Interconnect Analysis of Spatial Decomposition of Boolean Functions for Predictable Nanotechnologies

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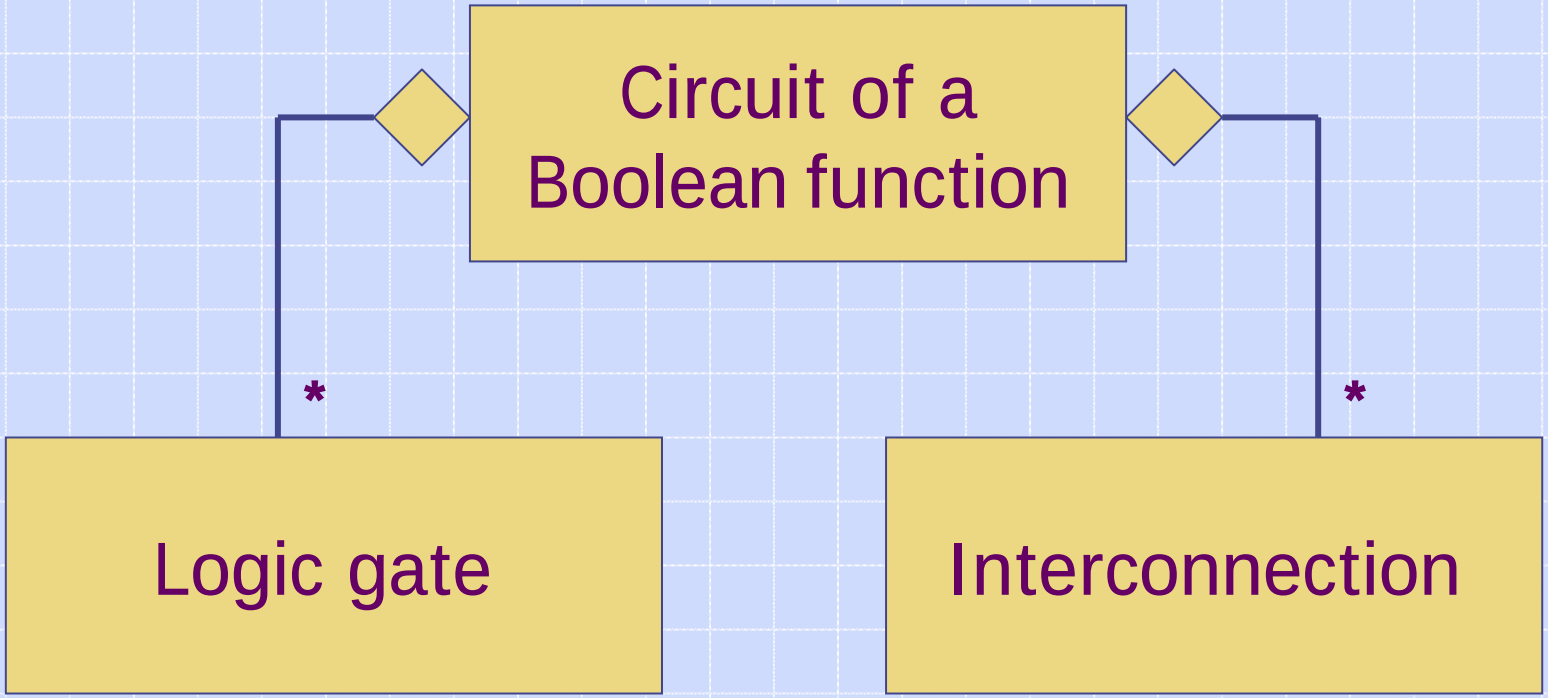
Outline

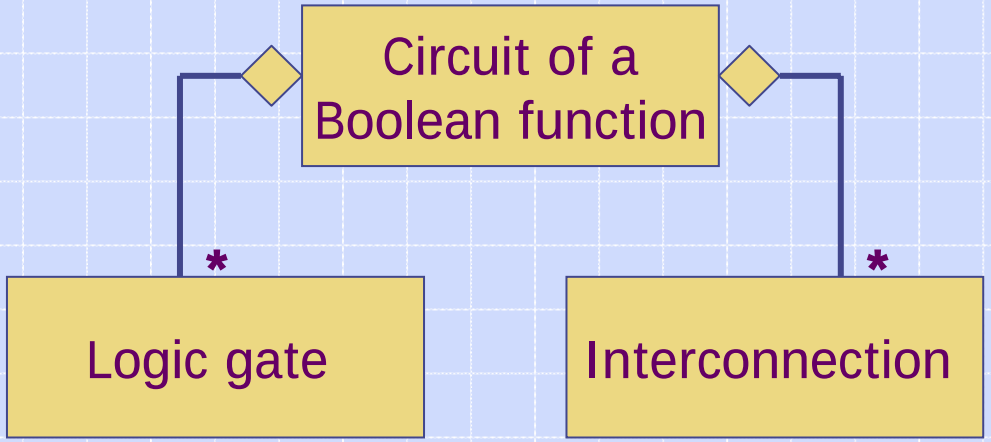
- Introduction
- Decomposition techniques - State-of-the-art
- Spatial Decomposition
- Problems of 3D embedding
- Assembling of the decomposed structure
- MUX-based assembling
- Experimental Results
- Discussion and Summary

Introduction



Introduction

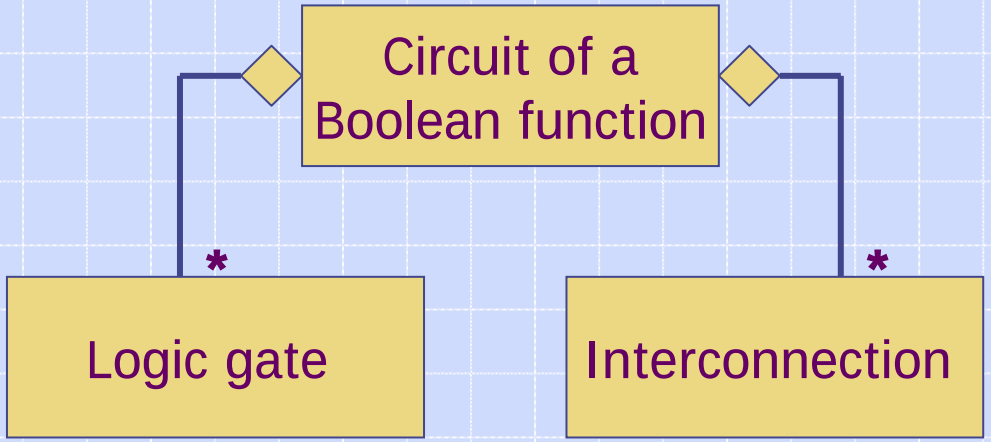
Classical technologies like DTL, TTL, nMOS, pMOS, CMOS



Area (2D)	large	small
Cost	high	low
Power dissipation	high	low
Delay	high	low

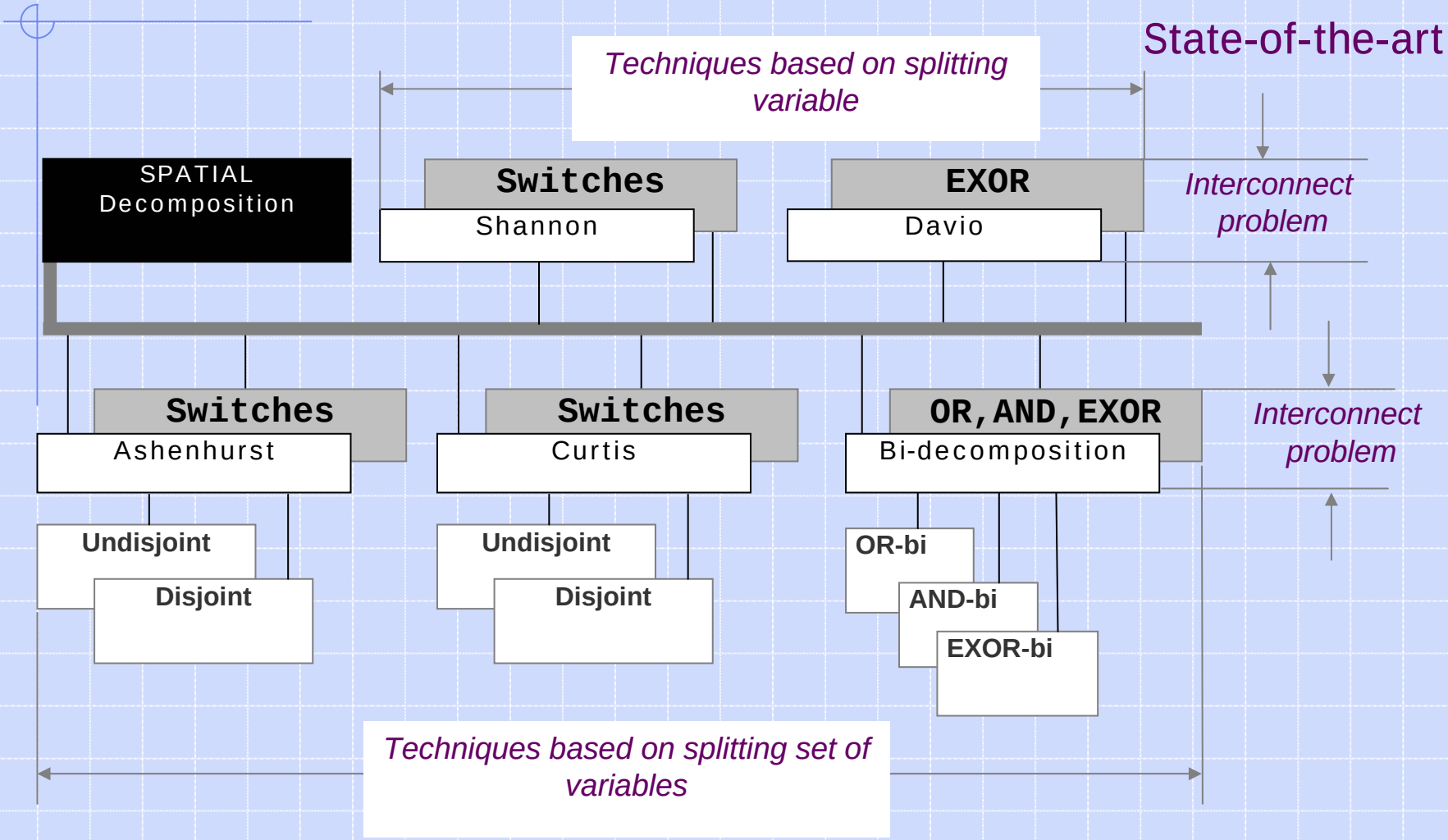
Introduction

Nanotechnologies like molecular electronics, single-electron devices, quantum-dot devices



Area (3D)	small	large
Cost	low	high
Power dissipation	low	high
Delay	low	high

Decomposition techniques



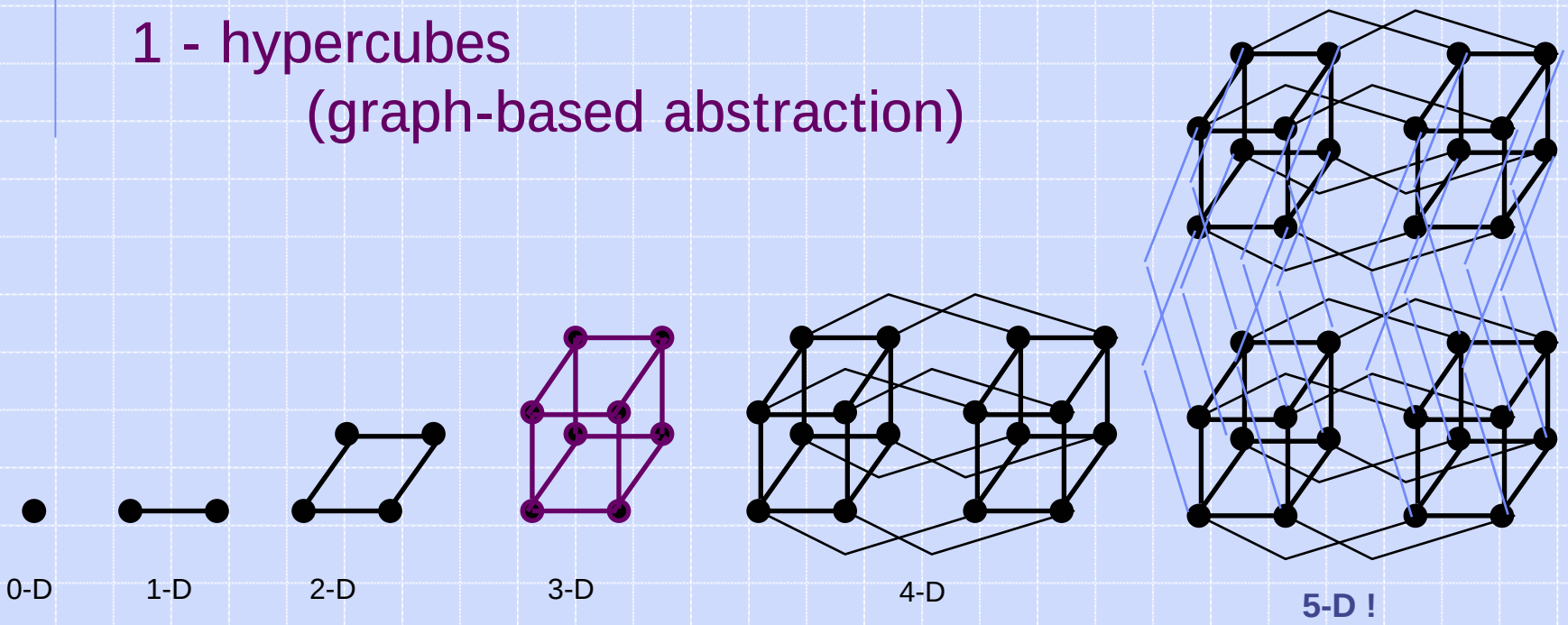
Spatial Decomposition

- Inspired by new technologies (nanostructures)
- Resemble approach to decomposing distributed systems (well-developed graph-based theory)
- Relevant to BDD-based decomposition (and BDD can be mapped into 3D!)

Spatial Decomposition

What structures represent an arbitrary Boolean function in 3D?

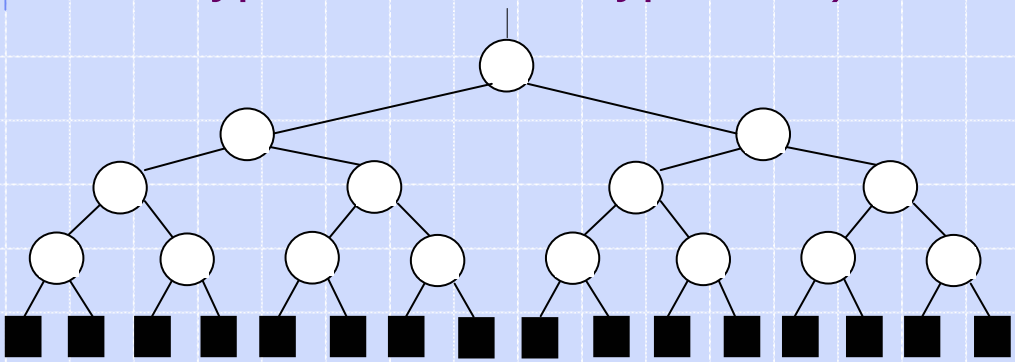
1 - hypercubes
(graph-based abstraction)

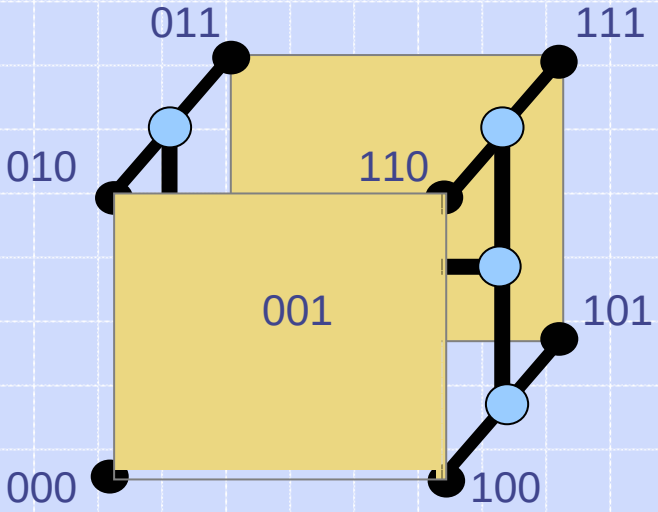


Spatial Decomposition

What structures represent an arbitrary Boolean function in 3D ?

2 - recently proposed *N* - hypercubes*
(decision tree embedded in a hypercube = *N* - hypercube)





*Shmerko, Yanushkevich, 3D feed-forward neural networks and their realization by nano-devices, Artificial Intelligence Review, 2003

Problems of 3D embedding

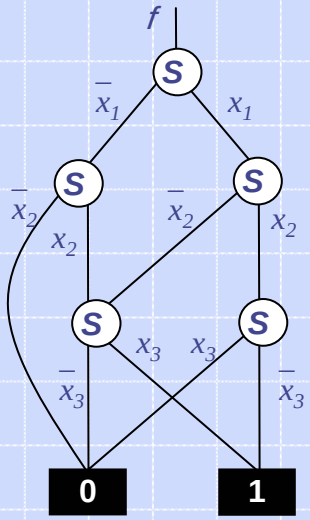
1. In 3D design, decomposition is used to solve the inverse problem, that means composition, or assembling of 3D structures

2. In BDD-based 3D structures, BDD-based decomposition must be adapted

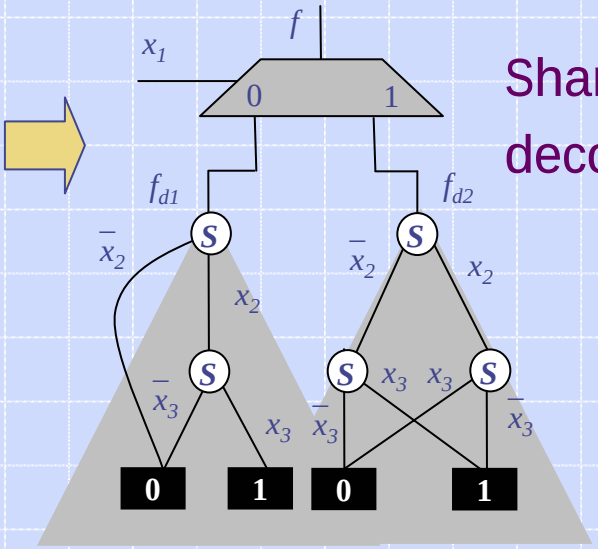
3. Problem of interconnects (critical in nanostructures) must be accommodated; in our case, only MUXes are allowed as connecting gates

Assembling of decomposed structure

Shannon-decomposition example

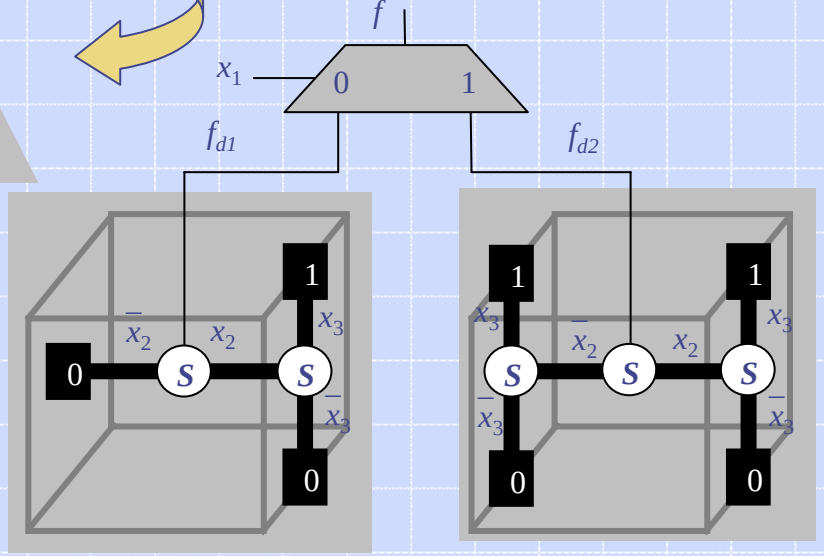


Decision diagram



Shannon-decomposition

MUX to join the *N* - hypercubes



Embed the trees into *N* - hypercubes

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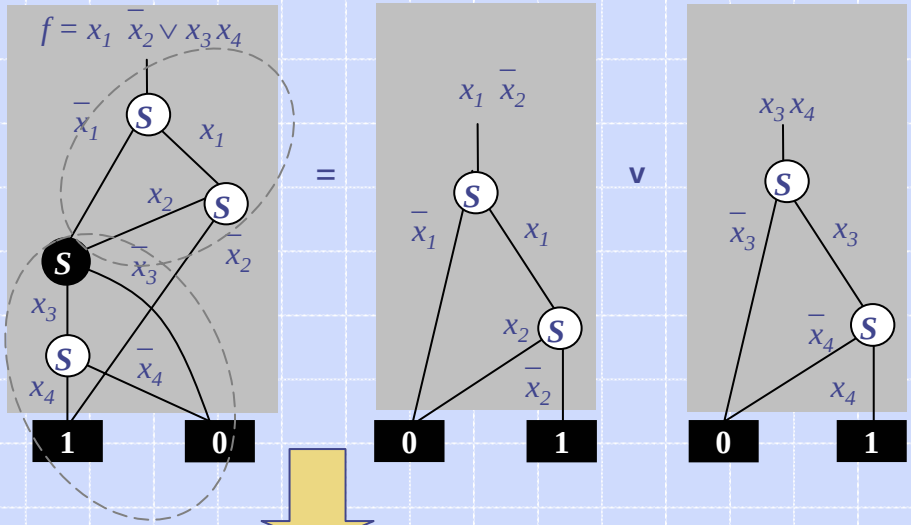
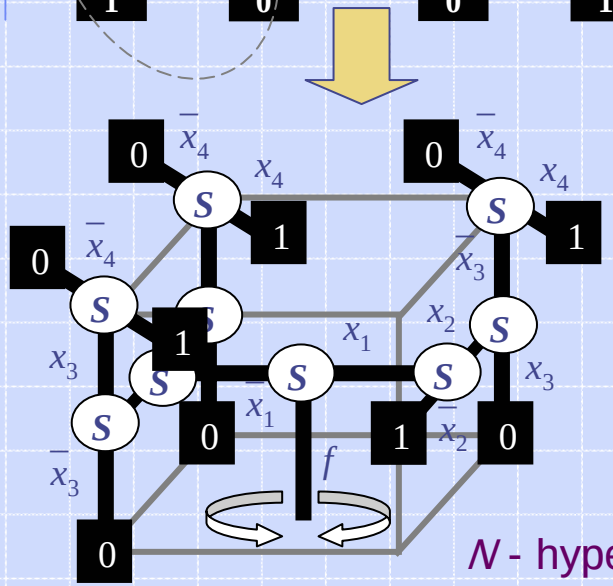
Assembling of decomposed structure



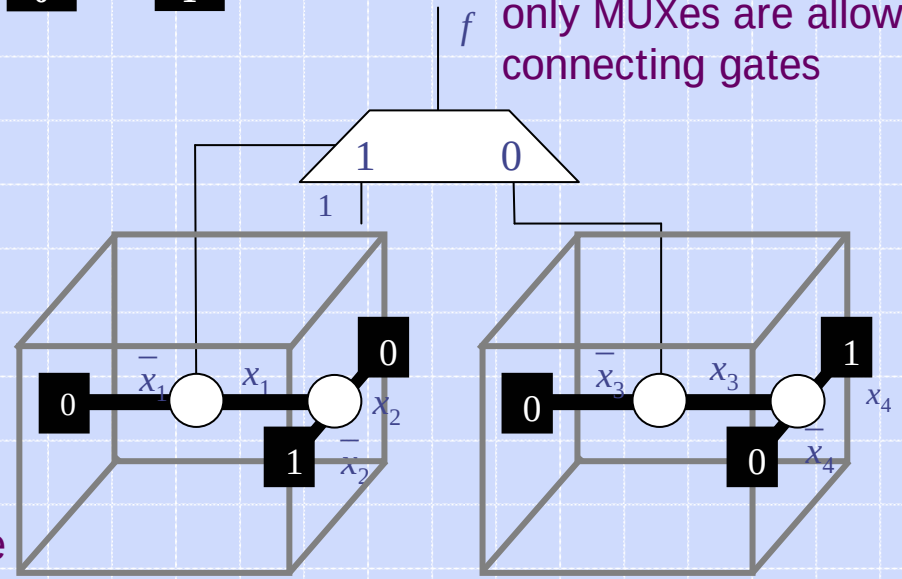
OR-bi-decomposition example

DD-based OR-bi-decomposition



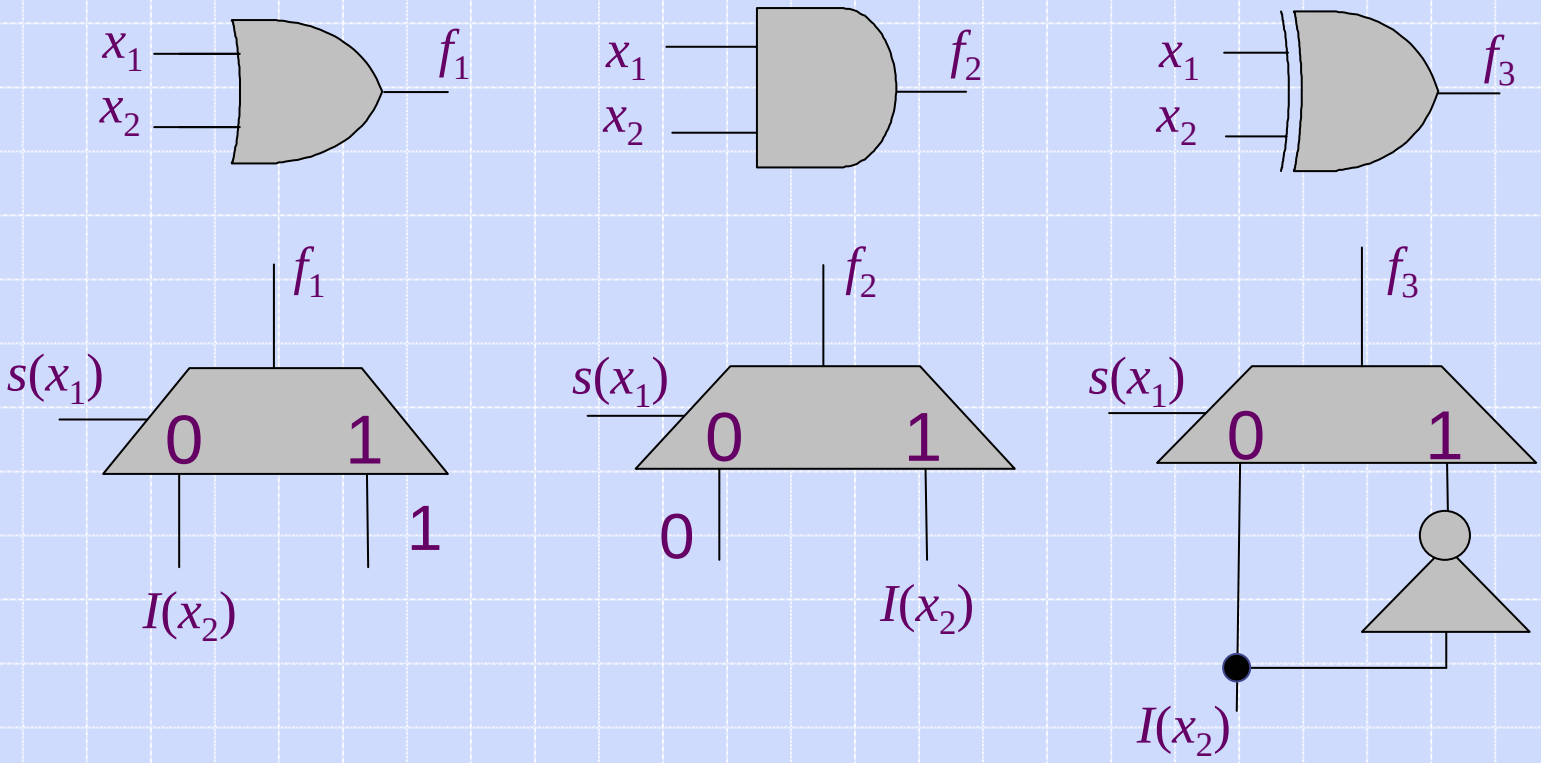
N - hypercube

Assembling *N* - hypercubes: only MUXes are allowed as connecting gates



MUX-based assembling

library of gates using MUXes



Experimental Results

TEST			SPACE SIZE					
	#O	#L	#x	#y	#z	#T	#C	#M
alu2	2	297	50	48	46	1982	5609	139
alu4	4	549	56	54	52	3470	10322	217
cordic	1	70	32	30	28	260	532	14
t481	1	2987	38	36	34	16051	43743	1445

#O is the output with the largest number of gates,
#L number of levels
#x , #y, #z are sizes of the hypercubes
#T is the number of terminal nodes
#C is the number of interconnects
#M is the number of multiplexers required for the MUX-based interconnect

Discussion and Summary

- The role of decomposition is twofold: implementing interconnect for composition of the decomposed functions, and partitioning of large networks to subnetworks.
- The choice of interconnect functions depends on the type of decomposition
- Design of 3D *N* - hypercubes uses multiplexer-based assembling technique
- AND-, OR-, EXOR-gates of Bi-decomposition is implemented using MUX representations of these elementary functions