2. Set `transition_fired = true`.
3. Execute `action` code (if any).
4. Execute the exit sequence (from current state up to the Least Common Ancestor, bottom-up).
5. Execute the entry sequence (from LCA down to target state, top-down).

### 6.3 Using Actions (The Mealy Aspect)

The `action` keyword allows you to execute code *during* the transition, before the old state is exited.

```
states:
reading:
  transitions:
    - guard: ctx.value > 100
      action: |
        println!("Moving {}->{}", t_src, t_dst);
        ctx.log_alert("Threshold_Exceeded");
    to: alert_mode
```

Listing 7: Rust example using action variables

```
states:
reading:
  transitions:
    - guard: ctx->value > 100
      action: |
        printf("Moving %s->%s\n", t_src, t_dst);
        log_alert(ctx, "Threshold_Exceeded");
    to: alert_mode
```

Listing 8: C example using action variables

### 6.4 Path Syntax

The `to:` keyword supports several addressing modes:

Syntax	Description
<code>/absolute/path</code>	From the root. Use for long jumps across the hierarchy.
<code>sibling</code>	A state in the same parent (lateral transition).
<code>./child</code>	A direct child of the current state (drill down).
<code>../uncle</code>	Up one level, then a sibling of the parent.
<code>.</code>	Self-transition: the state exits and immediately re-enters.
<code>null</code>	Machine termination. Exits all states up to root and stops.
<code>@decision_name</code>	Delegate to a named decision tree (see Section 9).
<code>/path/[a/tgt, b/tgt]</code>	Explicit fork into an orthogonal state (see Section 8).

### 6.5 Transition Scenarios

#### Lateral (Sibling to Sibling)

- **Exits:** A
- **Enters:** B

### Drill Down (Parent to Child)

- **Exits:** None (P remains active).
- **Enters:** C

### Move Up (Child to Parent/Uncle)

- **Exits:** C, then Parent P.
- **Enters:** U

## 6.6 Termination

Setting `to: null` causes the machine to exit all states from the current state up through root, then stop. After termination, `is_running()` (Rust/Python) or `sm_is_running()` (C) returns false.

## 7 History

A composite state with `history: true` remembers its last active child. When re-entered, it resumes from that child instead of the `initial` state.

```
process:  
  history: true  
  initial: step_a  
  states:  
    step_a:  
      transitions:  
        - guard: ctx.counter == 3  
          to: step_b  
    step_b:  
      transitions:  
        - guard: ctx.counter == 5  
          to: /other_state
```

Listing 9: History example

If the machine leaves `process` while in `step_b`, and later transitions back to `process`, it will re-enter `step_b` directly (skipping `step_a`).

## 8 Orthogonal States (Parallelism)

An orthogonal state runs multiple child regions simultaneously.

**Keyword:** `orthogonal: true`

```
parallel_task:  
  orthogonal: true  
  states:  
    region_a:  
      initial: idle_a  
      states:  
        idle_a: {}  
        working_a: {}  
    region_b:  
      initial: idle_b  
      states:
```

```

idle_b: {}
working_b: {}

```

Listing 10: Orthogonal state definition

When `parallel_task` is entered, **all** child regions are entered simultaneously. Each region ticks independently. When exiting, all regions are exited.

The state path for orthogonal states uses bracket notation: `/parallel_task/[region_a/idle_a,region_b/...]`

### 8.1 Safety: `transition_fired`

When a transition fires in one region, the other regions' ticks are skipped for that cycle to prevent inconsistent state. This is handled automatically via the `transition_fired` flag.

### 8.2 Fork Transitions (Drilling Down)

You can enter an orthogonal state by targeting its children directly.

1. **Implicit Fork:** `to: /run/g/a/sub_state`

The generator forces region `a` to `sub_state`. Other regions start at their `initial` states.

2. **Explicit Fork:** `to: /run/g/[a/sub_state, b/other]`

Explicitly sets the target for multiple regions at once.

### 8.3 Cross-Limb Transitions

A transition from one region to another region within the same orthogonal parent is a **cross-limb transition**. The generator handles this by exiting the target region's current state and entering the new target, while the source region remains unaffected.

### 8.4 Joining (Synchronization)

To “join” parallel states, place a transition on the **parent** that checks the status of the **children**.

```

main_task:
  orthogonal: true
  states:
    A:
      initial: working
      states:
        working:
          transitions:
            - guard: ctx.done_a
              to: finished
        finished: {}

    B:
      initial: working
      states:
        working:
          transitions:
            - guard: ctx.done_b
              to: finished
        finished: {}

  # Transition on the parent container
  transitions:
    - guard: IN_STATE(root_main_task_A_finished) && IN_STATE(
      root_main_task_B_finished)

```

```
    to: next_step
```

Listing 11: Join pattern (Rust guards)

**Note:** Use the `IN_STATE(X)` macro in guards for portable state checks. In Rust and Python, it expands to `ctx.in_state_X()`. In C, it expands to the `IN_STATE_X` macro.

## 9 Decisions (Logic Trees)

Decisions allow you to externalize branching logic. A decision node can point to states, or **chain to other decisions**.

**Restriction:** You cannot use `action` or `hooks` inside a decision block. Actions must be placed on the transition *leading to* the decision, or on the state transitions following it.

### 9.1 Defining Decisions

Decisions can be defined at the root level or within any state. They are collected into a flat namespace, so names must be unique across the entire model.

```
decisions:
  validate_input:
    - guard: ctx.input < 0
      to: /error/negative
    - guard: ctx.input > 100
      to: "@check_permissions" # Chain to another decision
    - to: /process/calc       # Default (no guard)

  check_permissions:
    - guard: ctx.is_admin
      to: /admin/override
    - to: /error/denied
```

Listing 12: Decision tree definition

### 9.2 Using Decisions

Reference a decision with the `@` prefix in the `to:` field:

```
transitions:
  - guard: ctx.data_ready
    to: "@validate_input"
```

Listing 13: Using a decision in a transition

Decisions can also be defined locally within a state:

```
my_state:
  decisions:
    local_check:
      - guard: ctx.x > 0
        to: positive
      - to: negative
  initial: waiting
  states:
    waiting:
      transitions:
        - to: "@local_check"
    positive: {}
```

```
negative: {}
```

Listing 14: Local decision definition

## 10 Complete Example

Below is a minimal but complete SMB file demonstrating the key features, with Rust as the target language.

```
language: rust

includes: |
  fn log(msg: &str) { println!("{}", msg); }

context: |
  pub counter: i32,

context_init: |
  counter: 0,

hooks:
  entry: |
    println!("Entering {}", state_full_name);
  exit: |
    println!("Exiting {}", state_full_name);

initial: active

states:
  active:
    initial: idle
    states:
      idle:
        transitions:
          - guard: ctx.counter >= 3
            to: working
      working:
        do: |
          ctx.counter += 1;
        transitions:
          - guard: ctx.counter >= 10
            to: null    # Terminate

error:
  entry: |
    log("ERROR STATE");
```

Listing 15: Complete SMB example (Rust)