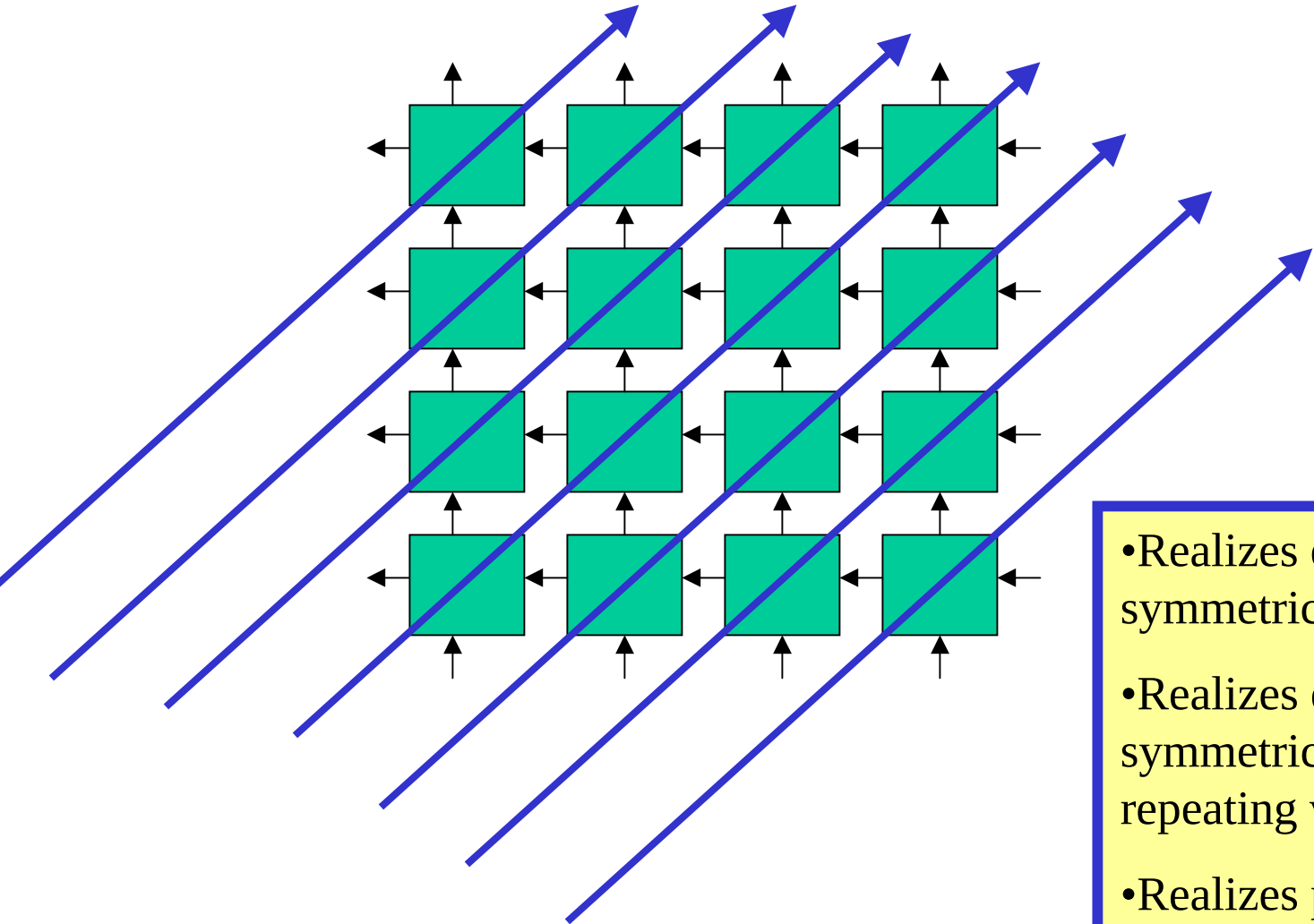
Regular Structures

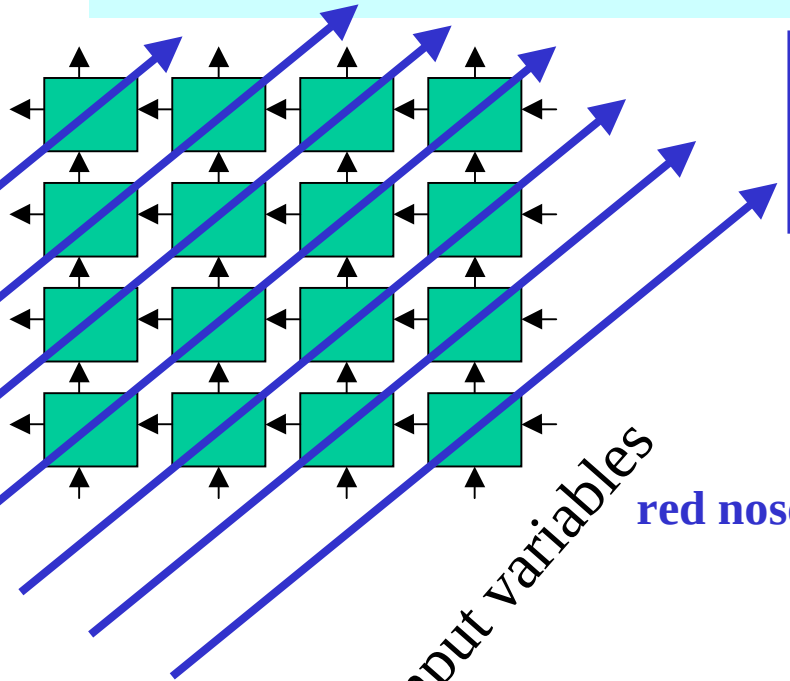
Lattice Structure for Multivalued and Binary Logic



- Realizes every binary symmetric function
- Realizes every non-symmetric function by repeating variables
- Realizes piece-wise linear multivalued functions

Patented by Pierzchala and Perkowski 1994/1999

Lattice Structure for Multivalued and Binary Logic



- Cell has three inputs and two outputs
- Both outputs have the same function

Multi-valued output variable

Binary input variables

red nose

beard

red eyes

0 1

Jeske

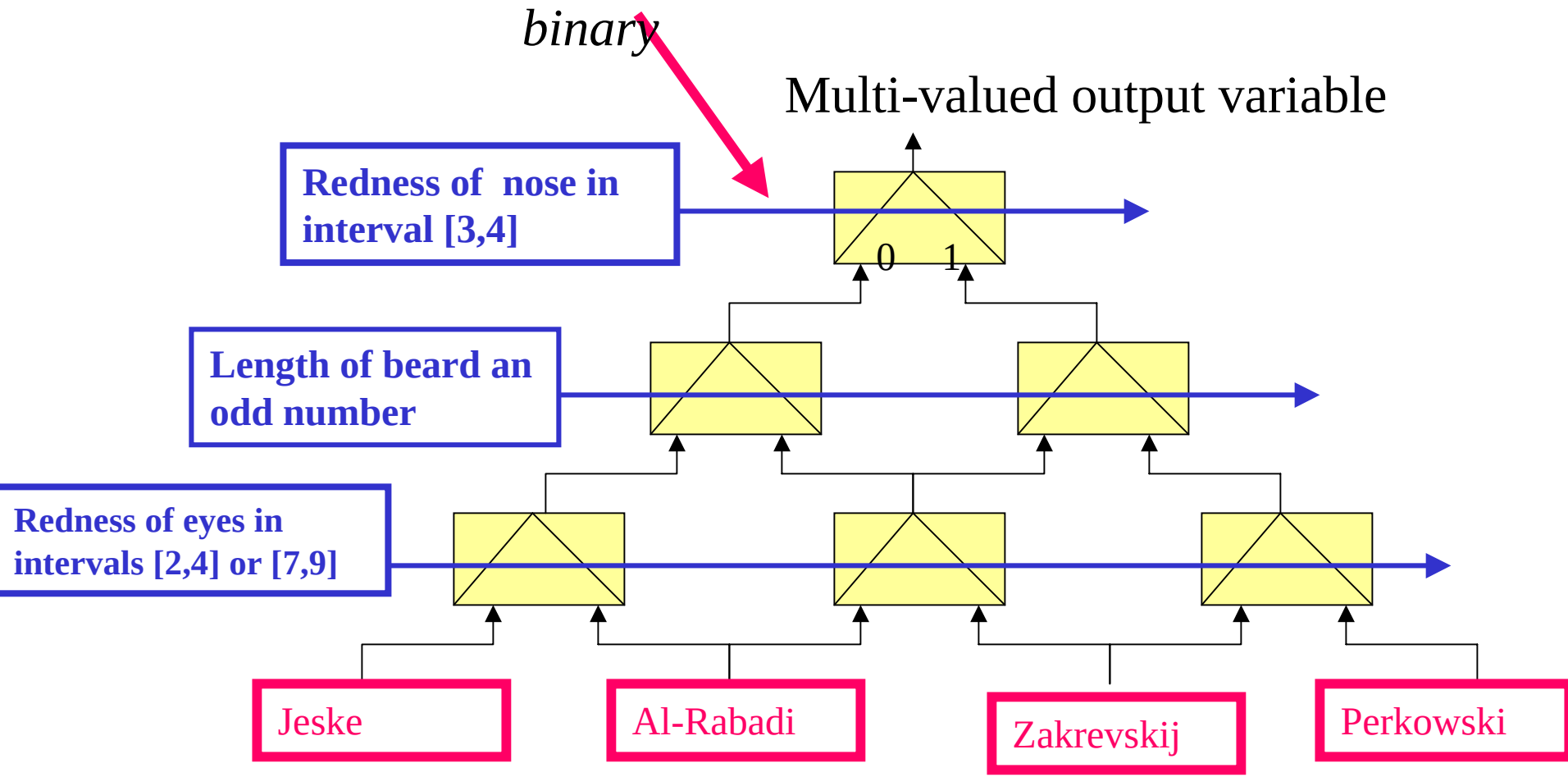
Al-Rabadi

Zakrevskij

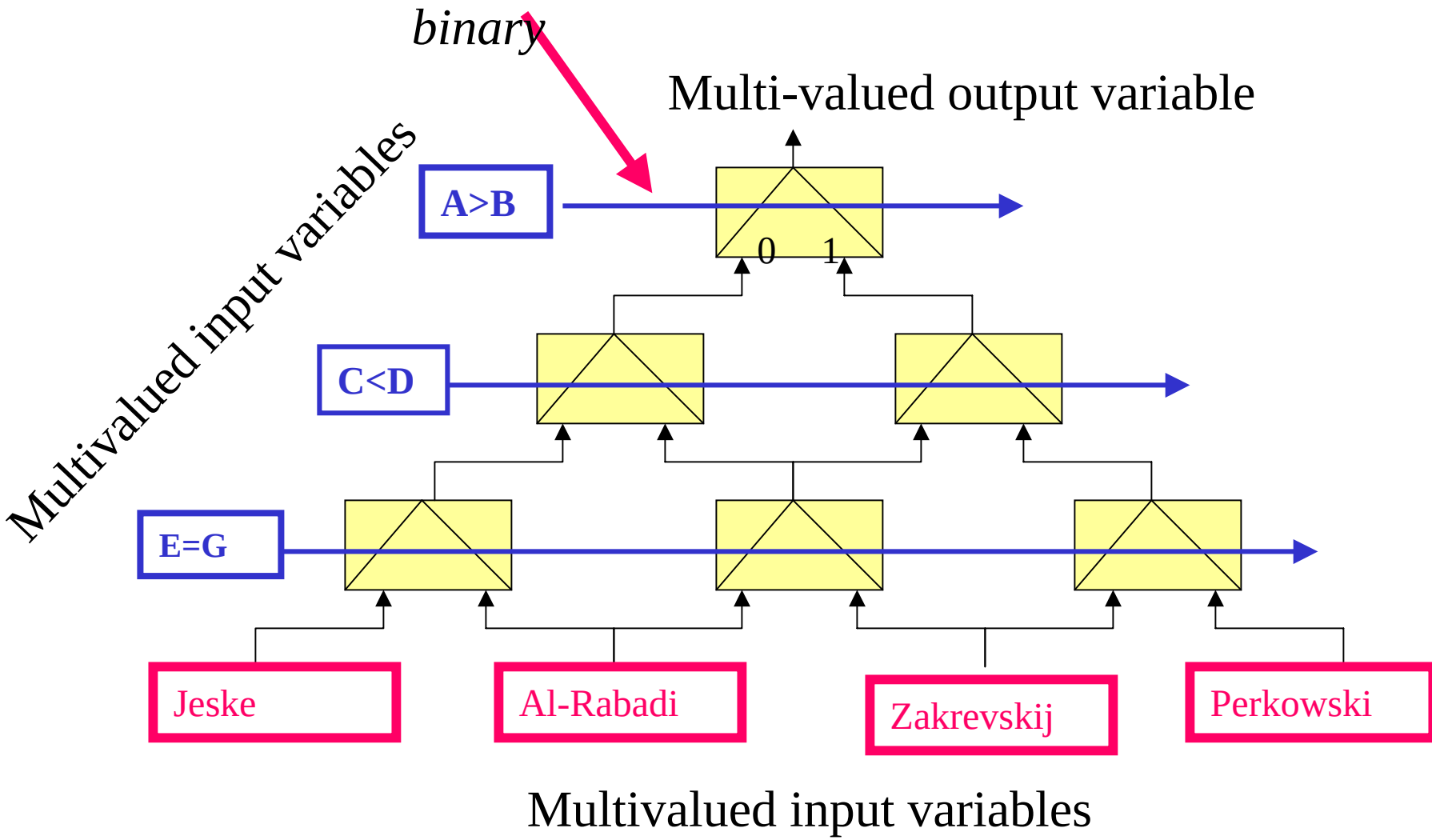
Perkowski

Multivalued variables

Lattice Structure for Multivalued and Binary Logic



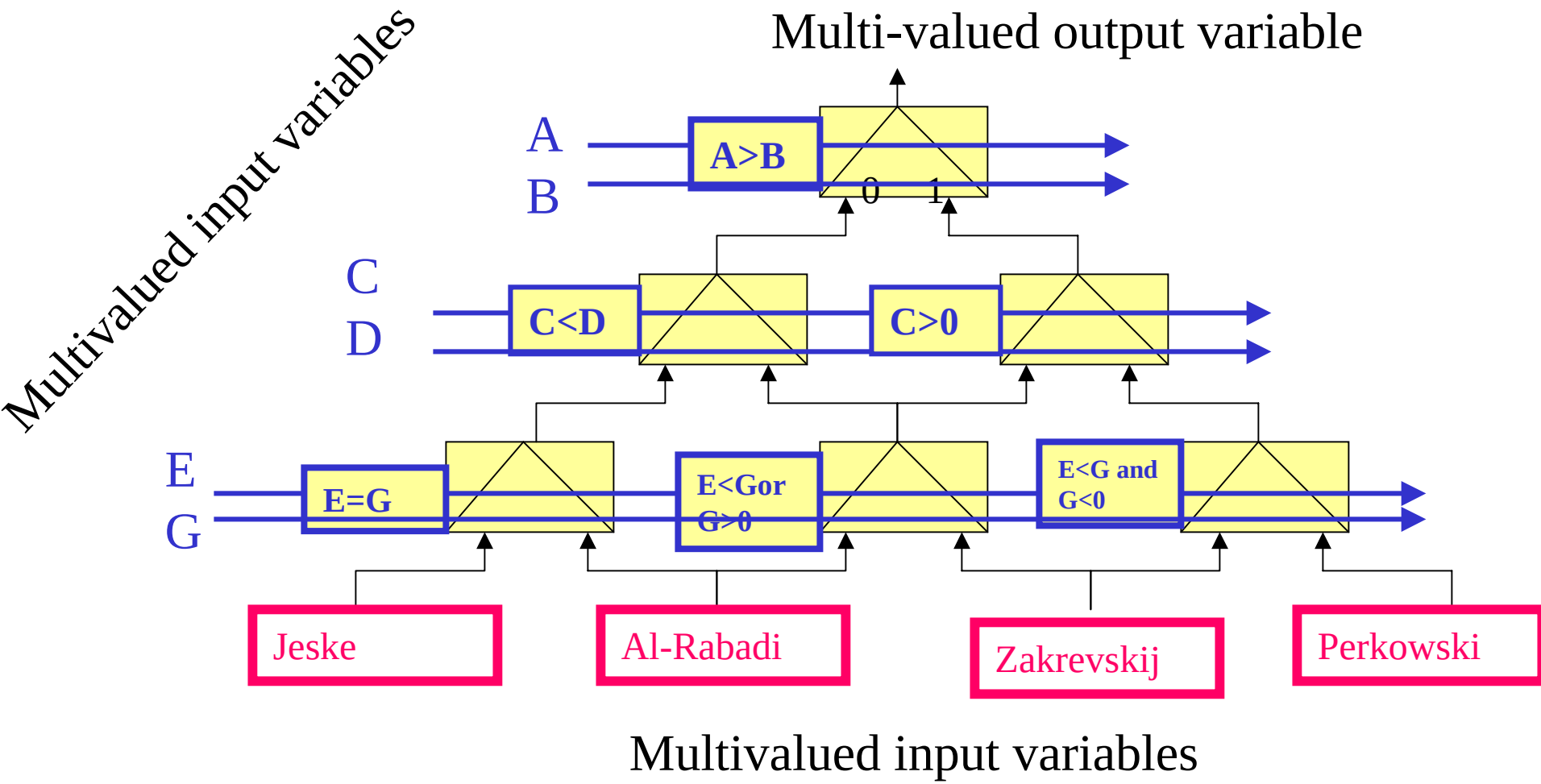
Lattice Structure for Multivalued and Binary Logic



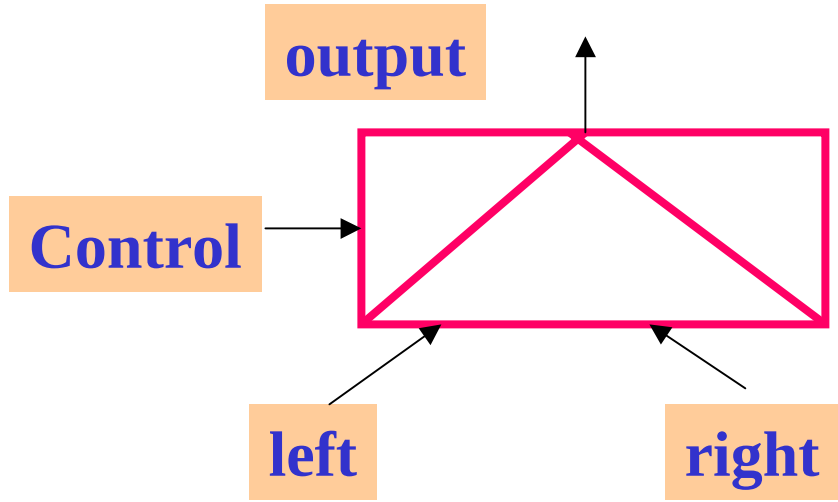
Lattice Structure for Multivalued and Binary Logic

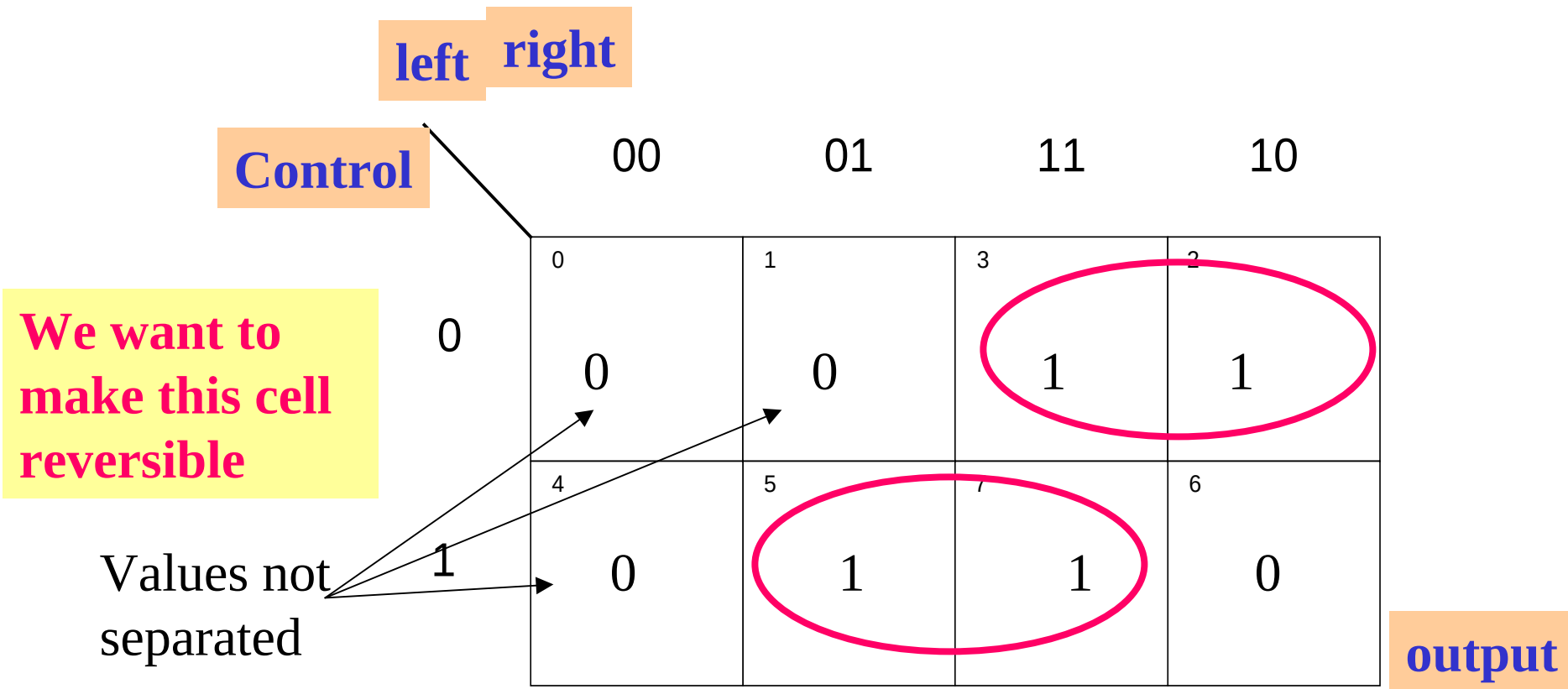
Cell has 4 inputs and 2 outputs

Can we make the cell reversible?

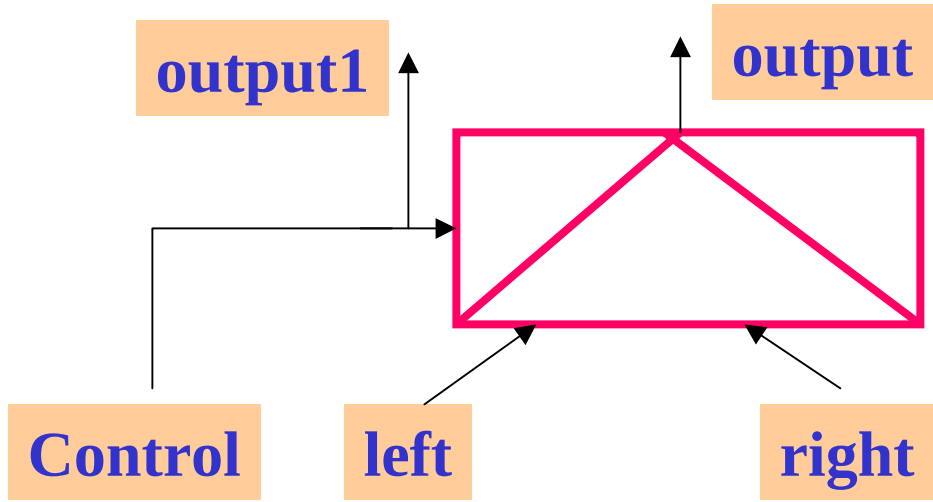


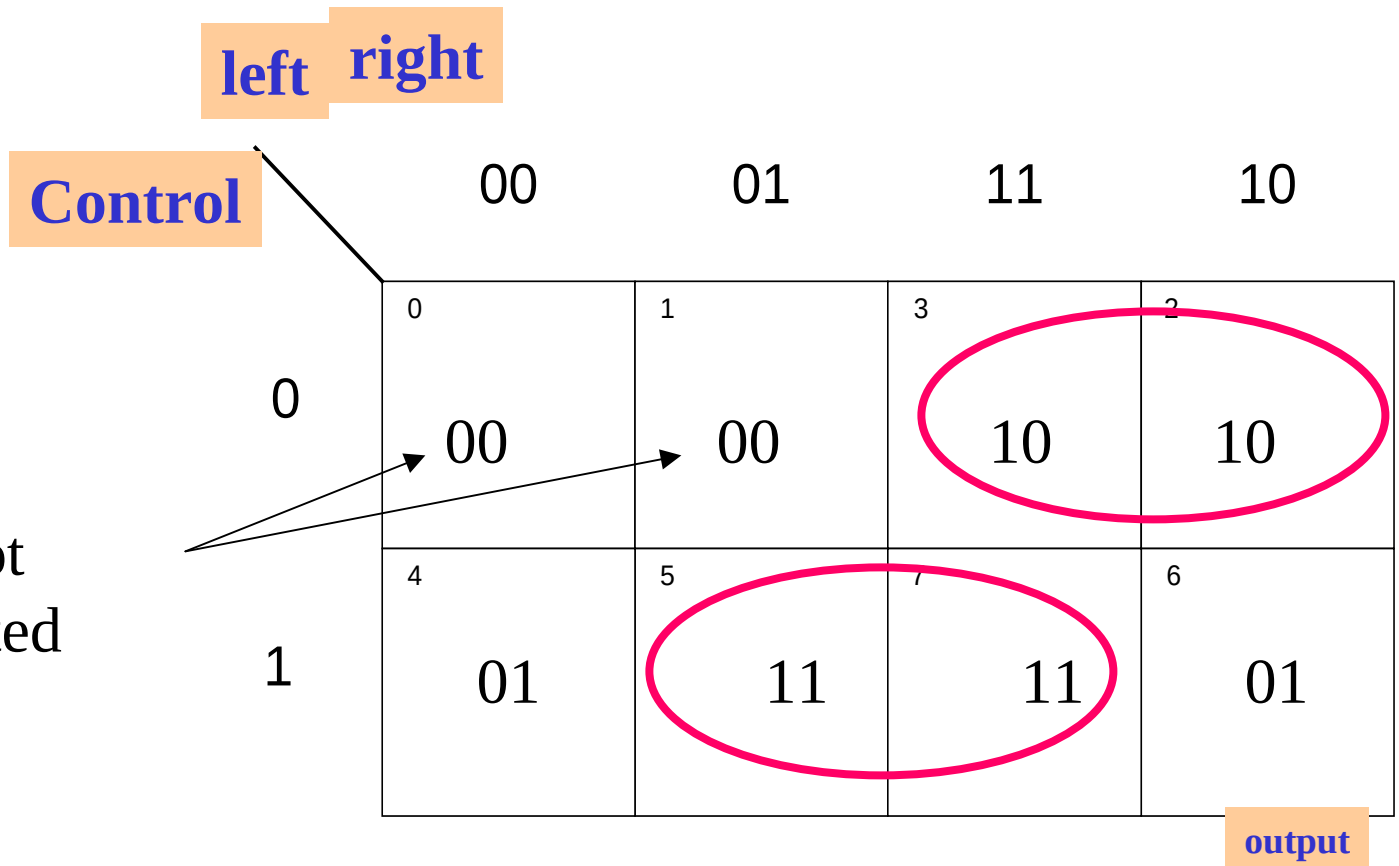
Control	left	right	output
0	value	-	value
1	-	value	value



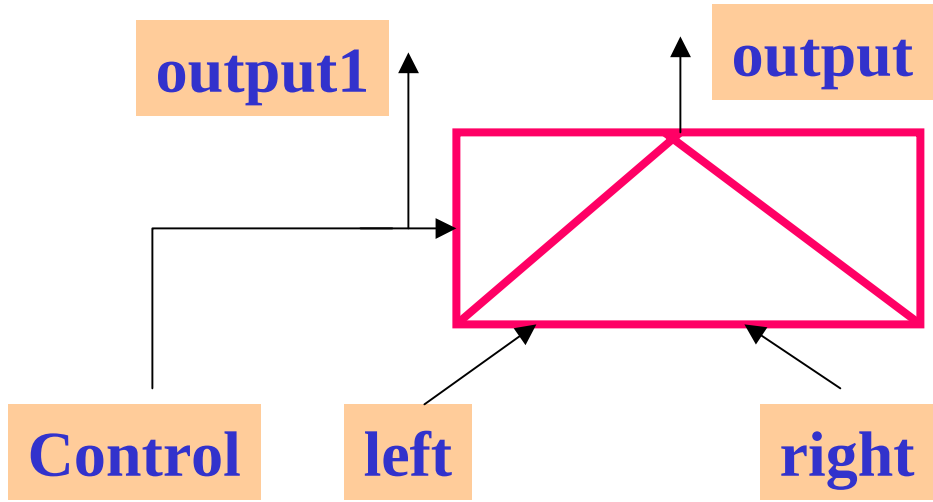


Let us try to repeat control variable in output





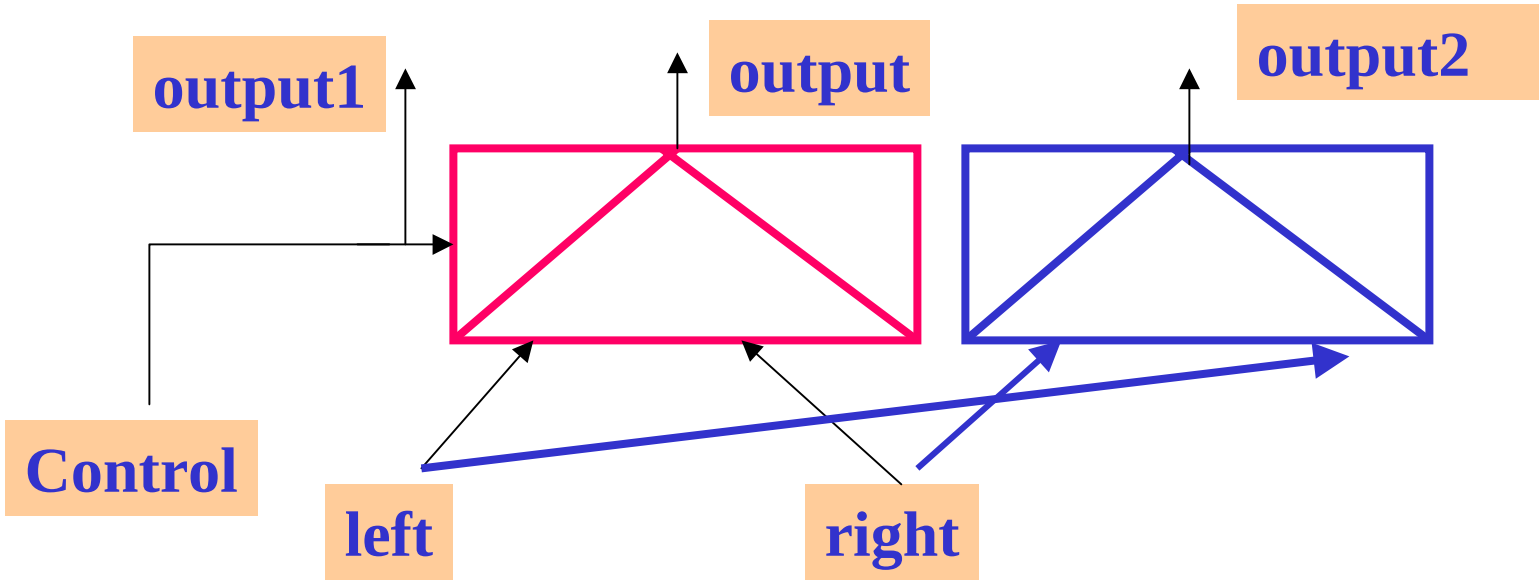
Repeating variables will not help



Now it works!

Control \ left right	00	01	11	10
0	0: 000	1: 001	3: 101	2: 100
1	4: 010	5: 110	7: 111	6: 010

output output1 output2



left right

Control

	00	01	11	10
0	0 000	1 001	3 101	2 100
1	4 010	5 110	7 111	6 010

output output1

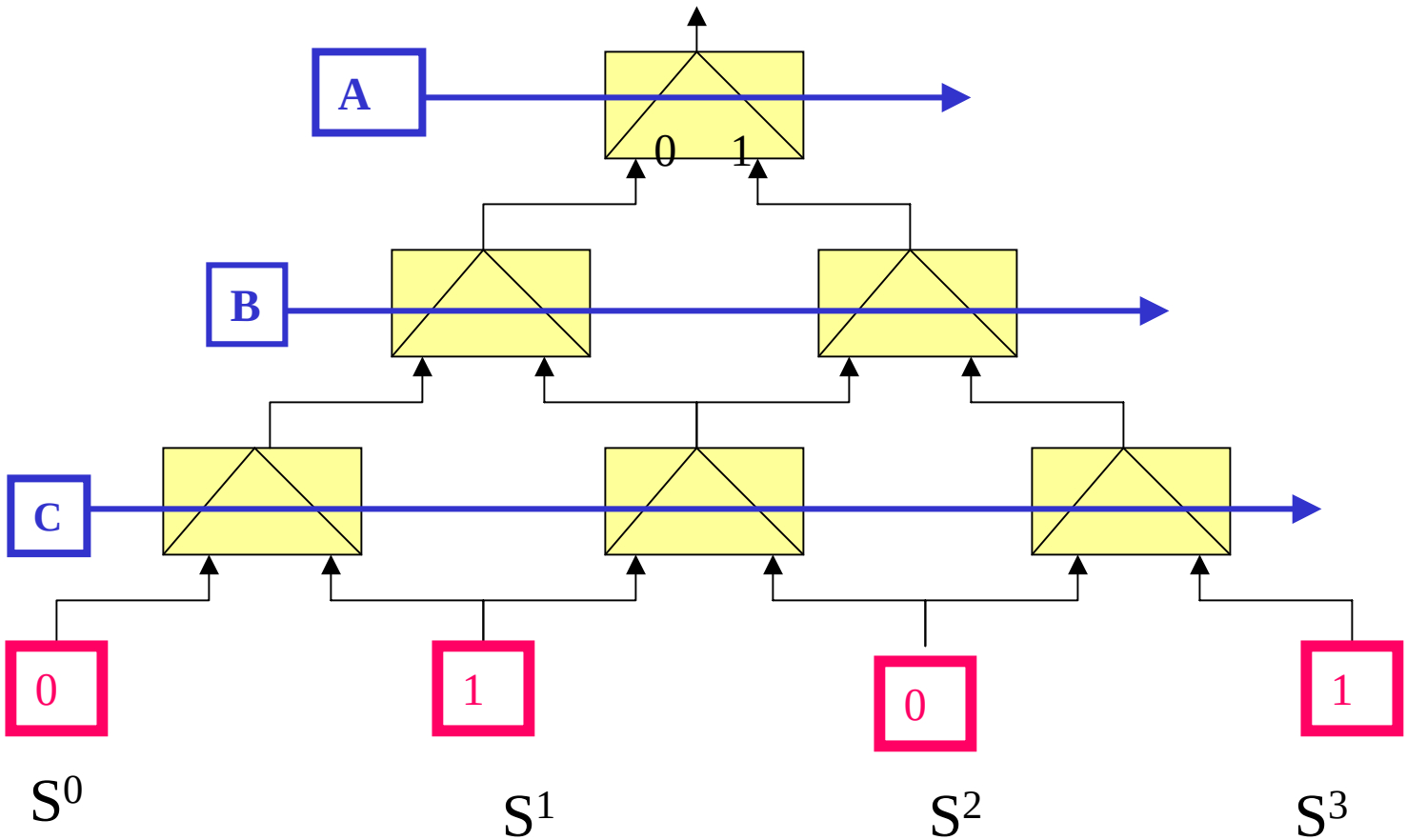
This means that we added another MUX

…. And we reinvented the Fredkin Gate ….!!!

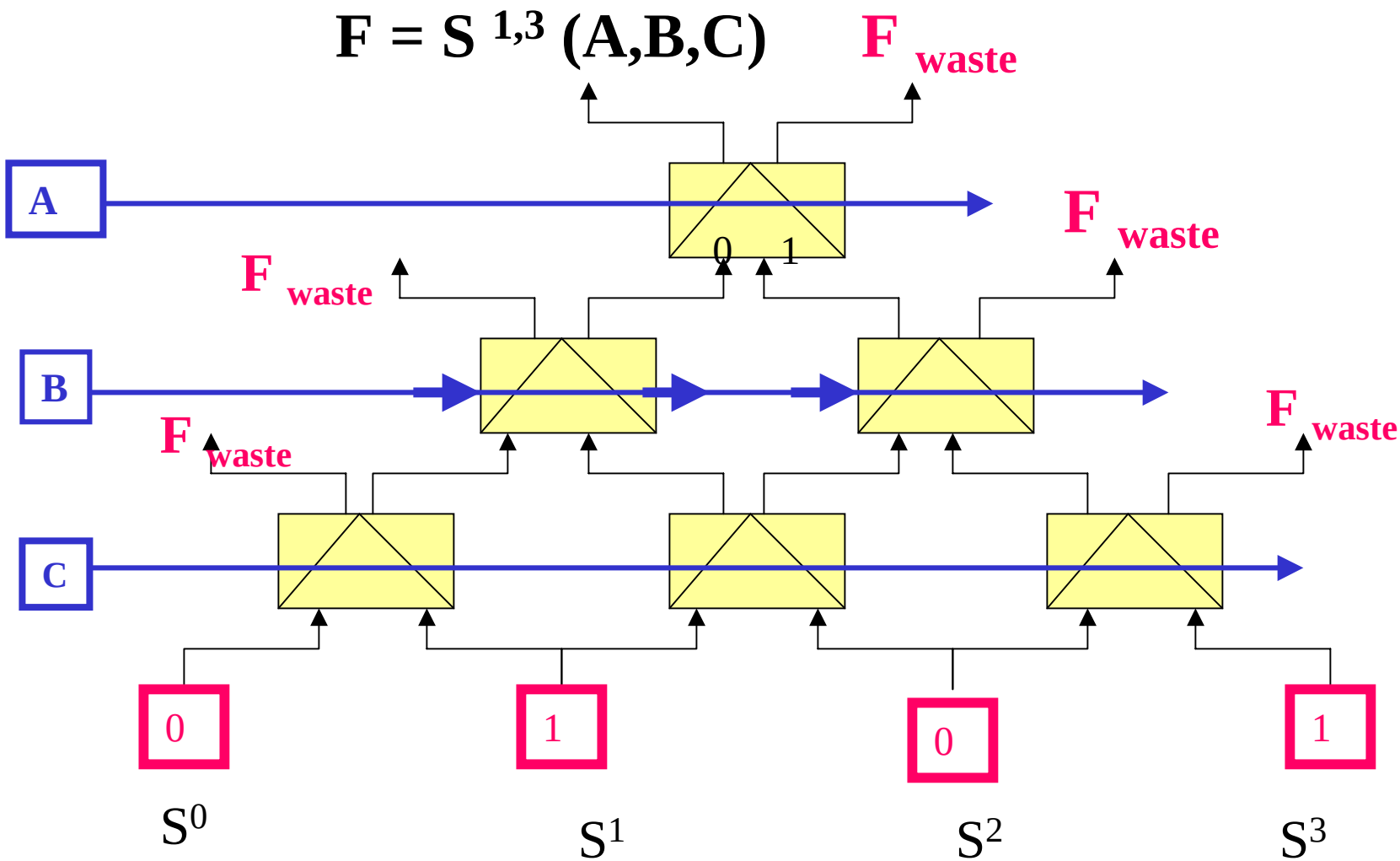
- But how to use it in a Lattice?

Lattice Structure for Binary Logic

$$F = S^{1,3}(A,B,C)$$



Reversible Lattice Structure for Binary Logic



Reversible Lattice Structure for Binary Logic

- **Advantages**
- **regular structure**
- **binary Fredkin Gate**
- **planar structure (good for Quantum Logic)**
- **Easy algorithmic creation**
- **Reasonable waste**

- **Disadvantages**
- **Variable ordering?**
- **Symmetrization?**
- **Waste still exist**

Should be patented!

Do you remember that there are other binary expansions?

- **All Binary Expansions**
- **Shannon - S**
- **Flipped Shannon - fS**
- **Positive Davio - pD**
- **Negative Davio - nD**
- **Flipped Positive Davio - fpD**
- **Flipped Negative Davio - fnD**

- **Ideas**
- **Fredkin = <Var, S, fS>**
- **what about these?**
  - **<Var, pD, fpD>**
  - **<Var, nD, fnD>**
  - **<Var, nD, pD>**
  - **….**

I checked some of them to work

Do you remember that there are other component functions of reversible gates

- **All Binary Balanced Expansic**
- **…..**
- **Linear functions - L**
- **Negations - N**
- **Majorities - M**

- **Ideas**
- **Fredkin = <Var, S, fS>**
- **what about these?**
  - **<N, pD, fpD>**
  - **<Var, M, fnD>**
  - **<Var, nD, L>**
  - **….**

I checked some of them to work

As you see, this opens a very broad area of research that will lead to invention of new reversible gates and regular structures that use them

- **Easy way to become a pioneer:**
- **Investigate all combinations**
- **Use genetic programming or other search methods to build structures and map functions to them**
- **There is a place for many researchers**
- **Nobody does this research**

But this was only for binary

What about multivalued, fuzzy, arithmetic or other logics?

…. And we reinvented the Fredkin Gate ….!!!

- But what about the variant with two control signals?

Multi-valued Fredkin Gate

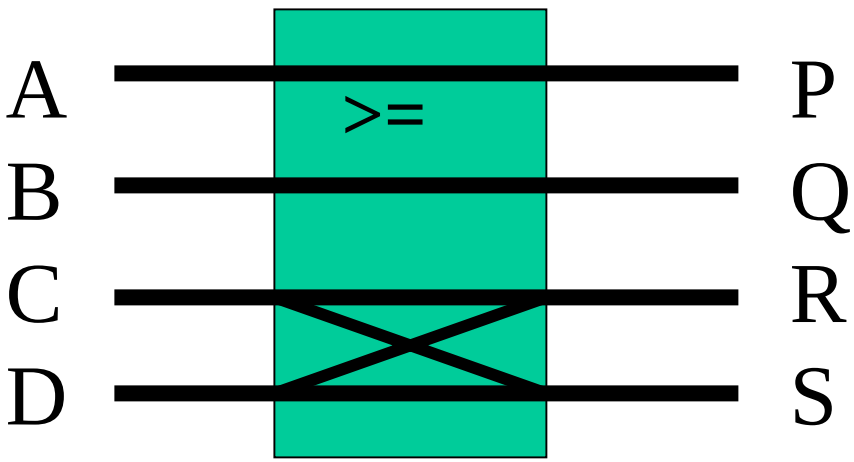
- MVFG is described by equations:

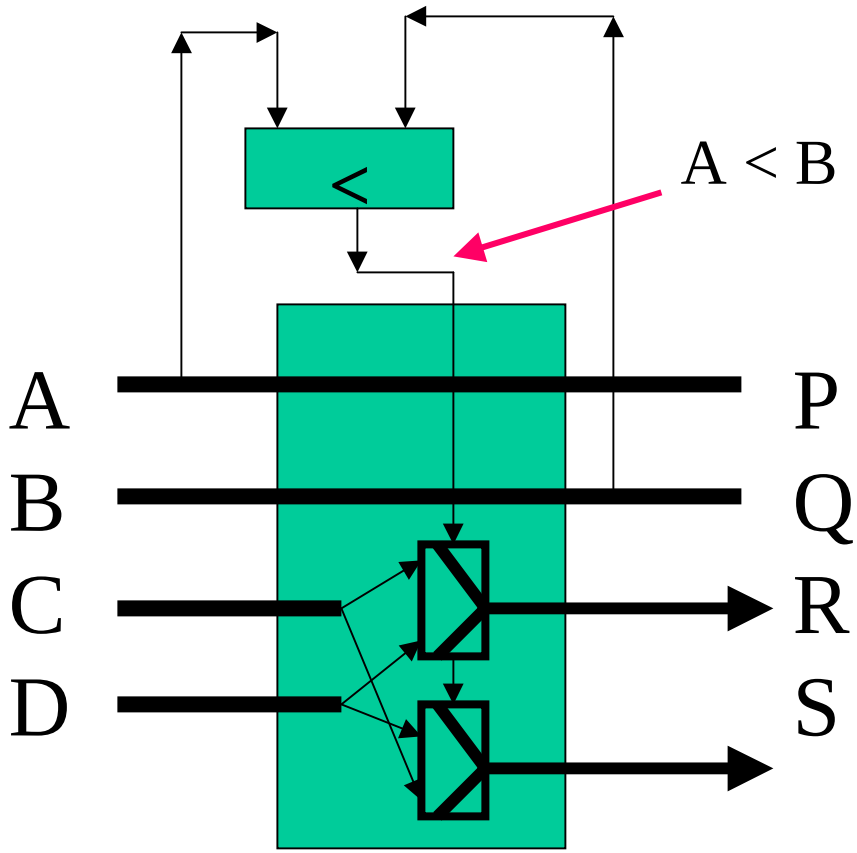
  P = A

  Q = B

  R = C ***if*** A < B ***else*** R = D

  S = D ***if*** A < B ***else*** S = C



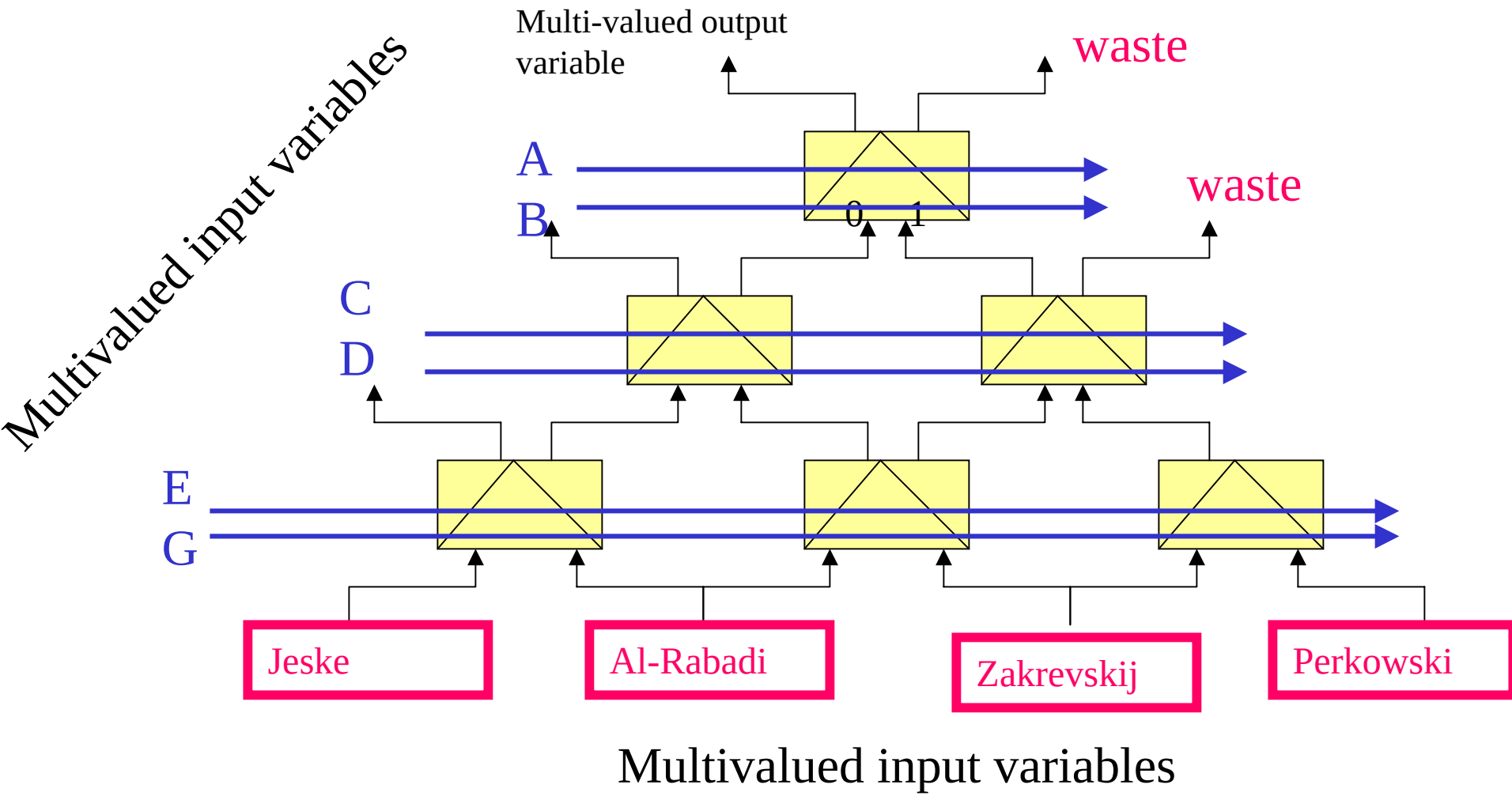


Lattice Structure for Multivalued and Binary Logic

Cell has 4 inputs and 4 outputs

MV and Generalized MV Fredkin

Cell is reversible!



Multi-valued logic generates less signals

Hence it generates less waste

Of course, it generates also less power, less connections and is easier to test

The main open research problem

- **The real-life functions are multi-output.**
- **Thus, there exists an opportunity to re-use some waste functions in other output functions**
- **This is a tough problem.**
- **I do not know now how to solve it!**

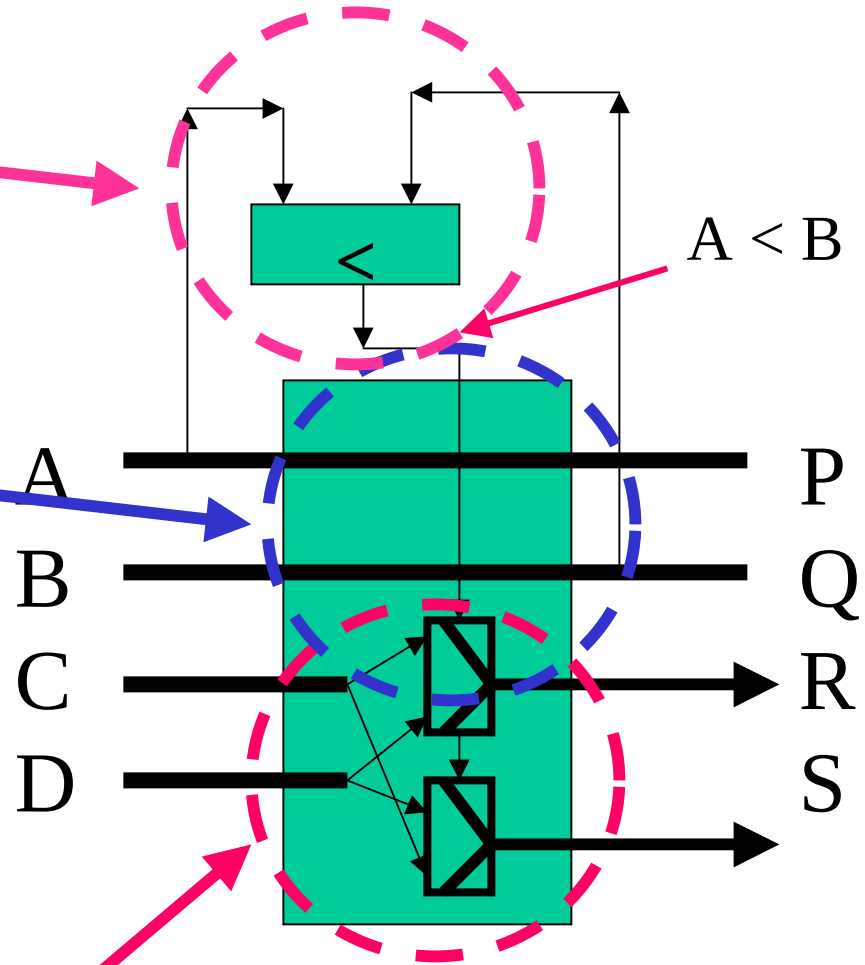
We need some group creativity

Generalized Multi-valued Fredkin Gate

Select other function of two variables

Select other pairs of VAR-type and NOT-type functions

Select other pairs of MUX-type functions

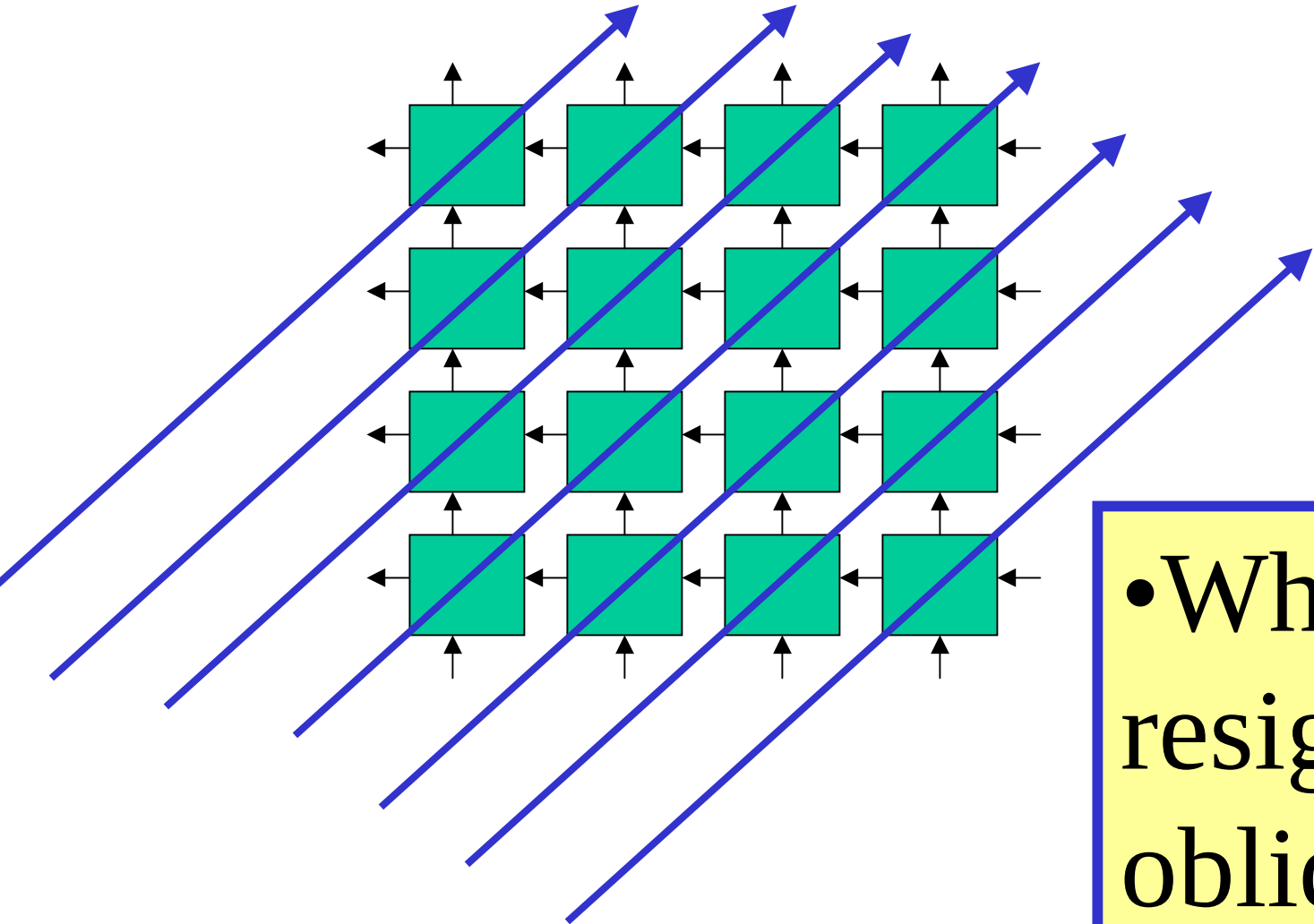


Generalized Multi-valued Fredkin Gate

- The number of these gates is astronomical
- We need both computer generation and some intelligence, simply generating them all would be a nonsense
- Very wide area of research
- It will give hints to gate designers what to look for

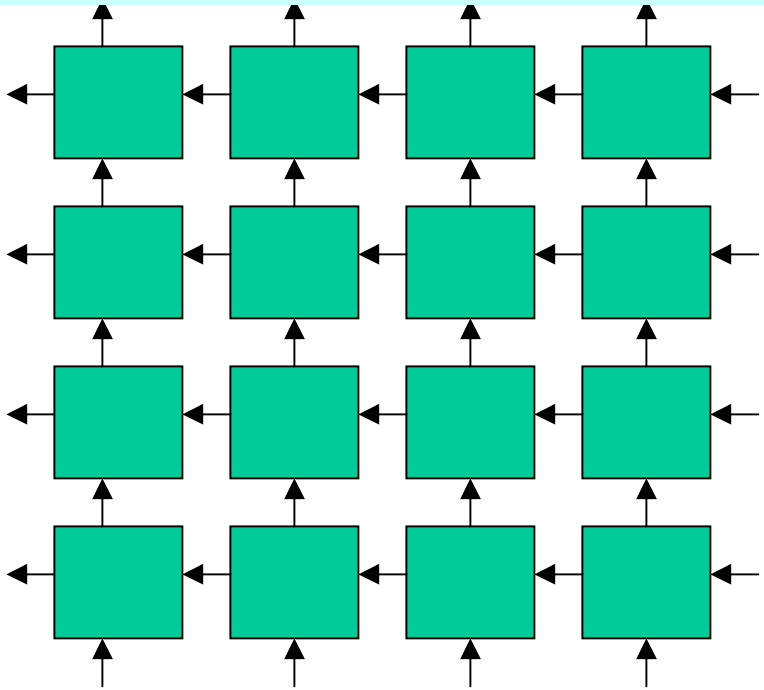

But this is only a beginning……

Let us go back to our fundamental invention…..

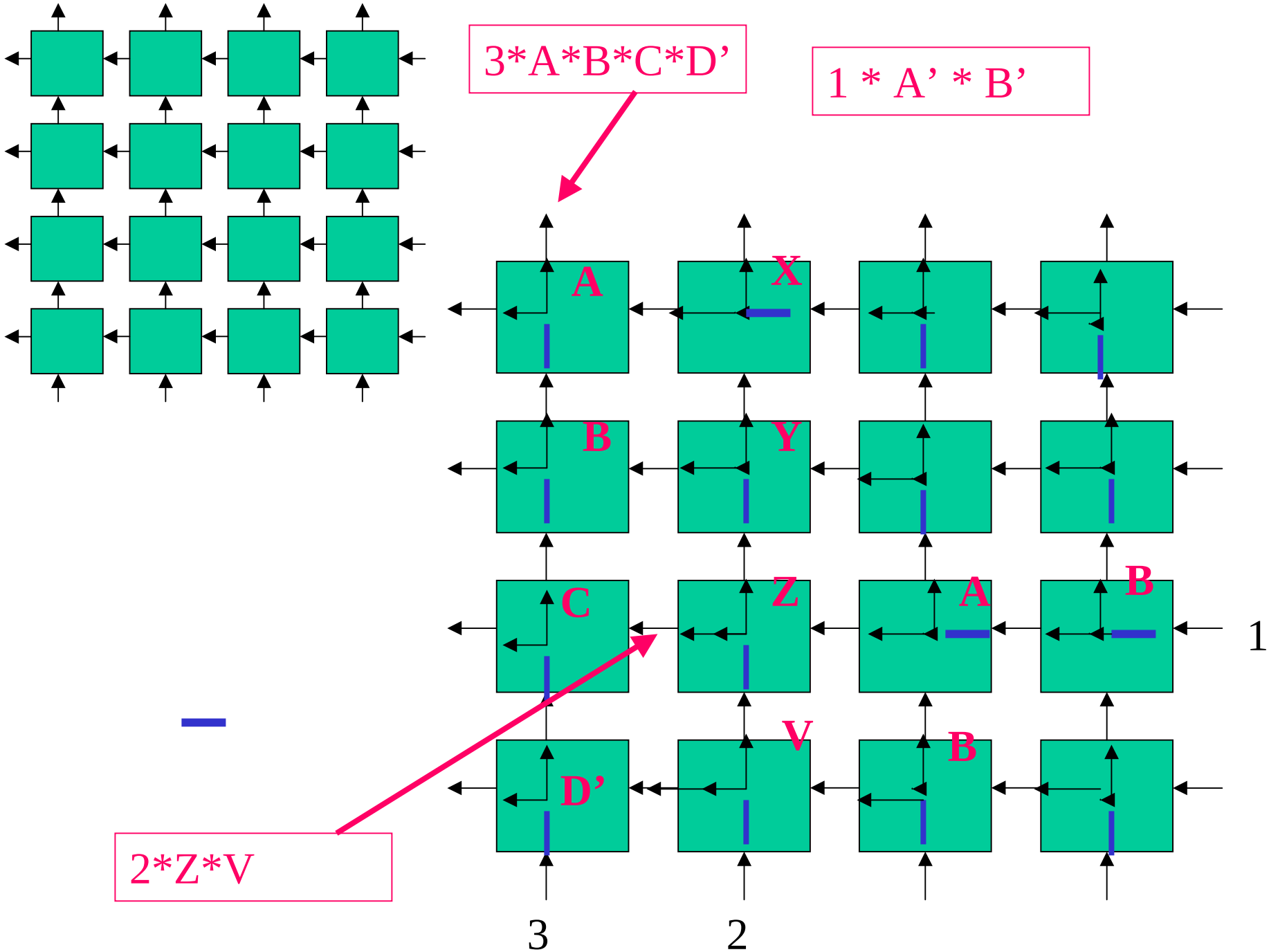


- What if we resign from oblique buses?

Buses are removed and each cell is programmed individually…..



- Some regularity is lost!


3*A*B*C*D’
1 * A’ * B’
A
X
B
Y
C
Z
A
B
1
V
B
D’
2*Z*V
3
2