CAMBRIDGE

Cambridge University Press
978-0-521-51374-6 - Semantic Techniques in Quantum Computation
Edited by Simon Gay and Ian Mackie
Index
More information

Index

J-decomposition, 250
x-rotation, 263
z-rotation, 264
dEQPL, 390
2-colorable underlying graph, 252

Aaronson-Gottesman algorithm, 441
abstract domain, 228
abstract interpretation, 207
abstract semantics, 208
  denotational, 229
  soundness, 209
abstraction function, 223
adequacy, 217
adjoint functor theorem, 384
Audenaert-Plenio algorithm, 450
auxiliary qubits, 173
axioms of PdEQPL, 394

basis structure, 30
BB84
  quantum coin-flipping protocol, 459
  quantum key distribution protocol, 415, 416, 461
Bell pair, 237
Bell state, 2, 15–17, 32, 75
Bell's experiment, 138
Bell's theorem, 16
bicategory, 33, 35, 45
  cartesian bicategory of relations, 46
  dagger cartesian bicategory of relations, 46, 47
bipartite normal form, 450, 451
bit flip, 329
Boolean lattice, 361
box, 111
bra-vector, 211
broadcasting, 67

call-by-value reduction, 153
cartesian closed category, 72
categorical
  logic, *see* logic, categorical
  quantum mechanics, 1, 6–18, 29
category
  $*$-autonomous, 5, 8, 26, 72
  cartesian closed, 2–5, 24
  compact, *see* category, compact closed
  compact closed, 9–12, 14, 19, 24, 26, 31, 33, 376
  dagger, 11, 247
  dagger compact, 11, 12, 20, 26, 33
  dagger symmetric monoidal, 11, 12, 31
  indexed, 29, 61
  inverse, 370
  Kleisli, 29, 51–53, 57
  monoidal, 6, 7, 18
  monoidal closed, 376
  of circuits, 94
  of commutative monoids, 99
  of finite-dimensional vector spaces, 9
  of generalized proof-nets, 122
  of matrices, 100
  of relations, 7, 9
  symmetric monoidal, 7–9, 11–13, 18, 21, 31
  total, 29, 61
  traced monoidal, 87
Cauchy sequence, 315
causal flow, 283
circuit model, 236
classical interface, 30, 56, 60
classical structure, 30, 33–41, 45, 46, 48, 50, 53, 57

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-51374-6 - Semantic Techniques in Quantum Computation
Edited by Simon Gay and Ian Mackie
Index
More information

Clifford
  group, 419, 444
  normal form, 450
  operator, 419
Clifford group, 238
cloning, 154
  axiomatization, 18
  uniform, 19, 25, 26
cloning collapse theorem, 19, 25
CNOT, 265
combinatory logic, 376
communicating quantum processes, *see* CQP
comonad, 165
compact closed category, 84
compact closure, 9
compact structure, 32
compact symmetric polycategory, 72, 91
comparison formulae, 391
complete lattice, 335
computation as patterns, 238
computational depth complexity, 260
coname, 10, 14, 17, 86
  partial, 86
concrete semantics, 209
controlled
  mixed quantum evolution, 60
  mixed quantum state, 60
  operation, 57
  pure quantum evolution, 57
  pure quantum measurement, 57
  pure quantum state, 57
convex closure, 54
convex combination, *see* mixture
convex combining, *see* mixing
convolution monoid, 42
copoint, 86
correcting set, 286
correction commands, 240
counit, 9, 12, 14, 85
CQP (communicating quantum processes), 416, 469
cryptographic protocols, 206
CTL, computational tree logic, 397
Curry-Howard correspondence, 72
currying, 86, 176
cut-elimination, 71, 106

dagger
  category, *see* category, dagger
De Morgan law, 335
deleting
  uniform, 26, 34
denotational model, 71
determinism, 247
Deutsch's algorithm, 189
Deutsch's problem, xi
Deutsch-Jozsa algorithm, 137, 145
diagonal morphism, 7, 19, 20, 24, 25
diagrammatic calculus, *see* graphical calculus
dimension, 33, 89
Dirac notation, 13
direct decomposition, 280
directed complete partial order (DCPO), 214
domain of signal, 240
domain theory, 213
dualizing object, 5

enrichment over commutative monoids, 99
entangled functions, 135
entanglement, 2, 15, 21, 25, 226, 236
  quantum information theory, 227
entanglement analysis, 225
entanglement commands, 240
EPR paradox, 225
EPR state, 15
EQPL (exogenous quantum propositional logic)
  complexity of model checking, 450
  extensions, 455
  semantics, 435
  syntax, 435
  verification algorithms, 447
error states, 150
exogenous logic, 390
exponential, 141

finite-dimensional Hilbert space, 73
flow
  causal, 291
  generalized, 286
  graphical interpretation, 286
  maximally delayed, 289
  optimal, 289
formal methods, 389
formal specification
  quantum coin-flipping, *see* quantum coin-flipping protocol, model checking
  quantum error correction, *see* quantum error-correction protocol, model checking
  quantum key distribution, *see* quantum key distribution protocol, model checking
  quantum teleportation, *see* quantum teleportation protocol, model checking
formal verification
  quantum coin-flipping, *see* quantum coin-flipping protocol, model checking

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-51374-6 - Semantic Techniques in Quantum Computation
Edited by Simon Gay and Ian Mackie
Index
More information

quantum error correction, *see* quantum error-correction protocol, model checking
quantum key distribution, *see* quantum key distribution protocol, model checking
quantum teleportation, *see* quantum teleportation protocol, model checking
free category, 72
free compact closed category, 89
Frobenius
algebra, 34, 49
commutative, 34, 51
special, 34
special commutative, 33, 34
special dagger, 30
condition, 34, 35
dagger structure, 25
functor
monoidal, 18

generalized flow
algorithm, 291
generalized proof-nets, 108
geometry of interaction, 378
GHZ, 266
Gottesman-Knill theorem, 419
graphical calculus, 16, 20, 31, 33, 35
Grothendieck construction, 29, 61

Hadamard operator, 242, 249
Hadamard transformation, 184
Haskell, 135, 173
Hermitian operators
quantum predicates, 324
hierarchy of quantum semantics, 224
Hilbert space, 315, 361
lattice of projectors, 363
subspace, 337

incompatible observables, 36
induction rules, 357
influencing walks, 297
Pauli, 299
interval analysis, 209
iniverse category, 369
involution, 90

Joyal's lemma, 4, 5, 24
Jozsa conjecture, 297

ket-vector, 211
Kleisli adjunction, 52
Kleisli category, *see* category, Kleisli, 164
Knaster-Tarski fixed point theorem, 349
Kraus decomposition, 246
Kraus representation theorem, 221
Kripke structure, 398

Löwner partial order, 316
lambda calculus, 71, 135
linear, 72
quantum, 139
lazy evaluation, 175
limits of quantum computation, 236
Lindenbaum-Tarski algebras, 361
linear exponential comonad, 165
linear logic, 141, 151
LISP, 135
logic
categorical, 2
category-theoretic, 375
classical, 4
epistemic, 417
exogenous, 390
exogenous quantum propositional, *see* EQPL
intuitionistic, 3–5, 71
intuitionistic multiplicative linear, 72
linear, 71, 379
multiplicative linear, 5, 9
quantum computation tree, *see* QCTL
temporal, 397, 414
loop, 90, 103

majorization, 50
MBQC
denotational semantics, 245
operational semantics, 244
semantics, 243
syntax, 240
universality, 249
versus circuit, 296
measurement, 236
measurement-based quantum computation, *see* MBQC
measurement calculus, 253
confluence, 257
extended, 292
termination, 255
measurement pattern, 240, 241
mixed state, 38, 77
mixing, 54
mixture, 54
ML, 135
model checking, 411, 414–416
modularity, 214
moinoidal tensor, 376
monads, 178
monoidal category, 82, 161

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-51374-6 - Semantic Techniques in Quantum Computation
Edited by Simon Gay and Ian Mackie
Index
More information

monoidal comonad (symmetric), 165
monoids, 178
monotonic, 214
morphism
  classical, 37
  completely positive, 38
  decoherent, 40
  doubly stochastic, 50
  positive, 37
  real, 41
  stochastic, 50

name, 10, 14, 17, 86
  partial, 86
natural deduction, 71
natural transformation
  monoidal, 18, 19, 26
Newman's lemma, 260
no-broadcasting theorem, 1
no-cloning theorem, 1, 19, 34
no-cloning theorem, 141
no-deleting theorem, 1, 26, 34
no-go theorem, 2, 25
NP-completeness, 449, 468

one-way model, 237
open graph
  extended, 293
  labelled, 276
operational semantics, 146
  QMCLang, *see* QMCLang, semantics
orthomodular lattice, 361, 363
orthomodular lattices, 335
orthomodular law, 335
orthonormal basis, 270

parity analysis, 208
partial isometry, 362, 365
  category, 369
  physical, 366
partial order, 366
path
  extreme, 252
pattern
  circuits, 300
  computation space, 242
  stepwise deterministic, 248
  synthesis, 281
  tensor, 243
  type, 242
patterns, *see* measurement patterns
Pauli
  group, 418, 443
  measurements, 295
  model, 268
  operator, 78, 238, 418, 441, 443
  spin matrices, 249
permutation, 49
phase flip, 329
phase map decomposition, 239
phase model, 267
picture calculus, *see* graphical calculus
point, 86
polycategorical, 247
polycategory, 72
polymorphic functions, 175
predicate transformers
  projective, 337
preorder, 213
PRISM model checker, 416
projection-based quantum computing, 275
projective weakest preconditions, 341
proof-net, 77
proof-nets
  local confluence, 118
  subject reduction, 117
  termination of reduction, 118
proof-slice, 109
pure quantum evolution, 55
pure quantum measurement, 56
pure quantum state, 55, 77
purely functional approach, 174

QCTL (quantum computation tree logic), 397
  complexity of model checking, 455
  interpretation over QMC models, 438
  semantics, 437
  syntax, 437
  verification algorithms, 452
QIL, 212
  program, 212
QIO monad, 183
QMC (quantum model checker), 416, 439
  case studies, 456–466
  complexity, 445
  graphical user interface, 439
  interpreter, 441
  model-checking algorithms, 446
  modeling language, *see* QMCLang
  parser, 440
  scheduler, 441
  simulation algorithm, 441
QMCLang
  semantics, 423
  syntax, 423
  type system, 432
quantum categorical semantics, 31
quantum cellular automata, 236

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-51374-6 - Semantic Techniques in Quantum Computation
Edited by Simon Gay and Ian Mackie
Index
More information

quantum closure, 147
quantum coin-flipping protocol
  model checking, 459
quantum commands, 348
quantum error-correction
  model checking, 464
quantum Fourier transform, 157, 196
quantum imperative language, *see* QIL
quantum information flow, 15–17
quantum information processing, 206
quantum IO monad, 173
quantum key distribution protocol
  model checking, 461
quantum Kripke structure, 399
quantum lambda calculus, 139
quantum logic, 70, 361
quantum measurements, 320
quantum mechanics, xi
quantum parallelism, 185
quantum programming language, xii, 212
quantum programming languages, 311
quantum state
  entangled, 75
quantum state transformers, 314
quantum states, 314
quantum system (in categorical quantum mechanics), 33, 75
quantum teleportation, 190
quantum teleportation protocol, 77
  description, 16, 420
  in categorical quantum mechanics, 17, 57, 58
  model checking, 456
quantum Turing machines, 236
quantum walk, 393
quantum weakest preconditions, 324, 325
  commutativity, 328

reachability relation, 151
relation, 43
reversible arithmetic, 192
reversible let, 173
rotation
  general, 265

Sasaki hook, 364
SAT problem, 395
scalar, 7, 13, 88
scheme, 135
semantics
  abstract, 228
  admissible, 221, 223
  constructive, 173
  hierarchy, 213
  observable, 218
  predicate transformer, 312
  probabilistic, 214
  pure, 216
semantics of dEQPL, 392
semiadditive category, 100
semiadditive functor, 100
shift operator, 367
Shor's algorithm, 194
signal shifting, 245, 259
specification
  formal, *see* formal specification
spectral decomposition, 317
spider, 35
stabilizer
  formalism, 416, 417, 468
    Aaronson-Gottesman simulation algorithm, 441
    complexity, 445
    efficient simulation, 419
    entanglement, 450
  group, 418
standardization, 238, 255
state transfer, 273
state-transfer approach, 238
stochastic state, 54
strength (of endofunctor), 51
strict compact closed category, 85
strict monoidal category, 84
strictness, 214
strong normalization of proof-nets, 82
subject reduction, 152
substitution, 151
subtype, 142
subtyping relation, 142
superoperators, 320
symmetric monoidal category, 83
syntax of dEQPL, 391

teleportation, 206, 263, 269
  abstract semantics, 230
teleportation algorithm, 145
teleportation procedure, 137
teleportation protocol, 237
teleportation technique, 238
temporal logic, 397
tensor
  product of Hilbert spaces, 15
  structure in a category, 6, 7
tensor-sum logic, 103
  syntax, 103
tensor-sum proof-nets, 108
topological space, 214

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-51374-6 - Semantic Techniques in Quantum Computation
Edited by Simon Gay and Ian Mackie
Index
More information

trace
  in a compact closed category, 87
  in a symmetric monoidal category, 12
  of a linear map, 12
transpose endofunctor, 33
Turing machine, 135
type inference, 155
type isomorphism, 154
type safety, 152
type theory, 173
type classes, 175
typing context, 143
typing judgment, 143

uncurrying, 86
uniformity of data, 153
unit, 6, 7, 9, 12, 14, 85
unitary embedding, 247
unitary transformations, 319
universal quantum computing, 237
universality, 251
  approximate, 251

verification
  formal, *see* formal verification

zero object, 95

© in this web service Cambridge University Press www.cambridge.org