Finite Statemachines

Specify and Implement dynamic Behaviour

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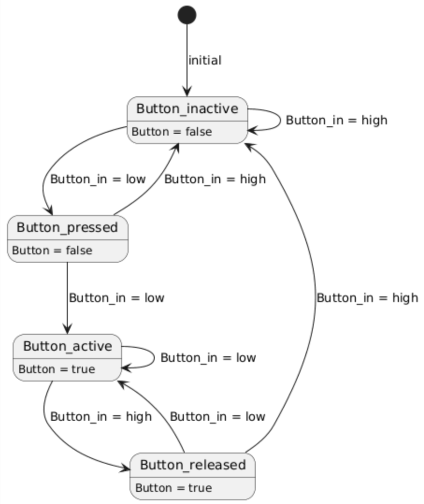
Example

Example Button Debounce

Button Debounce Statemachine

- Button Inactive - Button is registered as released
- Button pressed - latch event after first pressed
- Button active - Button is registered as pressed
- Button released - latch event after first release



Theory

Definition

Definition of a Statemachine

A finite-state machine (FSM) is a mathematical model of computation. It is an abstract machine that can be in exactly one of a finite number of states at any given time. The FSM can change from one state to another in response to some inputs; the change from one state to another is called a transition.

Definition

Parameters of a Statemachine:

- states s
- transitions t
- event σ

$$s \in \mathbf{S}$$

Definition of State

The state of a system is defined by the smallest possible number of its changeable internal parameters.
e.g.:

- velocity
- position
- temperature

Definition

Parameters of a Statemachine:

- states s
- transitions t
- event σ

$$t \in \mathbf{T}$$

Definition of Transition

A Transition is a change from one set of paramaters of a system to another one. e.g.:

- acceleration
- heat

Definition

Parameters of a Statemachine:

- states s
- transitions t
- event σ

$$\sigma \in \mathbf{\Sigma}$$

Definition of Event

A Event is a change of inputs of a system. e.g.:

- push of gas pedal
- expiration of time

Definition

Finite

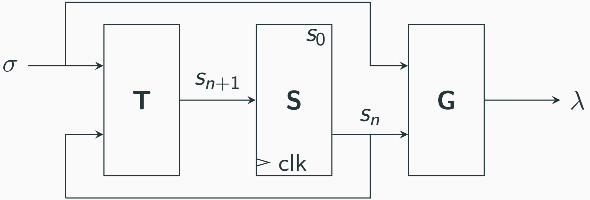
A finite Statemachine only implements a limited set of states **S**. This implicates a limited set of transitions **T** and a limited set of Events **E**

A Statemachine can be described as a set functions t operating on its internal state s. The output y depends on the internal state s, additionaly it may depend on the input σ.

$$s_{n+1} = t(s_n, \sigma) \tag{1}$$

$$\lambda = g(s_n, \sigma) \tag{2}$$

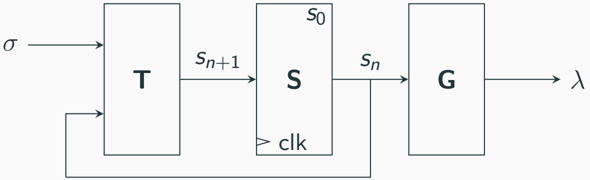
Mealy Machine



$$s_{n+1} = t(s_n, \sigma) \tag{3}$$

$$\lambda = g(s_n, \sigma) \tag{4}$$

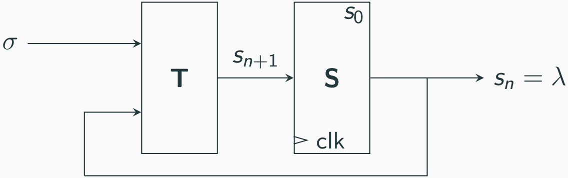
Moore Machine



$$s_{n+1} = t(s_n, \sigma) \tag{5}$$

$$\lambda = g(s_n) \tag{6}$$

Medvedev Machine



$$s_{n+1} = t(s_n, \sigma) \tag{7}$$

$$\lambda = s_n \tag{8}$$

Facts

- Statemachines, as per Definition, do not imply any timing behaviour.
- Every Memory implicitly holds state, thus implements a statemachine.
- The amount of states is proportional to the complexity of the statemachine.
- Every slightly complex component implements a statemachine.
- There can be multiple statemachines in a system.

Design of Statemachines

When to use a statemachine?

- Simple Behaviour that can be clustered
- Strict Deterministic control
- Ressource/Device Control

When not to use a statemachine?

- If a combinational logic is an alternative
- If a mathematical formula can be used instead (filters)
- Multiple Statemachines should never implement the same state

Senior Experience

State should be avoided.

Designtips

- Decide about timing (cyclic, synchronous, asynchronous)
- Number of states shall be reduced
- Hierarchical Statemachines are a good way to reduce states
- Statemachines that are directly or indirectly linked shall be avoided
- Make states explicit (no rotation direction as variable, no global variables)
- If a component implies state implement it as a statemachine (init, running, error)
- shall invalid transitions be neglected or treated as errors?

Questions

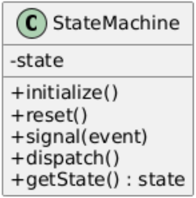
- How many states does a Integer(8-Bit) hold?
- How many states can a microcontroller with 2 KBytes of RAM and 16KBytes of ROM have?
- What is the maximum amount of transitions in a state machine with 4 States?

Questions

- How many states does a Integer(8-Bit) hold? **256**
- How many states can a microcontroller with 2KBytes of RAM and 16KBytes of ROM have? $\mathbf{2^{18000}}$
- What is the maximum amount of transitions in a state machine with 4 States? **16**

Software Specification

Interface of Statemachine Component



Interface	Description	Implements
initialize()	Initializes a statemachine	$s_n = s_0$
reset()	Sets a Statemachine back to Initial State	$s_n = s_0$
signal(e)	sets the event of the state machine	$\sigma = e$
dispatch()	executes the state transition (clock)	$s_{n+1} = t(s_n, \sigma)$
getState() : λ	accesses the output	$\lambda = g(s_n, \sigma)$

Features of Statemachine Component

- synchronous asynchronous dispatch (clock)
- use guard-function
- no reaction or transition or entry-function/exit-function
- use do-function
- use use output logic
- treat non-transition events

The more features you want the more complex the solution will be.

Senior Experience

Complexity increases Risk.

Synchronous/Asynchronous Dispatch

Synchronous Dispatch

When dispatching synchronously, the state transition is executed at the moment the event is created. This implicitly means the transition occurs at state transition.

Challenges:

- transition can occur at any time
- rapid state changes possible
- nested state changes possible

Asynchronous Dispatch

When dispatching asynchronously, the state transition is executed delayed to the moment of event creation. This implicitly means the transition occurs at state transition.

Challenges:

- events need to be memorized until dispatch
- decision necessarry: queued events or dumped events
- event queue overrun or lost events possible

Guard Function

Guard Function

A Guard Function is used to varify if a transition shall be performed. It overwrites the behaviour of a state machine.

Guard functions overwrite the defined behaviour of a state machine.
Thus they implicate a Exception.

Senior Experience

Exceptions shall be avoided.

Reaction to state change

No Reaction

If only state needs to be tracked it may not be needed to act on state changes.

Transition Function

A transition function can be used create behaviour that changes the state of the system.

Entry/Exit Function

It may be possible to split a transition function. The exit-function specifies the change out of a state. The exit-function specifies the change into of a state. Thus, entry- and exit functions are state related.

Challenge: entry and exit functions imply a state that is between all the states. This state is entered by the exit function and left by the entry function.

Do Functions

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Do Functions define Behaviour to be done in a state.

Challenge: Using do functions usually conflict with the scheduler. I prefer changing a schedule table in a entry/exit function.

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Output Logic

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The Output logic can be implemented inside the statemachine, using hooks (function pointers). For generic implementations this increases complexity.

Challenge: I prefer implementing the Output logic as a wrapper around the statemachine.

Non Transition Events

Non-Transition Events

Not every Event must lead to transition in any state. There must be a decision whether such events need to be treated (Error-Handling).

This decision is strictly use-case dependent. Personally i try to avoid error-handling in Non-Transition Events. Alternatively, if all defined events have defined transitions in every state, this issue can be avoided by design completely.

Software Implemtation

Implementation of Statemachine

- At the core a statemachine is basically a nested switch statement, thats a good way for dealing with small non-generic implementations.
- For handling more complex or generic implementations a table based approach may be better.

Senior Experience

(Nested) Switch statements are difficult to maintain.

Implementation of a generic Statemachine