Solutions to Assignment 4
State Machines

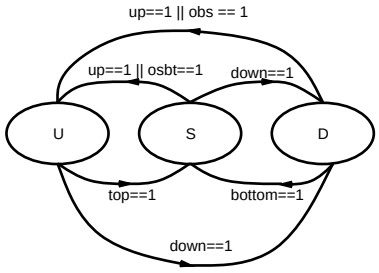
Question 1

Using the labels given in the diagram the inputs are: `obs` (obstruction detected), `up`, `down`,`top`, and `bottom`. The outputs are: `raise`, and `lower`.

There are 3 combinations of outputs: (1) the "raise" motor turned on, (2) the "lower" motor turned on, and (3) neither motor turned on. The controller must therefore have at least 3 states. We will assign these states the labels `U`, `D`, and `S`, respectively. We will attempt to produce a correct design with this many states and add additional states if required to meet the specifications. The outputs for each state are thus:

state	`raise`	`lower`
U	1	0
D	0	1
S	0	0

A simple state transition diagram would be as follows:



The diagram above (like the question itself) is ambiguous because the logical expressions for various state transitions are not mutually exclusive. For example, it is not clear what should happen if both the up and down inputs are '1'. These ambiguities need to be resolved before a controller can be implemented. The following state transition table unambiguously gives the transitions which are taken for each input condition. The symbol 'X' is used as the "don't care" value indicating that the same transition takes place regardless of the value of that particular input.

The tables below were prepared by assuming that the controller obeys the inputs in the following order of priority: obstruction, the expected limit switch in (top/bottom), and direction buttons (up/down). If both buttons are pressed simultaneously the door reverses direction.

A row containing N 'X's is equivalent to 2^N rows with the 'X's replaced with the 2^N combinations of 1's and 0's. A quick check is to make sure that if there are N_{in} inputs the sum of the 2^Ns is 2^Nin.

current state	input conditions					next state
	`obs`	`up`	`down`	`top`	`bottom`	
D	1	X	X	X	X	U
D	0	X	X	X	1	S
D	0	0	X	X	0	D
D	0	1	X	X	0	U
S	1	X	X	X	X	U
S	0	0	0	X	X	S
S	0	0	1	X	X	D
S	0	1	0	X	X	U
S	0	1	1	X	X	S
U	1	X	X	X	X	U
U	0	X	X	1	X	S
U	0	X	0	0	X	U
U	0	X	1	0	X	D

Note that in each state there is exactly one row (transition) that matches (would happen) any possible pattern (input). Anything else would be an ambiguous specification.

Question 2

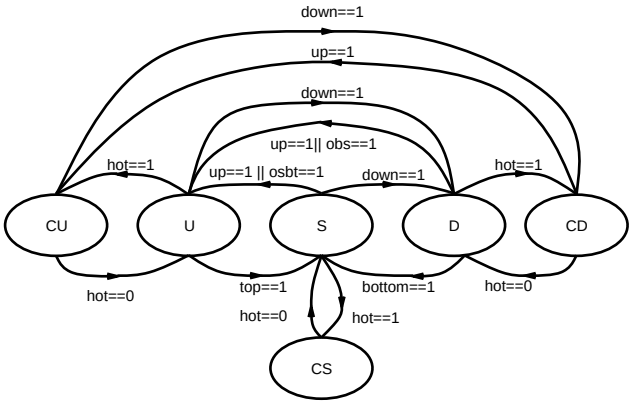
The additional input is labelled `hot`.

Adding three different "cooling" states, `CU`, `CD`, and `CS` allows the state machine's outputs to be "off" and still remember whether the state to return to when the motor cools.

The outputs for each state are now:

state	raise	lower
U	1	0
D	0	1
S	0	0
CU	0	0
CD	0	0
CS	0	0

A state transition diagram would be as follows:



The transition table is similar to the one above with the the `hot` input taking priority over the others:

current state	input conditions						next state
	hot	obs	up	down	top	bottom	
D	1	X	X	X	X	X	CD
D	0	1	X	X	X	X	U
D	0	0	X	X	X	1	S
D	0	0	0	X	X	0	D
D	0	0	1	X	X	0	U
S	1	X	X	X	X	X	CS
S	0	1	X	X	X	X	U
S	0	0	0	0	X	X	S
S	0	0	0	1	X	X	D
S	0	0	1	0	X	X	U
S	0	0	1	1	X	X	S
U	1	X	X	X	X	X	CU
U	0	1	X	X	X	X	U
U	0	0	X	X	1	X	S
U	0	0	X	0	0	X	U
U	0	0	X	1	0	X	D
CU	0	X	X	X	X	X	U
CU	1	X	X	0	X	X	CU
CU	1	X	X	1	X	X	CD
CD	0	X	X	X	X	X	D
CD	1	X	0	X	X	X	CD
CD	1	X	1	X	X	X	CU
CS	0	X	X	X	X	X	S
CS	1	X	0	0	X	X	CS
CS	1	X	0	1	X	X	CD
CS	1	X	1	0	X	X	CU
CS	1	X	1	1	X	X	CS

This particular answer is unambiguous and meets the requirements given in the question. Other solutions that met these two criteria would also be correct.