Microfluidic Very Large Scale Integration (VLSI)

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Modeling, Simulation, Testing, Compilation and Physical Synthesis

Springer

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Acronyms

ACCENT	A Compiler Compiler for the ENTire class of context-free languages
ALAP	As Late As Possible
ALL	Adaptive Left-to-right Leftmost derivation (parsing algorithm)
ANTLR	ANother Tool for Language Recognition
ASAP	As Soon As Possible
ATPG	Automatic Test Pattern Generation
CAD	Computer Aided Design
CL	Candidate List
CP	Constraint Programming
CPA	Colorimetric Protein Assay
CPAM	Constraint Programming-Based Application Mapping
CSR	Combined Scheduler and Router
DAG	Directed Acyclic Graph
DNA	Deoxyribose Nucleic Acid
EA	Example Application
EWOD	Electrowetting-on-dielectric
FDV	Finite Domain Variables
GCP	Graph Coloring Problem
GE	General Electric
GPA	General Purpose Actuation
GRASP	Greedy Random Adaptive Search Procedure
GUI	Graphical User Interface
HA	Hadlock's Algorithm
HC	Hill Climbing
HIV	Human Immunodeficiency Virus
HLS	High Level Synthesis
ID	Identifier

IDE	Integrated Design Environment
ISI	Institute for Scientific Information
ITRS	International Technology Roadmap for Semiconductors
IVD	In-Vitro Diagnosis
JSON	Java Script Object Notation
LALR	Look Ahead Left-to-right Rightmost derivation
LL	Left-to-right Leftmost derivation
LR	Left-to-right Rightmost derivation
LS	List Scheduling
LSAM	List Scheduling-Based Application Mapping
LSI	Large-Scale Integration
MHDL	microfluidic Hardware Description Language
MI	Microfluidic Innovations
MiS	Multilevel logic Synthesis
mLSI	microfluidic Large-Scale Integration
MOS	Metal Oxide Semiconductor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MSL	Multilayer Soft Lithography
mVLSI	microfluidic Very Large-Scale Integration
MVVM	Model-View-ViewModel
NMO	N-type Metal Oxide Semiconductor
NW	Naive Washing
PCR	Polymerase Chain Reaction
PDMS	Poly DiMethyl Siloxane
PLA	Programmable Logic Array
PLY	Python Lex-Yacc
PMOS	P-type Metal Oxide Semiconductor
RAM	Random Access Memory
RCL	Restrictive Candidate List
RNA	Ribose Nucleic Acid
SA	Simulated Annealing
SB	Synthetic Benchmark
TL	Tabu List
TS	Tabu Search
UML	Unified Modeling Language
USA	United States of America
μTAS	Miniaturized Total Analysis Systems
VLSI	Very Large-Scale Integration
WGA	Whole Genome Amplification
WPF	Windows Presentation Foundation
XML	eXtensible Markup Language

Notations

$\mathcal{A}(\mathcal{N}, \mathcal{D})$	Biochip architecture graph model, where $\mathcal{N}$ is the set of vertices and $\mathcal{D}$ is the set of edges
a_i	Reachable mixing ratio
$\mathcal{B}$	Binding function for operations on components
C	Set of execution times of a component
$\mathcal{C}(U_{\mathcal{C}}, V_{\mathcal{C}}, E_{\mathcal{C}})$	A connection bipartite graph model for a biochip architecture $\mathcal{A}$; $U_{\mathcal{C}}$ is the set of entry points, $V_{\mathcal{C}}$ is the set of exit points and $E_{\mathcal{C}}$ is the set of connections between them
$\mathcal{CF}$	Finite set of channel faults
$CF(N, t)$	Channel fault on component N, of type t
C_i	Execution time of operation O_i
$C_i^{M_j}$	Execution time of O_i on component M_j
$c(D_{i,j})$	Routing latency of directed edge $D_{i,j}$ in the architecture graph
$c(F_i)$	Fluid routing latency along flow path F_i
c_{max}	Maximum number of channel faults that can occur in $\mathcal{A}$, during fabrication
$CF(D_{i,j}, t)$	Channel fault on edge $D_{i,j}$, of type t
$Cost_{\mathcal{A}}$	Cost of architecture $\mathcal{A}$
$Cost_C(G_G)$	Approximated cost function for the grid graph G_G
C_R	The set of routing grid cells, which are occupied by one of more routes
$C_{R(E)}$	The set of cells which are occupied by routes in $R(E)$
$C'_{R(E)}$	The set of cells which are occupied by routes in $R'(E)$
$\mathcal{D}$	Finite set of directed edges in $\mathcal{A}$
$depth$	Depth in the mixing tree
$d_{\mathcal{G}}$	Deadline of the biochemical application graph $\mathcal{G}$
$D_{i,j}$	Directed edge in $\mathcal{D}$ from vertex N_i to vertex N_j
$d(p)$	A detour in the routing grid path p
E	The subset of edges that change from the current solution G_G to the neighbor solution G'_G

$\mathcal{E}$	Finite set of edges in $\mathcal{G}$
$e_{i,j}$	Directed edge in $\mathcal{E}$ from O_i to O_j
$e_{u,v}$	An edge in $\mathcal{C}$ that represents a connection from exit point u, to entry point v
$\mathcal{F}$	Finite set of flow paths in $\mathcal{A}$
F_i	A flow path in $\mathcal{F}$
F_{i-j}	A flow path between two vertices N_i and N_j in $\mathcal{N}$
F_i^{ON}	Set of all Boolean input combinations, for which ith output evaluates to 1
F_i^{OFF}	Set of all Boolean input combinations, for which ith output evaluates to 0
F_i^{DC}	Set of all Boolean input combinations, for which ith output evaluates to "don't care" (X)
$\mathcal{FS}$	Set of all possible fault scenarios in $\mathcal{A}$, under fault model $\mathcal{J}$
f	A fault scenario
$f(X)$	Boolean function for on-chip control
f_i	ith input fluid in the fluid mixture
$ft(f)$	Boolean variable that evaluates the connectivity of the architecture, under a fault scenario f
$\mathcal{G}$	Biochemical application graph model
$G_G(V_G, E_G)$	Grid graph, where V_G is the set of cells in the routing grid, and $E_G$is the set of edges defining adjacent cells
$\mathcal{G}_C(\mathcal{V}_C, \mathcal{E}_C)$	Coloring graph for pin-count minimization, where $\mathcal{V}_C$ are the vertices and $\mathcal{E}_C$ are the edges
H	Geometric dimensions of a component
$H(G_G)$	The neighborhood solutions of grid graph G_G
$Heater_i$	Heater component in the biochip architecture
$I_A(e_{uv}, e_{pq})$	Intersection function between routes e_{uv} and e_{pq}
$I(e)$	List of edges that intersect e
$I_R(c_i, c_j)$	Set of intersection cells between adjacent routing grid cells, c_i and c_j
In_i	Input port (reservoir) in the biochip architecture
$\mathcal{J}$	Fault model
$\mathcal{K}$	Finite set of routing constraints for $\mathcal{A}$
K_i	One of the routing constraints in $\mathcal{K}$, which is a finite set of flow paths that are mutually exclusive with the flow path $F_i \in \mathcal{F}$
$\mathcal{L}$	Component model library
$L(m)$	Set of all vertices of the subject tree corresponding to leaves of pattern trees for $m \in M(v)$
L_A	The approximated total length of the routes, found as the sum of the Manhattan lengths of all edges
L_M	Squared two-dimensional Manhattan distance
L_R	Total length of all routes in $\mathcal{C}$
$L_R(E)$	The total length of routes in $R(E)$

$L'_R(E)$	The total length of routes in $R'(E)$
$\mathcal{M}$	Finite set of components in an architecture
M_i	One of the components in $\mathcal{M}$
$M(v_i, v_j)$	Manhattan distance between v_i and v_j in the routing grid
$M(v)$	Set of all matching pattern trees in the Tree Covering Algorithm
$Mixer_i$	Mixer component in the biochip architecture
Met_i	Metering component in the biochip architecture
$\mathcal{N}$	Finite set of vertices in $\mathcal{A}$
$N(E)$	Number of intersections for edges E in solution G_G
$N'(E)$	Number of intersections for edges E in solution G'_G
N_A	Total number of intersections of channels
N_i	One of the vertices in $\mathcal{N}$
N_R	Total number of flow channel intersections
$N_R(E)$	The number of intersections that are removed when routes $R(E)$ are removed from G_G
$N'_R(E)$	The number of intersections that are introduced when the routes in $R'(E)$ are added to G'_G
$\mathcal{O}$	Finite set of vertices in $\mathcal{G}$
O_i	Operation in the application, one of the vertices in $\mathcal{O}$
$O_E(c)$	Overlap contribution for cell, c, in $C_{R(E)}$
Out_i	Output port in the biochip architecture
p	A path in the routing grid
$\mathcal{P}$	Set of operational phases of a component
P^2_R	Smallest power of two, greater than R
R	Total sum of desired mixing fluid ratios
$r(e)$	Set of cells for the route corresponding to connection e
$R(E)$	The set of routes corresponding to edges in E for solution G_G
Res_i	A reservoir in the biochip architecture
$R'(E)$	The set of routes corresponding to edges in E for solution G'_G
r_i	Mixing ratios specified in the biochemical application
$\mathcal{R}_f$	Flow channel routing
$\mathcal{R}_c$	Control channel routing
$\mathcal{R}_\mathcal{C}$	Resource constraints for the allocation task
RL	Ready list of operations for scheduling
$\mathcal{S}$	Finite set of switches in the biochip architecture $\mathcal{A}$
S_A	The approximated total squared route length, found as the sum of the squares of the Manhattan lengths of all edges
S_i	One of the switches in $\mathcal{S}$
S_R	Total squared length of all routes in $\mathcal{C}$
$Storage_i$	Storage component in the biochip architecture
t	Type of fault

T	Temperature a parameter in the Simulated Annealing Algorithm; T_0 is the initial temperature and $T_{termination}$ is the termination temperature
$T(V_T, E_T)$	Subject tree used in the Tree Covering Algorithm
$t_{O_i}^{start}$	Start time of operation O_i
$t_{O_i}^{finish}$	Finish time of operation O_i
Q_i	Biochip control input signals used as input for the on-chip control circuits
u	Pattern graph for the Tree Matching Algorithm
$\mathcal{U}$	Allocation of architectural components
v	Subject graph for the Tree Matching Algorithm
v_i	A vertex in graph G_G that represents cell c_i in the routing grid
V_i	Function mapping integer variables in the Aqua code to integer values
V_f	Function mapping fluid variables in the Aqua code to operations in the application graph $\mathcal{G}$
$\mathcal{VF}$	Finite set of valve faults
$VF(N, w, t)$	Valve fault w in component N, of type t
v_{max}	Maximum number of valve faults that can occur in $\mathcal{A}$, during fabrication
V_R	The total overlap of flow channel intersection
$V_R^{'}(E)$	Amount of overlap introduced from solution G_G to $G_G^{'}$
w_i	Waste outlet in the biochip architecture
$\mathcal{X}$	Scheduling and fluid routing information
Y	One-dimensional Boolean space
$\mathcal{Z}$	Biochip architecture layer model for placement and routing
$\mathcal{ZF}$	Biochip architecture fault model
Z_i	Control signal Boolean value for valves, which is an output of an on-chip biochip control circuit
$\mathcal{Z}_f$	Placement of components in the flow layer
$\mathcal{Z}_c$	Placement of valves in the control layer
$\mathcal{Z}(c)$	Set of all occupants of a routing grid cell c
$\mathcal{Z}_R(c)$	Set of routes at routing grid cell c
$\mathcal{Z}_{\in R(E)}(c)$	The set of routes at cell c that are in $R(E)$
$\alpha(T)$	The temperature reduction function in the Simulated Annealing Algorithm
$\delta(f)$	Application completion time under a fault scenario f
$\delta_{\mathcal{G}}$	Completion time of application $\mathcal{G}$
Δ	Cost increase from previous solution to current solution, s the initial solution is denoted with s_0
Ψ	Implementation model
ΔV_R	Change in overlap among flow channels in the architecture

η	Control logic (valve actuation sequence)
ϕ	Mapping of the application (binding and scheduling) onto $\mathcal{A}$
θ_i	Set of available components for O_i
ρ_i	Rounding error for mixing
σ_E	Cumulative rounding error in fluid ratios for mixing
σ_R	Sum of rounding fluid ratios for mixing