INDEX

2-exchange mutation, 468
2-opt mutation, 467

A
accuracy, 598, 603
acronyms, xxiii
active learning, 572
adaptive cultural model, 387
adaptive penalty method, 509
adaptive segregational constraint handling, 495, 516
adjacency representation, 460, 479
admissible point, 519
admissible set, 519
age factor, 589
aggregation, 550
all topology, 289
allele, 45
alternating edges crossover, 461
ant-Q, 280
ant colony optimization, 241
ant-Q, 260
ant colony system, 257
ant system, 246
approximated non-deterministic tree search, 261
beam ACO, 261
best-worst ant system, 261
candidate solution, 257
continuous domains, 252
convergence, 261
elitism, 260
exploration constant, 259
hypercube, 261
initial pheromone, 257
local pheromone decay, 258
local pheromone update, 257
negative reinforcement, 262
noisy fitness, 262
opposition-based learning, 398
population-based, 261
pseudo-random proportional rule, 257
rank-based ant system, 260
ant colony system, 257
ant system, 246
best-worst, 261
deposition constant, 248, 252
elitism, 247, 252
elitist, 260
evaporation rate, 248
heuristic sensitivity, 248, 264
initial pheromone, 248
initialization, 247
local search, 252
max-min, 255
mutation, 247
rank-based, 260
tuning parameters, 248
applications, 12
biased vector, 672, 681
combinatorial
dynamic, 672
composite, 674
constrained, 509, 657
dynamic, 672
feasibility ratio, 664
multi-objective, 665
dynamic, 585, 590–591, 672
chaotic, 675
combinatorial, 672
composition, 674
constrained, 672
knapsack, 672
large-step, 674
multi-objective, 672
noisy recurrent, 676
random, 673
recurrent, 676
simplified, 677
small-step, 673–674
traveling salesman, 672
multi-objective, 555, 665
constrained, 665
dynamic, 672
noisy, 677
rotation matrix, 672, 682
traveling salesman, 678
B.
Balestii, Nils, 42, 444
barrier function, 483
Bayesian algorithm, 445
Bayesian optimization, 340
Bayesian optimization, hierarchical, 341
beam search, 261
behavioral memory, 496
multi-objective optimization, 533
stochastic sampling, 497
belief spaces, 391, 393, 395
dynamic, 392
inertia, 395
benchmark, 622, 641
bias, 26, 680
bias vector, 672, 681
combinatorial
dynamic, 672
composite, 674
constrained, 509, 657
dynamic, 672
feasibility ratio, 664
multi-objective, 665
dynamic, 585, 590–591, 672
chaotic, 675
combinatorial, 672
composition, 674
constrained, 672
knapsack, 672
large-step, 674
multi-objective, 672
noisy recurrent, 676
random, 673
recurrent, 676
simplified, 677
small-step, 673–674
traveling salesman, 672
multi-objective, 555, 665
constrained, 665
dynamic, 672
noisy, 677
rotation matrix, 672, 682
traveling salesman, 678
B.
bacterial chemotaxis model, 434, 445
bacterial foraging optimization, 432, 446
chemotaxis, 433
cloning, 434
differential evolution, 434
dispersal, 434
elimination, 434
particle swarm optimization, 434
reproduction, 433
balance, 29
Barnes, Nils, 42, 444
barrier function, 483
bat-inspired algorithm, 445
Bayes' theorem, 499
Bayesian optimization algorithm, 340
Bayesian optimization, hierarchical, 341
beam ant colony optimization, 261
beam search, 261
behavioral memory, 496
multi-objective optimization, 533
stochastic sampling, 497
belief spaces, 391, 393, 395
dynamic, 392
inertia, 395
benchmark, 622, 641
bias, 26, 680
Schweifel, 2.22, 652
Schweifel, 2.26, 129, 286, 652
Schweifel, absolute, 652
Schweifel, double sum, 650
Schweifel, max, 651, 683
Schweifel, ridge, 650
Schweifel, sine, 652
Shekel’s foxholes, 654
sine envelope, 655
sphere, 62, 115, 125, 138, 291, 642
step, 653
tent, 649
Weierstrass, 657
weighted sphere, 648

Bermoulli’s Principle of Insufficient Reason, 618
best-worst ant system, 261, 264
best of the average, 618
best of the best, 618
bias vector, 672
Bible, 1, 38, 241, 377, 421
Bienert, Peter, 117
big bang big crunch algorithm, 445
bin packing problem, 477
binomial coefficient, 73
binomial distribution, 296, 310
bio-inspired computing, 3
biogeography-based optimization, 351
constrained optimization, 569
diversity, 533
dynamic system model, 370
citation, 360
citation, 360
citation, 360
emigration, 353
evolution strategy, 375
generational, 360
genetic algorithms, 369
habitat suitability index, 353
immigration, 353
initial immigration, 371
Markov model, 370
migration, 363, 392
blended, 365
linear, 359
sinusoidal, 364
multi-objective, 551
mutation, 363
opposition-based learning, 398
partial emigration-based, 367
partial immigration-based, 360, 366
positive feedback, 371
selection, 374
selection pressure, 374
statistical mechanics, 370
steady-state, 360
suitability index variable, 353
total emigration-based, 367
total immigration-based, 367
web site, 352, 370

biogeography, 354
Amazon rainforest, 358
archipelago, 371
Bikini Atoll, 358
distance effect, 371
global warming, 358
ice age, 358
initial immigration, 371
Krkuton, 357
migration
time correlation, 373
optimality of, 357
positive feedback, 358
prey and predator, 372
probability, 354
rank-based selection, 375
reproductive value, 372
resource competition, 373
species mobility, 372
biometrical analysis algorithm, 335
blended crossover, 213
BLX-a crossover, 213
Boltzmann annealing, 225
boundary search, 513
box plot, 625
Bow, George, 42
Bremner, Hans Joachim, 42
brute force, 439
bugs, 607
building block, 338

C
candidate solution, 28, 44
capacitated vehicle routing problem, 478, 680
cardinality, 449
cattail particle swarm optimization, 288
Cauchy PDF, 232
central force optimization, 438
Černý, Vlado, 223
charged system search, 444
chemical reaction optimization, 445
chemotaxis, 433
dl-square statistic, 336, 348
choose function, 74
chromosome, 45
classic crossover, 461
clearing, 196, 217
unique set, 196
closet, 61, 156, 434
close enough traveling salesman problem, 478
cloud computing, 601
center computing, 601
center topology, 270
clustering, 545, 551, 582
diversity, 556
fitness approximation, 567
co-evolution, 384
no free lunch, 621
co-evolution, 384
collective intelligence, 265
combinatorial optimization, 449
differential evolution, 305
opposition-based learning, 413
combining optimizers with mutual information
trees, 329, 333
communication, 610
compact genetic algorithm, 318, 348–349
extended, 337
competition vs. cooperation, 378
competitive learning, 322
computer intelligence, 2
constrained optimization, 238, 289, 309, 481
adaptive penalty methods, 492
adaptive segregational constraint handling, 485
behavioral memory, 496
biogeography-based optimization, 509
boundary search, 513
coevolutionary penalties, 489
constraint difficulty, 511
cultural algorithm, 383, 505
dynamic methods, 487
dynamic penalty methods, 490–491
exponential, 491
superiority of feasible points, 490
eclectic evolutionary algorithm, 488
elitism, 489, 510
exponential dynamic penalty, 491
superiority of feasible points, 491
feasible set, 481
Genocop, 502
Genocop II, 503
Genocop III, 503
hybrid algorithms, 482
infeasibility driven evolutionary algorithm, 496
infeasible set, 481
multi-objective, 505, 513, 518, 531
multimembered evolution strategy, 498
niched-penalty approach, 498
penalized cost function, 486
penalty factors, 486
penalty function approach, 482
ranking, 506
c-level comparisons, 508
constraint order, 507
maximum constraint violation, 507
repair algorithms, 482
segregated genetic algorithm, 492
self-adaptive fitness formulation, 493
self-adaptive penalty function, 494
special operators, 482, 501
special representations, 482, 499
static methods, 486–487
static penalty approach, 508
stochastic ranking, 497
superiority of feasible points, 487
dynamic penalty methods, 490
exponential dynamic penalty, 491
traveling salesman problem, 516
constraint difficulty, 511
constraint programming, 512
constraint satisfaction algorithms, 512
continuous population based incremental learning, 343
continuous univariate marginal distribution
algorithm, 342
contour matching, 296, 309
cost function, 13
course outline, 8
covariance matrix adaptation evolution
strategy, 135
covariance matrix self-adaptive evolution
strategy, 135
Cramer, Michael, 142
creation, 38
cross entropy, 261
cross validation, 583
crossover, 47, 48, 51, 53, 56, 209
arithmetic, 212
bi-sexual, 211
blended, 213
DLX-n, 213
discrete, 209
discrete sexual, 126
dominant, 126
flat, 212
fuzzy, 213
gender-based, 215
gene pool recombination, 211
global, 126
global uniform, 211
heuristic, 213
intermediate global, 126
intermediate sexual, 126
inver-over, 415
linear, 213
matrix, 89
multi-parent, 211
multi-sexual, 211
multiple-point, 210
nicheing, 194, 371
parametric, 126
probability, 79, 89, 156
scanning, 211
segmented, 210
shuffle, 212
simple, 209
simulated binary, 213
single-point, 209
species-based, 194, 371
tree-based, 146
two-point, 210
uniform, 210
crowding, 197, 219
crowding distance, 560
crowding
deterministic, 197
distance, 540, 543, 551
diversity, 556
factor, 197
standard, 197
cuckoo search, 444
cultural algorithm-influenced evolutionary program, 384
cultural algorithm, 377
  adaptive cultural model, 387
  belief space, 381
  co-evolution, 384
  constrained optimization, 383, 505
  culture Wars, 393
  diversity, 383
  generalized other model, 393
  mathematical model, 383
  multi-objective optimization, 394
  neighborhood size, 387, 396
  opposition-based learning, 417
  selection pressure, 389–390, 395
  stochastic information sharing, 389
  subcultures, 383
  traveling salesman problem, 389
  tuning parameters, 383
cultural evolutionary programming, 384
curse of dimensionality, 81
cybernetic solution path, 118
cycle crossover, 468, 471

D
Darwin, Charles, 38, 351–352
Darwin, Robert, 38
de Jong, Kenneth, 35, 43, 191, 197, 642, 644, 646, 653–654
de Vries, Hugo, 39
decision trees, 567
decision variable, 13
deduction, 499
deduction, 2
delta function
  Kronecker, 328
density, 546
design and analysis of computer experiments, 569
  Latin hypercube sampling, 574
  uniform sampling, 574
determinant, 70
deterministic crowding, 197
differential evolution, 293, 681
  adaptation, 309
  artificial bee colony, 436, 446
  bacterial foraging optimization, 434
  base vector, 300
  binomial distribution, 296
  classic, 296
combinatorial optimization, 395
convergence, 302
crossover, 294
crossover rate, 295, 298, 311
DE/best/1/bin, 295
DE/best/1/L, 299
DE/best/2/bin, 299
DE/best/2/L, 299
DE/rand/1/bin, 296–297
DE/rand/1/either-or, 300
DE/rand/1/L, 296, 310
DE/rand/2/bin, 299
DE/rand/2/L, 299
DE/target-to-best/1/bin, 300
DE/target/1/bin, 300
DE/target/1/L, 300
DE/target/2/bin, 300
DE/target/2/L, 300
difference vector, 294, 300
discrete, 307, 310
dither, 303
evolution strategy, 309–310
genetic algorithm, 307
hybridization, 309
jitter, 303
mixed-integer, 306, 310
mutant, 310
mutant vector, 294, 298, 318
opposition-based learning, 398
scale factor, 296, 302
stepsize, 296, 311
teaching-learning-based optimization, 441
trial vector, 294
tuning parameters, 296
variations, 296
diplomacy, 39, 215
direct initialization, 180
discrete crossover, 299
discrete sexual crossover, 126
displacement mutation, 467
dissimilarity threshold, 196
distance cutoff, 196
distance
  Euclidean, 678
    three-dimensional, 679
  geographical, 678
  Manhattan, 679
  maximum, 679
  pseudo-Euclidean, 679
  x-ray crystallography, 679
diversity, 192, 353, 383, 470, 609
diversity evolutionary multi-objective optimizer, 536
diversity
cleaning, 196
clustering, 556
crowding, 197, 556
entropy, 556
fitness sharing, 196
grids, 558
mates restriction, 556
multi-objective optimization, 523
niching, 194
restricted tournament selection, 197
species-based crossover, 194
dominant crossing, 126
dominant genes, 40
domination, 519, 559
Dorigo, Marco, 243
dual inheritance, 382
dual learning, 416, 418
adaptation speed, 417
decision threshold, 417
dynamic fitness, 588
population-based incremental learning, 417
valid duals, 417
Dubins traveling salesman problem, 478
duplicate individuals, 157, 192, 217, 219, 469, 472, 561
dynamic approximate fitness-based hybrid evolutionary algorithm, 578
dynamic fitness, 584
age factor, 589
approximation, 586
change detection, 585, 593
dual learning, 588
elitism, 588
hypermutation, 559
immigrant schemes, 588, 590, 592
marker individuals, 585
memory-based approaches, 593
opposition-based learning, 588
population-based incremental learning, 588
predictive evolutionary algorithm, 587
reinitialization, 586, 586, 592
stochastic selection, 590
dynamic optimization, 347, 417
performance evaluation, 503
web site, 601
dynamic penalty method, 509
superiority of feasible points, 509
dynamic system model, 82
biogeography-based optimization, 370
proporionality vector, 82
dynamic topology, 269
eigenvalue, 70
eigenvector, 70
Einstein, 28
El Farol, 379
elitism, 157, 188, 217, 219, 237, 560
biogeography-based optimization, 360
constrained optimization, 489, 510
differential evolution, 302
dynamic fitness, 588
estimation of distribution algorithms, 316, 319
evolution strategy, 125
current fitness, 584
multi-objective biogeography-based optimization, 554
multi-objective optimization, 532
current swarm optimization, 269, 283
current ant system, 248, 260
current address of author, 4
emigration, 353
ensemble techniques, 582
entropy, 224, 325, 348
diversity, 556
error function, 123
estimation of Bayesian networks algorithm, 340
estimation of distribution algorithms, 313
adaptation, 347
continuous optimization, 341
elitism, 316, 319
hybridization, 347
particle filtering, 347
estimation of Gaussian network algorithm, 347
estimation of multivariate normal algorithm, 347
ethics, 627
Euclidean distance, 578
Euler, Leonhard, 449
evolution control, 577
evolution strategy, 96, 117, 191, 217, 223, 309
\((\mu+\lambda), 128
\((\mu+1), 125
\((\mu, \lambda), 128
\((\mu, \lambda, p), 131
(1+1), 118
biogeography-based optimization, 375
covariance matrix adaptation, 135
covariance matrix self-adaptive, 135
differential evolution, 310
elitism, 126
Markov model, 137
multi-membered, 128
multi-objective optimization, 540, 551
mutation rate, 131
self-adaptive, 131
steady-state, 125
two-membered, 118
evolutionary algorithm
bias, 25, 680
performance evaluation
dynamic fitness, 593
robustness, 601
INDEX

vector evaluated, 552
multi-objective genetic algorithm, 542
multi-objective optimization, 238, 309, 347, 517
e-based, 537
e-box, 537
e-constraint method, 533
e dominance, 522
adaptation, 557
admissible point, 519
admissible set, 519
aggregation, 528
archive, 534
biogeography-based optimization, 551
clustering, 545
constrained, 506, 513, 518, 531
convergence, 544
core, 519
crowding distance, 540
cultural algorithm, 394
density, 548
diversity, 523, 832, 536, 543, 556
domination, 519
efficient point, 519
elitism, 532, 543–544
evolution strategy, 540, 551
expensive fitness functions, 557
fitness approximation, 508
gender-based, 534
goal attainment, 524
goal programming, 524
goals, 524
Hajela-Lin genetic algorithm, 532
hybridization, 557
hyper-volume, 525
ideal point, 525
lexicographic ordering, 532
Markov model, 558
multi-objective genetic algorithm, 542
niched Pareto genetic algorithm, 542
noisy fitness functions, 557
nondominated point, 519
nondominated search, 519
nondominated sorting genetic algorithm, 533
noninferior point, 519
Pareto archived evolution strategy, 551
Pareto front, 519
Pareto optimality, 519
Pareto set, 519
particle swarm optimization, 556
product aggregation, 529
raw cost, 544, 560
relative coverage, 528
self-adaptive penalty function, 495
sharing parameter, 542
simple, 535
strength Pareto evolutionary algorithm, 544
strength value, 544, 560
superiority, 519
target vector optimization, 524
tournament selection, 532, 538, 542
user preference, 557
utopia point, 523
vector evaluated genetic algorithm, 531
weak domination, 519
web site, 558, 561
weighted sum approach, 528, 561
multi-parent crossover, 211, 309
multi-performance optimization, 518
multi-sexual crossover, 211
multimembered evolution strategy, 498
multinomial theorem, 74, 76, 78
multiple-point crossover, 210
multiple model approximation, 579–580
Murnoe, Eugene, 352
mutation, 49–50, 56, 214
biogeography-based optimization, 383
Gaussian, 215
isotropic, 119
tree-based, 146
uniform, 214–215
mutual information, 329, 348
mutual information maximization for input clustering, 324, 333

N
n-coloring problem, 473
natural selection, 36, 40
positive feedback, 358
nature-inspired computing, 3
nearest-neighbor initialization, 452, 472, 479
stochastic, 453
nearest-insertion initialization, 455
nearest two-neighbor initialization, 453, 479
negative reinforcement
ant colony optimization, 262
particle swarm optimization, 286, 392
neighborhood size
cultural algorithm, 387
neural networks, 2, 12, 48, 322, 445
fitness approximation, 507
opposition-based learning, 397
overfitting, 582
niching count, 195
dissimilarity threshold, 196
distance cutoff, 196
niching radius, 196
sharing function, 195
niching set, 196
niched-penalty approach, 498, 509
niched Pareto biogeography-based optimization, 553
niched Pareto genetic algorithm, 542
niching, 194, 371
NK models, 567
no free lunch, 174, 465, 610, 614
coevolution, 621
noisy fitness, 594, 603
fitness approximation, 598
Kalman evolutionary algorithm, 598
multi-objective optimization, 557
resampling, 596
non-deal penalty approaches, 485
non-dominated point, 519
non-dominated set, 519
non-dominated sorting biogeography-based optimization, 552
non-dominated sorting genetic algorithm, 539–540
non-dominated sorting genetic algorithm II, 560
non-inferior point, 519
non-stationary fitness, 584
normalized hypervolume, 526
normalized reference-point hypervolumes, 527, 555
notation, 6

O
objective function, 13
online surrogate updating, 568
operations research, 518
opposition-based learning, 384, 397, 681
adaptive, 417–418
ant colony optimization, 398
biogeography-based optimization, 398, 404
combinatorial optimization, 413
cultural algorithm, 417
degree of opposition, 400
differential evolution, 398, 403
dual learning, 416
dynamic fitness, 588
fitness-based, 411–412
fitness-based proportional, 413, 419
fuzzy logic, 402
genetic algorithms, 397
initialization, 403
jumping rate, 403, 415
jumping ratio, 411, 415
modular opposition, 398, 418
neural networks, 397
opposition pressure, 411
partial opposite, 389
particle swarm optimization, 398
probabilities, 406
quasi opposite, 402, 419
quasi reflected opposite, 402
reflected opposite, 398, 419
reinforcement learning, 397
search for novelty, 417
simulated annealing, 398
super opposite, 402
traveling salesman problem, 413, 480
greedy opposite, 414
type 1 opposition, 401
type 2 opposition, 401
optimal allocation of trials, 29
optimality vs. stability, 357
optimization
combinatorial, 20, 449
constrained, 16, 30, 289, 481
discrete, 449
examples, 11
local, 180
multi-objective, 16, 149, 517
multimodal, 19, 193–194
cso-opt mutation, 467
order-based crossover, 459, 471
order crossover, 458, 471, 480
ordinal representation, 463, 479
over-selection, 201, 218
overfitting, 582
ensemble techniques, 582
overstatements, 614, 621
Owens, Alvin, 43, 95

P
panmictic crossover, 126
parallelization, 555
Pareto archived evolution strategy, 551
Pareto front, 18, 30–31, 519, 551
concave, 529
convex, 530
Pareto optimality, 519
Pareto set, 18, 31, 519, 559, 561
Pareto set distance, 524
Pareto, Vilfredo, 529
partially matched crossover, 457, 471
particle swarm optimization, 265
acceleration, 289–290
adaptation, 288
artificial fish swarm algorithm, 426
bacterial foraging optimization, 494
catfish, 288
combinatorial problems, 289
constriction, 273
constriction coefficient, 290, 292
deterministic, 269
elitism, 269, 283
firefly algorithm, 431, 446
fully informed, 262, 291, 317
gravitational search algorithm, 438–439, 446
group search optimizer, 428
hybridization, 299
inertia, 267
inertia weight, 271
initialization, 289
interacting swarms, 289
learning from mistakes, 285
learning rates, 269
linear, 269
multi-objective optimization, 556
mutation, 259
negative reinforcement, 286, 290
neighborhood size, 268, 291
neighborhoods, 269, 290
opposition-based learning, 398
shuffled frog leaping algorithm, 429
stability, 273, 290
topology, 269, 289
tuning parameters, 268
velocity, 269
velocity limiting, 270
velocity update
INDEX 739

global, 279
web site, 289
path representation, 457, 479
peer review, 627
penalized cost function, 466
penalty function approaches, 482-483
exterior point, 485
interior point, 483
performance evaluation
average of the average, 618
average of the best, 618
best of the average, 618
best of the best, 618
box plot, 625
dynamic optimization, 593, 604
mean average performance, 594
mean best performance, 604
success rate, 628
phenotype, 45
pheromone, 242, 244
evaporation, 242, 244
mathematical model, 245
PID control, 619
Pincus, Martin, 233
polynomial models, 567
polyplody, 40, 215
population-based ant colony optimization, 261
population-based optimization, 2
population, 44
diversity, 192
initial, 51, 180, 217
seeding, 180
uniformity, 192
varying size, 215
population based incremental learning, 321, 340
continuous, 343
dual learning, 417
dynamic fitness, 588
learning rate, 345
tuning parameters, 323, 343
positive feedback, 244
biogeography, 358
natural selection, 358
precision, 698, 603
predators and prey, 265
predictive evolutionary algorithm, 587
premature convergence, 154, 192
prerequisites, 5
Price’s selection and covariance theorem, 92
Price’s theorem
genetic programming, 173
Price, Kenneth V., 293
prime numbers, 103
principle of insufficient reason, 408
prisoner’s dilemma, 105, 379
always cooperate, 105
grim strategy, 106
iterated, 105
punish strategy, 106
tic-for-tac, 106
tit-for-two-tails, 106
variations, 108
probabilistic incremental program evolution, 174
probabilistic model-building genetic algorithms, 313
probability
law of large numbers, 83
total probability theorem, 71
problem-specific information, 112, 141, 150, 168, 174, 408, 469, 473, 499, 503-503,
509, 511, 557, 609, 618-620
pruning, 547, 549, 551
detrimental, 550
pseudo-Euclidean distance, 679
pseudo-random numbers, 629
pseudo-random proportional rule, 257
publication, 610
Q
Q-learning, 290
Quammen, David, 351
quartic polynomial, 14

R
random numbers, 628
generator, 73
random search, 617
corvergence, 261
randomness, 27
rank-based ant system, 260, 264
rank-based selection, 203, 218
biogeography-based optimization, 375
rank weighting, 203
real-world problems, 16, 29, 42, 163, 166, 182,
193, 234, 254, 263, 293, 352, 370, 389,
406, 411, 481, 498, 498, 501, 510, 512,
517, 524, 540, 551, 554, 601, 611, 614,
619-620, 622-623, 642, 677, 680, 683
recessive genes, 40
Rechenberg, Ingo, 117, 594
reciprocal exchange mutation, 468, 471
recombination, 269
record-to-record travel, 445
recursion, 152
recess, see recursion
recursive least squares
fitness approximation, 568
reference-point hypervolume, 527, 555
reinforcement learning, 397
reinitialization, 237, 239
relative coverage, 528, 559
repair algorithms, 482
repeatability, 630
representation, 50
binary code, 183
grey code, 183
reflected binary code, 183
worst-case problem, 185-187
resampling, 596, 603
fitness inheritance, 597
response surface, 568, 568
restricted tournament selection, 197
Riccati equation, 590
ring topology, 270
river formation dynamics, 444
robotics, 12, 44
robustness, 601, 619
rotation estimation, 583
rotation matrix, 672
roulette-wheel selection, 198, 206, 213, 436, 471
genetic programming, 201

S

Samuel, Arthur, 142
SAX, 213
scanning crossover, 211, 369
scheduling problem, 476
schema, 64
average fitness, 65
counterexamples, 67
crossover, 65
defining length, 65, 167
fragility, 171
instance, 65
length, 167
mutation, 66
order, 65, 167
pessimistic theory, 173
structure, 167
theorem, 66
Schwefel, Hans-Paul, 117
search domain, 406
search for novelty, 384
opposition-based learning, 417
segmented crossover, 210, 218
segregated genetic algorithm, 492
selection, 56, 199
fitness-proportional, 46
fitness-proportate, 46
linear ranking, 205
over-selection, 201
rank-based, 203
rank weighting, 203
roulette-wheel, 46, 48, 56, 60, 76, 97, 154, 360
roulette wheel, 60
sigma scaling, 202
square-rank, 204
stochastic universal sampling, 199
tournament, 97, 154, 207
selection pressure, 199, 205, 217–219
biogeography-based optimization, 374
cultural algorithm, 399–390, 395
tournament selection, 207
self-adaptive fitness formulation, 493, 515
self-adaptive penalty function, 494, 516
multi-objective optimization, 495
separable problems, 296, 298, 304, 370, 395
sequential ordering problem, 478, 680
sharing function, 195
shifting mutation, 498
shortcuts, lack thereof, 608
shortest-edge initialization, 453, 479
shuffle crossover, 212
shuffled complex evolution, 429
shuffled frog leaping algorithm, 429, 446
particle swarm optimization, 429
sigma scaling, 202, 218
simple crossover, 209
simple evolutionary multi-objective optimizer, 535
simulated annealing, 223
acceptance probability, 227, 239
candidate generation, 227, 237, 240
cooling, 227
dimension-dependent, 234, 236
exponential, 228, 239
inverse, 228, 239
inverse linear, 232, 239
linear, 227, 239
logarithmic, 290, 299
energy, 225
opposition-based learning, 398
reinitialisation, 237
temperature, 225–226
tuning parameters, 226
simulated binary crossover, 213
single-point crossover, 209, 214, 218
Smith, Stephen, 142
society and civilization algorithm, 444
soft computing, 2
soft constraints, 486
soft tournament, 218
solution feature, 13
solution manual, 5
space gravitational optimization, 438
special operators, 482, 501
special representations, 482, 499
decoders, 499
specializing island model, 371
speciation, 51
species-based crossover, 194, 371
square-rank selection, 204, 375
biogeography-based optimization, 376
square topology, 270
squeaky wheel optimization, 445
stability vs. optimality, 357
standard crowding, 187
static topology, 269
stationary points, 14
statistical mechanics, 225
biogeography-based optimization, 370
statistical significance, 610
F-test, 536
t-test, 531
Wilcoxon test, 640
statistics
cochrane’s, 336
first-order, 315, 321, 333
second-order, 315, 324, 333, 335
steady-state evolution strategy, 125
steady-state evolutionary algorithm, 190, 217
INDEX

- generation gap, 191
- stochastic diffusion search, 444
- stochastic gradient ascent, 281
- stochastic hill climbing with learning by vectors of normal distributions, 343
- stochastic initialization, 456
- stochastic ranking, 497, 509
- stochastic sampling, 497, 566
- stochastic universal sampling, 199, 218
- stochasticity, 508
- Storm, Rainier, 293
- strength Pareto biogeography-based optimization, 554
- strength Pareto evolutionary algorithm, 544, 560
- stud evolutionary algorithm, 207, 279, 375
- biogeography-based optimization, 375
- genetic algorithm, 298
- sub-population, 215
- success rate, 625
- Sudoku, 479
- suitability index variable, 353
- superiority of feasible points, 515
- superorganism, 241
- support vector machines, 567, 578
- surrogate model, 866
- survival of the fittest, 37, 40
- survival of the mediocre, 154
- swarm intelligence, 3, 265

T

- t-test, 631
- assumptions, 633
- misinterpretations, 635
- tabu search, 422
- target vector optimization, 524
- Taylor series, 587
- teaching-learning-based optimization, 441, 446
- differential evolution, 441
- termination criterion, 49, 181
- theory, 510
- theory vs. practice, 161, 163
- three-dimensional Euclidean distance, 679
- threshold accepting, 445
- topology, 269
- all, 269
- cluster, 270
- dynamic, 269
- gbest, 269
- lbest, 269
- ring, 270
- square, 270
- static, 269
- von Neumann, 270
- wheel, 270
- total probability theorem, 409
- tournament selection, 207, 375, 498
- biogeography-based optimization, 375
- genetic programming, 201
- multi-objective optimization, 532
- restricted, 197
- selection pressure, 207
- soft, 207
- strict, 207
- tournament size, 207
- traveling salesman problem, 20, 31, 223, 246, 451
- applications, 451
- asymmetric, 247, 451, 689
- Berlin52, 249
- close-enough, 478
- closed-path, 413
- constrained optimization, 516
- cost function, 451
- crossover, 457
- alternating edges, 461
- classic, 451
- cycle, 458
- heuristic, 462
- intersection, 465
- inver-over, 460
- order-based, 459
- order, 458
- partially matched, 457
- union, 466
- cultural algorithm, 389
- distance matrix, 452
- Dubins, 478
- dynamic, 672
- edge, 451
- graph coloring problem, 476
- initialization, 452
- greedy, 452
- Inversion, 467
- nearest-neighbor, 452
- nearest two-neighbor, 453
- shortest-edge, 453
- stochastic, 456
- leg, 413, 451
- mutation, 487
- 2-exchange, 468
- 2-opt, 467
- displacement, 467
- Insertion, 467
- Inversion, 467
- or-opt, 467
- reciprocal exchange, 468
- shifting, 468
- open-path, 413
- opposition-based learning, 413
- path representation, 457
- proximity, 413
- relative proximity, 414
- representation, 487
- adjacency, 460
- matrix, 464
- ordinal, 483
- segment, 451
- selection, 498
- symmetric, 451
- total proximity, 414
- Ulysses16, 413, 678
valid tour, 451
web site, 470, 678, 680
trust regions, 579
TSPLIB, 470, 678, 680
tuning parameters, 49, 59, 155, 177, 228, 248, 610
cultural algorithm, 383
differential evolution, 296
particle swarm optimization, 268
population based incremental learning, 323, 343
Turing, Alan, 41, 142
Twain, Mark, 621
two-membered evolution strategy, 118
two-point crossover, 210, 218
Tylor, Edward, 378

U
Ulam, Stanislaw, 26
Ulysses, 675
uniform crossover, 210, 218, 369
uniform mutation, 214-215, 439
uniform portfolio, 199
union crossover, 466
univariate marginal distribution algorithm, 319, 333, 348-349
continuous, 342
user preference
multi-objective optimization, 557
utopia point, 523

validation, 610
Vecchi, Mario, 223
vector evaluated biogeography-based optimization, 552, 560
vector evaluated genetic algorithms, 531
vector optimization, 518
Verbeek, Hogier, 358
Visla, Paul, 324
von Neumann topology, 270
von Neumann, John, 26, 41
von Tschermak, Erich, 39

W
Wallace, Alfred, 37, 352
Walsh transform, 92
Waleh, Michael (Jack), 43, 95
weak domination, 519
web site
biogeography-based optimization, 352, 370
book, 1
dynamic optimization, 601
multi-objective optimization, 558
particle swarm optimization, 289
traveling salesman problem, 470, 678, 680
weighted graph coloring problem, 474
wheel topology, 270
Whitley, Darrell, 622
Wilcoxon test, 640
Wilson, Edward, 352
writing, 610

X
x-ray crystallography, 679