Races & cycles

A Race Condition occurs when more than one state variables change in response to a change in input (of an asynchronous sequential ckt).

Examples: [Courtesy: Prof. Otman Adam Al-Basir, University of Waterloo]

y_1y_2 \ x	0	1
00	00	11
01	00	01
11	00	01
10	00	11

$x=0,\ y_1y_2=00$
$x \to 1$

Depending own order of change of variables:

1. $00 \to 01$ (y_2 changes first)
2. $00 \to 10 \to 11 \to 01$
3. $00 \to 11 \to 01$ (Direct) (y_1 changes first)

Both leads to the same stable state [$x=1,\ y_1y_2=01$].

This is non-critical race.

y_1y_2 \ x	0	1
00	00	11
01	00	11
11	00	11
10	00	10

$x=0,\ y_1y_2=00$
$x \to 1$

Possibilities:

1. $00 \to 01 \to 11$ (y_2 changes first).
2. $00 \to 10$ (y_1 changes first)
3. $00 \to 11$ (Direct)

Different stable state.

critical race

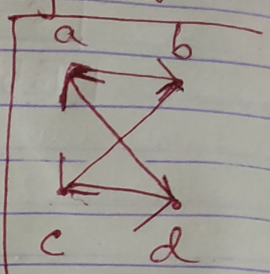
Must be avoided!

Methods of eliminating races

① Choosing a race-free state assignment (if possible).

example

Sec. state	$x=0$	$x=1$
a	a	b
b	c	b
c	c	d
d	a	d



Transition diagram

Assignment 1:

a	00
b	01
c	10
d	11

	$x=0$	$x=1$
00	00	01
01	10	01
10	10	11
11	00	11

BAD assignment

$y_1y_2 = 11$, $x: 1 \to 0$

① $11 \to 10$ (y_2 changes first)

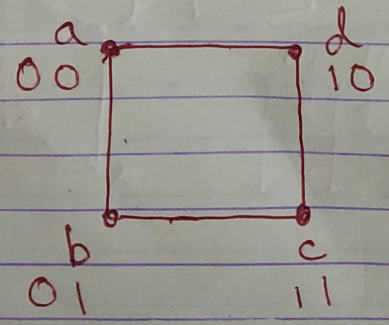
② $11 \to 00 \to 00$ (Both changes together)

critical race.

Assignment 2:

a	00
b	01
c	~~10~~ 11
d	~~11~~ 10.

GOOD assignment. All transitions are between adjacent states.



2-dimensional Boolean cube.

Transitions are along the edges.

In general: Try to embed the symbolic states into vertices of n-dim cube, s.t. all transitions are along the edges.

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Not always possible

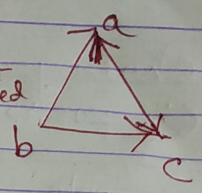
sec. state	00	01	11	10
a	a	c	a	a
b	a	c	b	b
c	c	c	b	a

x_1x_2

un-circled

[Table 11.13 of Kohavi-Jha]

Transition diagram



No race-free assignment exists.

② Introduction of cycles: (if necessary) introduce additional unstable states, and route the transitions via them.

assignment	sec. state	00	01	11	10
00	a	a	c	a	a
01	b	a	c	b	b
11	c	c	c	b	x
10	x	–	–	–	a

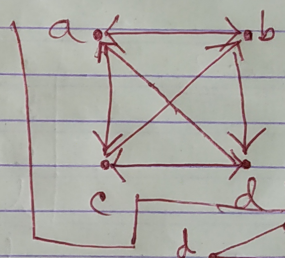
x_1x_2

Ensure: Cycles terminate on a stable state.

Ex-2.

sec. state	00	01	10	11
a	a	a	c	b
b	a	b	d	b
c	c	b	c	d
d	c	a	d	d

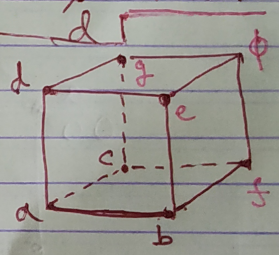
x_1x_2



No race-free assignment exists.

	00	01	10	11
a	a	a	c	b
b	a	a	e	b
c	c	f	c	g
d	g	a	d	d
e	–	–	d	–
f	–	b	–	–
g	c	–	–	d

	00	01	11	10
0	a	c	f	b
1	d	g		e



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