

# INDEX

- Accelerometers, 310–312  
 MMG detected by, 308–309
- Acclimatization, hypoxia and, 422–423
- Action potential propagation, velocity of, 84–85
- Action potentials (APs), 181, 182. *See also* Motor unit action potentials (MUAPs)  
 propagation along muscle fiber, 19–20
- Activity performance, with SEMG feedback, 450
- Activity profiles, fiber membrane, 210–213
- Acute reflexive spasm, 439
- A/D (analog-to-digital) conversion, 43, 44, 121–122
- Admissibility condition, 273, 274
- Advanced signal processing techniques, 259–302  
 EMG signal decomposition, 281–292  
 monitoring manifestations of muscle fatigue, 292–300  
 parametric and nonparametric context of, 260–261  
 theoretical background of, 261–280
- Agglomerative hierarchical algorithm, 54
- Aging, 10  
 muscle physiology and, 417–420
- Air-coupled condenser microphone, 310–311
- Akaike's information criterion (AIC), 136
- Algorithms. *See* Hierarchical algorithms
- Aliasing effect, 121, 122
- Allostatic load model, 354
- $\alpha$ -motoneuron, 2, 6
- Amplification, of electrically elicited surface EMG (—waves), 119
- Amplifiers, 43–44
- Amplitude  
 AP, 29  
 CMAP, 332–333  
 EMG, 97–100  
 MUAP, 32, 33, 43  
 of recorded signals, 43
- Amplitude coding, 461–462
- Amplitude data reduction, 347–348
- Amplitude distribution, 152
- Amplitude estimation, 139–145  
 applications of, 145  
 surface EMG, 139–145
- Amplitude estimator performance, measures of, 141
- Amplitude histogram, 389
- Amplitude map, 331, 332
- Amplitude normalization procedures, 368
- Amplitude probability distribution function (APDF) method, 348
- Amplitude processing, 141–145
- Amplitude resolution, 45
- Amplitude spectrum, 218, 219
- Amplitude variables, 346
- Amyotrophic lateral sclerosis (ALS), 333
- Anaerobic threshold (AT), 15
- Analog notch filters, 121
- Analog-to-digital (AD) conversion. *See* A/D (analog-to-digital) conversion
- Anatomical parameters  
 effect on EMG variables, 249–250  
 influence on conduction velocity estimates, 196
- Animal muscle, 243–244
- Animals, effects of spaceflight on, 423–424
- Antagonist muscle, 235
- Antagonists, inhibition of, 14
- Antalgic posture, 440
- Anti-aliasing filters, 382
- Antigravity slow-twitch muscles, 423
- “Area ratio,” 237–238
- arg phase function, 285
- ARMA. *See* Autoregressive-moving-average (ARMA) time series model

*Electromyography: Physiology, Engineering, and Noninvasive Applications*, edited by Roberto Merletti and Philip Parker.

ISBN 0-471-67580-6 Copyright © 2004 Institute for Electrical and Electronics Engineers, Inc.

- AR (autoregressive) model, 136, 206, 268
- Articular fault, biomechanical, 441
- Artificial limbs, multi-joint, 470. *See also* Protheses
- Associated Hermite expansion, 70
- “Augmented feedback,” 408
- Autocorrelation functions, 155, 456
- Autocorrelation sequence, 135
- Autogenic inhibition, 13
- Autogenics training program, 445
- Autonomic nervous system, 436
- Autoregressive-moving-average (ARMA) time series model, 136, 268, 294, 458
- Autoregressive transfer function criterion, 136
- Auxiliary connections, 44
- Average rectified value (ARV), 140, 346
- Axial movements, study of, 384
- Axonal damage, 334
- Axonal stimulation technique, 38
- Back Analysis System (BAS), 410
- Back pain, EMG and, 404–411. *See also* Low back pain (LBP)
- Bandpass filtering, 50–51  
effect on MUAPs, 51
- Bandwidth, of crosstalk signals, 93
- Barlett-Brillinger-Rosenblatt equation, 268
- Bartlett method, 279
- “Battery” effect, 110
- Bayesian decision theory, 260
- “Belly-tendon” montage, 328
- Bessel functions, 89, 109
- Biceps brachii muscle, contraction modes of, 72
- Bicepstral decomposition, 290
- Bilinear time-frequency representations (TFRs), Cohen’s class of, 271–272
- Bioelectric muscle activity, sources of, 209–210
- Biofeedback, 141, 389  
muscle function and, 443  
SEMG, 352
- Biofeedback applications  
to impairment syndromes, 436–443  
SEMG, 435–450
- Biofeedback techniques, SEMG, 443–450
- Biofeedback training, 405, 407
- Biological interference, 58
- Biological signals, xv
- Biological variation, 58
- Biomechanical calibrations, 347
- Biomechanics, occupational, 388–389
- Biomedical research, 301
- Biomedicine, applications of nonlinear techniques to, 154–155
- Biorthogonal wavelet bases, 275
- Biphasic single differential waveform, 95
- Bipolar channels, 464
- Bipolar lead, 329
- Bipolar recording, 92, 338
- Bipolar SEMG electrodes, 124
- Blocking phenomenon, 335
- Body mechanics instruction, 449
- Boston elbow, 462
- Boundary conditions, 88
- Bracing, learned, 439–440
- “Bracing efforts,” 435
- Branched electrode configuration, 114, 177
- Burst duration, 369
- $C(q, k)$  formula, 268, 288
- Calibration function, 347
- Casale, R., 403, 411
- Central fatigue, 292
- Central nervous system (CNS), 323  
control strategy assessment for, 248–249  
disorders of, 324–326
- Central point electrode, 177
- Cerebral palsy, 14, 387
- Certainty-based classification, 60
- Channel-based conduction velocity estimation, 186–190
- Channelopathies, 17
- Choi-Williams distribution (CWD), 297
- Chronic ailments, myalgia-type, 353
- Chronic faulty motor programs, 442–443
- Chronic pain, “muscle tension model” of, 405
- Cinderella model, 352, 353, 357
- Clancy, E. A., 133
- Classification phase performance, evaluation of, 69–70
- Clustering, of MUAPs, 53–57
- Clustering algorithms, 53  
example output of, 57  
for EMG signal decomposition, 56–57
- Clustering techniques, 49, 54–56
- CMAP amplitude, 331, 332–333. *See also* Compound muscle action potential (CMAP)
- CMAP waveforms, 330, 331
- Coefficient of variance, 71–72
- Cohen’s class, 301  
of bilinear time-frequency representations, 271–272
- Collateral reinnervation, 33, 34
- “Collision neurography,” 334

- Common drive, 9, 74  
 Common mode input voltages, 119  
 Common mode rejection ratio (CMRR), 44, 118–119  
 Common noise, 221  
 Complete-linkage distance metric, 54  
 Complete-linkage technique, modified, 56  
 Completely superimposed MUAPs, 63  
 Compound muscle action potential (CMAP), 208. *See also* CMAP entries  
   deriving conduction properties from, 333–335  
   motor nerve conduction and, 326–328  
 Compound signals, multichannel models of, 261–263  
 Computer-based biofeedback, 445  
 Computer models, 205  
 Concentric (shortening) muscle action, 9  
 Concentric needle electrode, 30–31, 34–35  
 Concentric ring system, 177  
 Conduction, abnormal, 336  
 Conduction properties, CMAP-derived, 333–335  
 Conduction velocity (CV), 20, 84–85, 100–101. *See also* Conduction velocity estimation; Global CV  
   muscle-fiber, 39  
 Conduction velocity estimation, 182, 185–196. *See also* Muscle-fiber CV estimation  
   algorithms for, 187–190  
   channel-based methods for, 186–190  
   global, 236  
   influences on, 196  
   for more than two channels, 190–191  
   single-MU, 186, 191–196  
 Conjugate mirror filter (CMF), 277  
 ConMac electrode, 39–40  
 Continuous wavelet transform (CWT), 273–275, 298  
 Contractions. *See also* Dynamic contractions;  
   Eccentric contraction (EC); Isometric contractions  
   electrically elicited, 148, 248  
   manifestations of muscle fatigue during, 222–226, 238–242  
   voluntary, 146  
 Coordination training, 443  
 Cram, J. R., 435  
 Craniocervical flexion action, 409, 410  
 Cross-correlation coefficient, 91  
 Cross-correlation function CV estimation, 188–189  
 Cross-sectional area (CSA), decrease in, 421  
 Crosstalk, 91–97, 250, 368  
   detection system selectivity and, 92–97  
   spatial filters and, 180  
 Crosstalk signals, 91  
   shape of, 93  
 Cross-term interference, 301  
 Cross-terms, 272  
 Cumulants, 264–265  
   properties of, 265–266  
   of random processes, 266–267  
   system identification using, 267–269  
 Cumulative function, 189  
 Current density source, 85–86  
 Cutoff frequencies, 109, 175  
 Cylindrical probes, 414  
 Daniell method, 279  
 Data format, 45  
 Data normalization, 368  
 Data reduction, 347–348  
 Data storage, 44, 45  
 dc voltages, of electrodes, 110–111  
 Deactivation training, 446  
 Decomposition, performance indexes for, 68  
 Decomposition algorithms, 68  
 Decomposition EMC, 36, 41  
 Deconditioning, SEMG and, 438  
 Decorrelation, 140  
 Deep motor units (MUs), 92–93, 248  
 Deep muscles, recruitment of, 408  
 “Degree of isotropy,” 177  
 Delay, defined, 187  
 Delayed onset of muscle soreness (DOMS), 375  
 Delay estimation, for nonidentical signals, 186–187  
 Demodulation, 143–144  
 Demyelination, 334  
   diseases associated with, 335  
 Dendrogram, 54  
 Depolarization zone, 82  
 Depth parameter, 283–284  
 Derived variables, in multifactorial analysis, 397  
 Destructively superimposed MUAPs, 63  
 Detail, defined, 277  
 Detected motor units (MUs), association with  
   reference MUs, 67–68  
 Detection system parameters, 196  
   effect on EMG variables, 249–250  
 Detection systems, modeling, 215–218  
 Detection system selectivity, crosstalk and, 92–97

- Deterministic difference, 67
- Deterministic signals, spectral estimation of, 134–137
- Deterministic structures, 159, 161
- Developed force, surface EMG features and, 97–101
- Difference filtering, first- and second-order, 51
- Differential configuration, 111–113
- Digital adaptive noise cancellation filters, 121
- Digital filter banks, 278
- Digitized signals, features of, 45
- Dimensionality reduction, 467
- Dirac delta function, 113, 114
- Discrete wavelet transform (DWT), 275–277
- “Discriminating characters,” 259–260
- Discrimination training, 446
- Disease, MUAP parameter changes in, 32–34
- Disparately detected MUAPs, 65, 66
- Disselhorst-Klug, C., 169
- Dissimilarity measures, 53
- Distance matrices, 55, 157
- Distance measures/metrics, 53, 54
- Distribution function method of CV estimation, 189–190
- Disuse atrophy, 438
- Disynaptic inhibition, 14
- Divisive hierarchical algorithm, 54
- Doncarli, C., 259
- Doppler-delay domain, 271–272
- Dorsiflexion, 394, 397
- Double differential (DD) configuration, 111, 112, 114
- Doublets, 73–74
- Down-sampling, 275
- Downtraining, 443
  - relaxation-based, 444–445
  - threshold-based, 445
- “Driven right leg” (DRL), 119
- Duration, MUAP, 32
- Dynamic contractions, 293
  - effect on surface EMG variables, 251
  - manifestations of muscle fatigue during, 296–300
- Dynamic control, 470
- Dynamic membrane model, nonlinear, 17
- Dynamic movement, generalization to, 446–448
- Dynamic tasks, regions of muscle activity during, 154
- Dysfunctional muscle activity, isolation of, 443–444
- Dysponesis, 435, 437
- Dystonia, 325
- Eccentric contraction (EC), 9
  - muscle damage and, 375
- Electrical activity (EA), 346
  - objective of recording, 28
- Electrically elicited contractions, 148
  - effect on EMG signal features, 248
- Electrical stimulation, fatigue and, 235
- Electrical stimulator, 44
- Electrode arrays, 127
- Electrode montages, 89–91
- Electrode orientation, 196
- Electrode placement, 183
  - “optimal,” 99
- Electrodes. *See also* Electrode placement configuration, distance, and location of, 111–115, 126, 216, 250
  - European recommendations on, 123–127
  - impedance, noise, and dc voltages of, 110–111
  - intramuscular, 49, 81
  - material used for, 123
  - shape and size of, 91, 124, 216–218, 250
  - transfer function of, 108–109
- Electrode-skin impedance, 91, 110, 218, 366
- Electrode-skin interface, 108, 109
  - properties of, 111
- Electromechanical coupling efficiency (EMCE), 318
- Electromechanical delays (EMD), 315
- Electromyogram (EMG), xv. *See also* Electromyography (EMG); EMG entries
- Electromyographic patterns, 389
- Electromyographic signal alterations, muscle fatigue and, 348–352
- Electromyographic techniques, potential of, 344
- Electromyography (EMG). *See also* Electromyogram (EMG); EMG entries; Surface electromyography (SEMG)
  - computers and, xvi
  - early use of, 343
  - functional models of, 138
  - in kinesiology, 381–382
  - macro, 39–40, 75–76
  - mental stress and, 356
  - needle, 30–36
  - psychological effects on, 353–357
  - scanning, 41–42
  - single-fiber, 36
  - spatial and temporal parameters of, 406
  - stress and, 355–356
  - versus MMG, 316–318
  - work-related disorders and, 345

- Electronic voltage noise, 119
- Elicited contractions, manifestations of muscle fatigue during, 224–226
- Embedding dimension, choice of, 156
- Embedding theorem, 155
- EMG amplitude, 98. *See also* Electromyogram (EMG)
- estimation of, 134, 139–145
  - relation to force, 99–100
  - variability in, 126, 389
- EMG applications, in ergonomics, 343–358
- EMG data processing applications, in ergonomics, 345
- EMG decomposition technique, 41
- EMG detection, 89–91
- EMG equipment, 43–44
- time resolution of, 45
- EMG filters, 120–121
- EMG frequency range, 109
- EMG front-end amplifiers, 115–120
- “EMG gaps,” 348
- EMG machines, 44
- EMG modeling, 205–227
- additional applications of, 226–227
  - basic assumptions in, 209
  - bioelectric muscle activity and, 209–210
  - detection systems, 215–218
  - fiber membrane activity profiles and, 210–213
  - inverse modeling, 222
  - motor unit recruitment and firing behavior, 218–222
  - motor unit structure and, 213–214
  - of muscle fatigue, 222–226
  - phenomenological models, 207
  - structure-based SEMG models, 207–209
  - volume conduction and, 214–215
- EMG pattern analysis, 395
- EMG profiles, 391–392
- linear envelope and, 390–391
- EMG recordings, 7, 117
- EMG signal acquisition, 49
- EMG signal decomposition, 47–77, 281–292. *See also* EMG signal decomposition algorithms
- applications of results of, 70–77
  - MUAP detection and, 50–52
  - steps in, 48–66
  - using higher order statistics, 287–292
  - using wavelet transform, 281–286
- EMG signal decomposition algorithms, 56–57
- performance evaluation for, 67–70
- EMG signal decomposition system, 50
- EMG signal features, physiological phenomena affecting, 247–248
- EMG signal generation, 1–20
- amplitude and, 97–100
  - biophysics of, 81–102
  - conduction velocity and, 100–101
  - crosstalk and, 91–97
  - EMG detection and, 89–91
  - intracellular action potential and, 85–86
  - signal source, 82–85
  - spectral frequencies and, 101
  - volume conductor and, 87–89
- EMG signals. *See also* EMG signal decomposition; EMG signal generation; Intramuscular EMG signals; Surface EMG signal
- attributes of, 50
  - electrode size and, 91
  - frequency analysis of, 293
  - history of, xv–xvii
  - needle, 42–43
  - nonstationarity of, 293
  - processing of, 345–346
  - simulation of, 139
- EMG signal spectrum, estimation of, 121, 147, 148. *See also* EMG spectrum
- EMG variables, 153
- estimate repeatability for, 251–252
  - parameters affecting, 249–250
  - “true” value of, 250
- Emotions, in the neuromuscular network, 436
- End-of-fiber components, influence on CV
- estimation, 100
- End-of-fiber effects, 86, 102
- End-of-fiber potentials, 95
- Endpoint control, 470–471
- Energetics, muscle, 15–16
- Energy metabolism, effect on motor units, 10–11
- Energy spectral density, 148
- Englehart, K. B., 453
- Epilepsy, 324
- Epoch length/overlap, in stationary and nonstationary conditions, 150–152
- Equilibration training, left/right, 448–449
- Equivalent input voltage noise density, 119
- Equivalent statistical bandwidth, 459
- Ergodicity, 264
- Ergonomics, 388
- amplitude data reduction and, 347–348
  - EMG applications in, 343–358
  - muscle fatigue indicators in, 348–352
  - musculoskeletal disorders and, 352–353

- SEMG biofeedback in, 352
  - workload concepts in, 344–345
- Euclidean similarities, 60
- European Concerted Action Surface EMG for Noninvasive Assessment of Muscles, 107
- European recommendations, on electrodes, 123–127
- Excitation-contraction (E-C) coupling, 11
- Exclusive MUAPTs, 65
- Exclusive trains, 66
- Exercise
  - HA fatigue during, 422
  - with SEMG feedback, 449
- Exercise physiology applications
  - SEMG, 365–377
  - strength and power training, 372–375
  - time and frequency domain analysis, 368–369
  - tips related to, 366–368
  - walking versus race walking and running, 370–371
- Exposure variation analysis (EVA) method, 348, 350
- Extracellular longitudinal current, 83
- “Exuberant” projections, 14
- False positives/negatives, 68–70
- Far-field potentials, 89
- Far-field signals, 93, 95
- Farina, D., 47, 81, 133, 169, 233
- Fast Fourier transform (FFT), 293. *See also* FFT periodograms; Short-time Fourier transform (STFT)
- Fast-twitch fatigable (FF) motor units, 3, 9
- Fast-twitch fatigue-resistant (FR) motor units, 3
- Fast-twitch fibers, 299
- Fast twitch motor units, 242
- Fast-twitch muscle fibers, 4
- Fast-twitch muscles, 423
- Fatigue, 348–349. *See also* Muscle fatigue
  - indexes of, 233, 237–238
  - inhibitory metabolites and, 16
  - mechanical versus myoelectric manifestations of, 235
  - pathological, 335–338
  - sites of, 234
- Fatigue assessment, 247–248
- Fatigue indexes, estimate repeatability for, 251–252
- Fatigue plots, 225, 237, 239, 240, 351
  - in different conditions or subjects, 241
- Fatigue studies, 161
- Fatigue variables, 349
- “Fatigue vector,” 238
- Fatiguing stimulation, 313
- Faulty motor programs, chronic, 442–443
- “Faulty motor schema,” 436
- Feature extraction, 465
  - for pattern recognition, 52–53
- Felici, F., 365
- FFT periodograms, 294
- Fiber composition, 242
  - modifications of, 244–246
- Fiber density (FD), 36–37
  - estimation of, 36
- Fiber inclination angle, 196
- Fiber length, 250
- Fiber membrane activity profiles, 210–213
- Fiber type composition, age and, 418–419
- Fiber type modification, hypoxia-induced, 421
- Fiber typing, 242–246
- Filligoi, G., 133
- Filtering effect, volume-conductor-mediated, 82
- Filters, EMG, 120–121
- Final prediction error (FPE), 136
- Finite impulse response (FIR) filter, 216
- Finite-time integrator, 390
- Firing behaviors, 75
  - modeling, 218–222
- Firing instants, 67
  - synchronization of, 220–222
- Firing-pattern analysis, 71–74
- Firing-pattern information, 56, 59
  - MUAPT, 64
- Firing patterns, 71, 208
  - dependent, 138
  - MU, 74–75
- Firing processes, MU, 220
- Firing rates (FRs), 7–9
  - influence on MMG, 316–318
  - instantaneous, 73
- Fisher test, 252
- Foot-contact sensors, 390
- Force, 97–101
  - conduction velocity and, 100–101
  - in motor unit modeling, 213–214
  - relation to EMG amplitude, 99–100
  - spectral frequencies and, 101
  - versus MMG, 313–315
- Force level, surface EMG variables and, 248
- Force measurement, isometric, 337
- Force signal, spike-triggered averaging of, 75
- Force training, 373

- Force twitch, MMG and, 314
- Fourier approach, 150
- Fourier-based spectral estimators, 134–135
- Fourier integral, 269
- Fourier transform (FT). *See also* FT fiber areas; Short-time Fourier transform (STFT); Two-dimensional Fourier transform
- in time-frequency representations, 269
- Frequency analysis, 293
- Frequency content, 42–43
- Frequency domain, information extraction in, 145–153
- Frequency domain analysis, 410–411
- SEMG, 369
- Frigo, C., 381
- Front-end amplifiers, 115–120
- FT fiber areas, percentage of, 372
- Functional activity performance, with SEMG feedback, 450
- Functional diagnosis, 393
- Fusimotor neurons, 12
- Gait analysis, 371–372. *See also* Movement analysis
- linear envelope and, 389–393
  - mechanical effect of muscle contraction and, 385–386
  - motor control strategies and, 384
  - multifactorial analysis and, 393–397
  - pathophysiologic factors in, 387–388
  - SEMG applications in, 381–397
- Gait initiation studies, 384
- Gaussian distribution, 220, 221
- Gaussian probability density function, 144
- General wavelet packets, 278
- Generator model, 135–136
- Global CV, 247
- estimates of, 100–101
- Global processing techniques, 163
- Glycogen depletion, 11
- Glycolytic energy metabolism, 5
- Golgi tendon organs (GTOs), 13
- Grid electrode systems, 179
- Group Ia inhibitory interneurons, 13–14
- Group Ib interneurons, 13
- Guarding/bracing, learned, 439–440
- “Guided imagery,” 445
- Hägg, G. M., 343
- Harmonic components, 369
- Health professionals, teaching and training, 227
- Heisenberg uncertainty principle, 272
- Hemiplegia, 393–394
- Henneman’s size principle, 218, 219, 247
- Henon map, 156
- Hermens, H. J., 107, 205
- Hermens synchronization model, 221
- Herniated disc, 439
- Heuristic rules, multi-joint movement and, 469
- Hierarchical algorithms, 54
- Hierarchical clustering methods, 54
- High-density multichannel recording, 338–341
- High-pass filtering, 95, 118, 121
- High-pass spatial filters, 171, 174
- crosstalk and, 180
- Higher order statistics, EMG signal decomposition using, 287–292
- Hodges, P., 403
- Hodgkin-Huxley model, 17–19
- HOS-based EMG decomposition, 289–290
- HOS-based methods, 301
- H-reflex studies, 14
- Hudgins, B. S., 453
- Human motor system, 2
- Humans, effects of spaceflight on, 423
- Humeral rotation rule, 469
- Hyperactivity, psychophysiological stress-related, 436–437
- Hypermobility, joint, 441–442
- Hypobaric hypoxia, 420–423
- Hypothalamic pituitary-adrenal cortical (HPA) system, 355
- Ia inhibitory interneurons, 13–14
- IAP shape, approximation of, 85. *See also* Intracellular action potentials (IAPs)
- Ib interneurons, 13
- IMNF signals, 298
- Impairment syndromes, biofeedback application to, 436–443
- Impedance, of electrodes, 110–111
- Independent identically distributed (IID) samples, 141
- Indexes of performance, 68
- Information enhancement, via multifactorial analysis, 393–397
- Information extraction, in frequency domain, 145–153. *See also* Multi-channel information extraction techniques; Single-channel information extraction techniques
- Inhibition, 439
- learned, 440–441
- Innervation number estimate, 419
- Innervation processes, 456–457

- Innervation ratios, 243
- Innervation zones (IZs), 250, 367  
atlas of, 126
- Input impedance, SEMG amplifier, 116–118
- Instantaneous median frequency (IMDF), 280
- Instrumentation, principles of, 43
- Integrated EMG (iEMG), 7, 336, 346, 368
- “Integrative” analytical approach, 206
- Intelligent hand, 470
- Interdischarge intervals (IDIs), 59
- Interelectrode distances (IEDs), 124, 175–176, 250  
decrease of, 114–115
- Interference attenuation, 142
- Interference pattern, 33, 42, 207
- Interference surface signal, 76
- Interference terms, 272
- International Society of Electromyography and Kinesiology (ISEK), xvi
- International Society of Electrophysiology and Kinesiology, 344
- Interneurons, 13–14
- Interpolation, 390
- Interpulse intervals (IPIs), across MUs, 220
- Intracellular action potentials (IAPs), 82, 101–102, 209–210, 247, 248. *See also* IAP shape  
generation and extinction of, 85–86
- Intracellular muscle-fiber action potentials, 209–210
- Intraclass Correlation Coefficient (ICC), 252
- Intrafusal fibers, 12
- Intramuscular electrodes, 89
- Intramuscular EMG signals  
decomposition of, 47–77  
EMG signal decomposition performance, 67–70
- Intramuscular recordings, 27–29  
modeling of, 207
- Intramuscular scanning EMG, 92
- Intramuscular spike recordings, 8
- Inverse binominal (IB<sup>2</sup>) filter, 176–177
- Inverse modeling, 222
- “Inverse problem,” 1
- Ion channels  
dynamics of, 17–18  
dysfunction of, 17  
transmembrane, 209
- Isokinetic contractions, 299
- Isokinetic dynamometer, 298
- Isolation training, 444
- Isometric constant force contractions, 238
- Isometric contractions, effect on surface EMG variables, 246–250. *See also* Isometric voluntary contractions
- Isometric exercise, 367
- Isometric muscle actions, 11
- Isometric voluntary contractions, manifestations of muscle fatigue in, 238–242
- Isotropic transfer function, 90, 217
- Isqnonlin* function, 291
- Jabre, J., 27
- Jiggle (degree of instability), 32, 33, 58
- Jitter, 58, 416  
neuromuscular transmission and, 37–39  
value of, 38
- Joint analysis of EMG spectrum and amplitude (JASA) method, 153–154, 351–352
- Joint angle patterns, 394
- Joint hypermobility/hypomobility, compensation for, 441–442
- Joint kinematics, 384, 387
- Joint torque estimation, 141
- Journal of Electromyography and Kinesiology*, xvi, xvii
- Jull, G., 403
- Kadefors, R., 343
- Karlsson, S., 259
- Kegel exercises, 416
- Kinematic control, 470
- Kinematic coupling, 469
- Kinesiological EMG, 367
- Kinesiological studies, force estimation in, 98–99
- Kinesiology, electromyography in, 381–382
- K*-means technique, modified, 56
- Knowledge-based expert systems, 44
- Lactate paradox, 421
- Lactic acid production, 242–243, 246
- Lactic acidosis threshold, 15
- Lambert-Eaton myasthenic syndrome (LEMS), 38–39, 333
- Laplace filters, 174
- Laplacian probability density function, 144
- Laser-detected MMG (laser-MMG), 311, 315
- Laser distance sensors, MMG detected by, 307–308
- LDD (longitudinal double differential) filter, 174
- “Learned disuse,” 440
- Learning (neural) pattern classification approach, 465

- Least-mean-square (LMS) cumulant-based optimization, 290
- Left/right equilibration training, 448–449
- Level coding, 458
- Linear array recording, 339
- Linear core-conductor model, 83
- Linear electrode arrays, 181–183
- Linear envelope (LE), 368, 389–393  
EMG profiles and, 390–391
- Linear time-invariant (LTI) filter, 135–136
- Line source model, 82
- LINE value, selecting, 158–159
- Linked trains, 66
- Load estimation, 346–347
- “Local frequency” parameter, 296
- Localized fatigue, 349
- “Localized muscular fatigue,” 292
- Log-periodogram, 280
- Longitudinal conductivity, 88
- Lorentz–Mackey–Glass differential delay equation, 156
- Low back pain (LBP), 405, 439. *See also* Back Analysis System (BAS)  
rehabilitation for, 407–408
- Low-pass differentiation, 50–51
- Low-pass filtering effect, 89
- Low-pass filters, 121, 140
- Macro EMG, 39–40, 75–76
- Macro intramuscular signals, averaging of, 75
- Macro MUAPs, 39, 75–76
- Mainframe, 44
- Mallat’s pyramid, 275–276
- MA (moving average) model, 136, 268
- Markov chains, 260
- “Mathematical microscope,” 298
- Mathematical models, 205–206
- Matthews/Kleine synchronization model, 221–222
- Maximal voluntary contractions (MVCs), 7, 10, 50, 71, 194, 234, 316, 347  
EMG signal during, 145
- Maximal voluntary electrical activation (MVE), 347
- Maximum likelihood estimators (MLEs), 187–189, 190–191, 194, 197, 198
- McArdle’s disease, 16, 243, 338
- Mean absolute value (MAV), 140, 458
- Mean firing rates, 71–72  
cross-correlation of, 74–75
- Mean frequency (MNF), 149, 411  
properties of, 150
- Mean frequency of the power spectrum (MNF), 295. *See also* IMNF signals;  
Mean frequency (MNF); Mean power frequency (MPF)  
as a fatigue indicator, 299
- Mean power frequency (MPF), 7, 10, 346, 350–352, 410–411. *See also* Mean frequency (MNF); Mean frequency of the power spectrum (MNF)
- Mean spike frequency, 152–153
- Mean square error (MSE), 144, 187–188, 192
- Mean value of consecutive differences (MCD), 37
- Measured variables, in multifactorial analysis, 393–397
- Measurement, repeatability of, 367
- MEC strategies, emerging, 463–471. *See also* Myoelectric control (MEC)
- Mechanical muscle response, hypoxia and, 421
- Mechanomyogram (MMG), 305–307. *See also* MMG entries; Surface mechanomyogram
- Median frequency (MDF), 149, 221, 224, 237, 240, 346, 350–351, 376, 410–411  
properties of, 150
- Median load level, 348
- Melin, B., 343
- Membrane potential, plot of, 211
- Membrane voltage phenomenon, 17
- Mental stress, EMG activity and, 356
- Merletti, R., 1, 81, 107, 169, 205, 233
- MES control, pattern-recognition-based approach to, 463–468. *See also* Myoelectric signal (MES)
- MES measurement strategies, 464–465
- Metal-electrolyte contact, 110
- Method of images, 88
- Microgravity, 423
- Microgravity effects, 424–425  
on neuromuscular system, 423–425
- Microphones, MMG detected by, 310
- Mihelin, M., 27
- MIMO decomposition, 291. *See also* Multiple-input, multiple-output (MIMO) models
- Minimum description length criterion (MDL), 136
- MMG detection techniques, 307–310. *See also* Mechanomyogram (MMG)
- MMG detectors, comparison of, 310–312
- MMG generation (MMGg), 307, 312
- MMG sensors, comparison of, 307–310
- Modeling, 64  
goal of, 206

- Modified beamforming, 191  
 Moment-angle loop, 396  
 Moments, 264–265  
 Monochromatic wave, 269  
 Monopolar needle electrode (MNE), 31, 35–36  
 “Monopolar” potential distribution, 108  
 Monopolar recording system, 92  
 Monopolar signals, 97, 223  
 Monosynaptic stretch reflex, 12  
 Monte Carlo method, 260  
 Moritani, T., 1  
 Mother wavelet, 273, 277  
 Motoneurons (MNs), 2  
   synaptic input to, 221  
 Motor axon stimulation, jitter measurement during, 38  
 Motor control, 3  
   physiology of, 2–16  
 Motor control strategies, study of, 47, 384  
 Motor control system, peripheral, 11–15  
 Motor copy training, 449  
 Motor nerve conduction (MNC), compound muscle action potential and, 326–328  
 Motor nerve conduction testing, 328  
 Motor nerve testing, 328  
 Motor programs, chronic faulty, 442–443  
 Motor unit action potential conduction velocity (MUAPCV), 350  
 Motor unit action potentials (MUAPs), xv, 28, 29, 47, 182, 210. *See also* MUAP entries; MUAPT entries; Superimposed MUAPs  
   certainty-based classification of, 60  
   clustering of, 53–57  
   defined, 31  
   duration of, 33  
   multiply-detected, 64, 66  
   representation of, 84  
   shape similarity of, 70  
   single-surface, 93  
   supervised classification of, 58–62  
 Motor unit activation pattern, 316, 318  
 “Motor unit counting,” 333  
 Motor unit modeling, inclusion of force in, 213–214  
 Motor unit recruitment, modeling, 218–222  
 Motor unit remodeling, 419  
 Motor units (MUs), 2–6, 27–28. *See also* MU entries  
   de-recruitment of, 248  
   double discharge of, 73–74  
   firing rates of, 7–9  
   “fractions” of, 42  
   interpulse intervals across, 220  
   physiological properties of, 6  
   recruitment and firing frequency of, 6–11  
   reference and detected, 67–68  
   representation of, 84  
   scanning EMG of, 42  
   structure of, 213–214  
   types of, 3  
 “Mottler plan,” 465  
 Movement analysis. *See also* Gait analysis  
   biofeedback and, 389  
   occupational biomechanics and, 388–389  
   SEMG applications in, 381–397  
 Moving-average (MA) system response, 268  
 MUAP classification, certainty-based, 60. *See also* Motor unit action potentials (MUAPs)  
 MUAP parameters, 32–34  
 MUAP raster plots, 62  
 MUAP recognition, 49  
 MUAP shapes, 49  
   distribution of, 50  
   nonstationarity of, 60  
   variability in, 58  
 MUAP summation, 329  
 MUAP trains, 137, 207, 221  
 MUAPTs, 53, 56  
   defined, 52  
   firing times of, 65–66  
 MUAPT temporal relationships, 64–66  
   defining and measuring, 65–66  
 MUAP waveforms/shapes, 63, 208, 210  
 MU architecture, 32. *See also* Motor units (MUs)  
 MU CV distribution, automatic estimation of, 182  
 MU firing patterns, 10, 66, 67  
   correlation between, 74–75  
 MU firing processes, 220  
 MU firing rates, 247  
 MU interpulse intervals, 220  
 Multichannel information extraction  
   techniques, 169–199  
   muscle-fiber conduction velocity estimation, 185–196  
   spatial filtering, 170–180  
   spatial sampling, 180–185  
 Multichannel models, of compound signals, 261–263  
 Multichannel recording, high-density, 338–341  
 Multichannel surface EMG signals, 184  
 Multichannel surface potentials, extraction of, 76  
 Multi-electrodes, 36

- Multifactorial analysis, information  
enhancement via, 393–397
- Multi-joint artificial limbs, 470. *See also*  
Prostheses
- Multi-joint movement, 469–470
- Multimodal parametric search (MPS), 281–283
- Multi-MUAP EMG analysis, 41
- Multi-pass certainty-based supervised  
classification algorithm, 60
- Multiple bipolar channels, 464
- Multiple-input, multiple-output (MIMO)  
models, 262–263, 281, 287. *See also*  
MIMO decomposition
- Multiple-input, single-output (MISO) model,  
262, 281
- Multiple MES channels, 464
- Multiple myoelectric channels, 460
- Multiply-detected MUAPs, 64, 66
- Multiresolution analysis (MRA), 276, 277, 279
- Multivariable approach, in stochastic  
processes, 265
- MU recruitment threshold, 247
- Muscle(s), 1–2  
architecture of, 331  
force production in, 97–98, 153  
frequency response of, 315  
mechanical model of, 314–315
- Muscle activation, modalities of, 405
- Muscle activity, 5  
bioelectric, 209–210  
effect on motor unit recruitment and firing  
frequency, 9–10  
isolation of, 443–444  
mechanical outcome of, 397
- “Muscle belly-montage,” 125
- Muscle cartography, 330–332
- Muscle cell membrane, electrophysiology of,  
17–20
- Muscle contractions, 2–16  
detecting, 305  
mechanical effect of, 385–386
- Muscle control procedures, training in,  
446–448
- Muscle damage, EC-induced, 375
- Muscle damage studies, SEMG, 375–377
- Muscle deactivation, 13
- Muscle disease, MUAP and, 34
- Muscle dysfunction, 435
- Muscle endurance, aging and, 420
- Muscle energetics, 15–16
- Muscle energy metabolism, 16
- Muscle fatigue, 234–235. *See also* Fatigue  
during dynamic contractions, 296–300  
effect on motor unit recruitment and firing  
frequency, 10  
electromyographic signal alterations  
indicating, 348–352  
estimates of EMG variables and fatigue  
indexes, 251–252  
fiber typing and, 242–246  
during isometric voluntary contractions,  
238–242  
mechanical manifestations of, 292  
modeling, 222–226  
monitoring, 295–296  
myoelectric manifestations of, 222–226,  
233–253, 292–300, 419–420  
during static contractions, 293–296  
surface EMG variables and, 236–238,  
246–251
- Muscle fatigue modification, hypoxia-induced,  
421–422
- Muscle-fiber action potentials, 209–210
- Muscle-fiber conduction velocity (CV), 39,  
242–243, 410. *See also* Conduction  
velocity (CV)  
estimation of, 185–196
- Muscle-fiber propagation velocity, 39
- Muscle fibers, 4  
action potential propagation along, 19–20  
model of, 20  
types of, 3, 4
- Muscle force, 98–99  
surface EMG spectral variables and, 153
- Muscle function, biofeedback and, 443
- Muscle geometry, 367
- Muscle kinematics, 385, 397
- Muscle overload, 375, 408
- Muscle pathology studies, 40
- Muscle physiology, age-related effects on,  
417–420
- Muscle sensor, orientation on, 125
- Muscle signals, crosstalk, 91
- Muscle spasm, reflexive, 439
- Muscle stimulation, selective, 93, 94
- Muscle strength, aging and, 417–418
- Muscle surface displacement, 308
- Muscle surface oscillation, 306–307
- Muscle synergy, 386
- Muscle tension, 356  
psychological stress and, 358
- “Muscle tension model,” 405
- Muscle thickness, recording changes of, 305
- Muscle transverse diameter changes, 314
- Muscular contractile function, 16
- Muscular disorders, 179

- Muscular weakness, progressive, 418
- Musculoskeletal disorders, 352–353  
     psychological stress and, 355  
     work-related, 388
- Musculoskeletal injuries, 374–375
- Musculoskeletal tension, psychological factors  
     in, 357
- MU synchronization, 223, 224, 373–374
- Mutual information concepts, 66
- M-waves, 148, 208, 225–226
- M-wave scale factor, 148
- Myalgia, work-related, 298
- Myasthenia gravis (MG), 333
- Myoelectric channels, 455–460
- Myoelectric control (MEC), 453–455. *See also*  
     MEC strategies  
     conventional, 460–463
- Myoelectric controllers, 455
- Myoelectric signal (MES), 453, 471. *See also*  
     MES entries  
     “slowing” of, 344
- Myofibril protein degradation, 424
- Myopathic MUAP, 34
- Myopathy, congenital, 244
- Myosin isoforms, 424
- Myotonia congenita (MC), 337–338
- NDD (normal double differentiating) filter,  
     174–176, 179–180
- NDD-filtered channels, 182–183
- Neck muscle activity, patterns of, 409
- Neck pain, EMG and, 404–411
- Needle and wire detection techniques, 27–45  
     conventional needle EMG, 30–36  
     needle electrode recording characteristics,  
         29–30  
     special needle recording techniques, 36–42  
     needle EMG signal characteristics, 42–43  
     recording equipment, 43–45
- Needle electrodes, 29–30  
     concentric, 34–35  
     monopolar, 35–36
- Needle electromyography, 28  
     conventional, 30–36  
     at increasing voluntary contraction, 34  
     techniques of, xvi, xvii
- Neonatal neuronal exuberance, 14
- Nerve conduction testing, 335
- Nerve lesions, 33
- Nerve stimulation, 327
- Nervous system, 323–324. *See also* Neural  
     entries
- Network connections, 44
- Neural excitation processes, 16
- Neural network approaches, 470
- Neural networks, self-organizing, 56
- Neural projections, 14
- Neuroendocrine systems, psychological stress  
     and, 355
- Neurogenic disorders, 28
- Neurological diseases, 17
- Neurological rehabilitation, 411–417
- Neurology, 324  
     central nervous system disorders, 324–326  
     clinical applications in, 332–335  
     CMAP and motor nerve conduction,  
         326–328  
     CMAP generation and, 328–332  
     high-density multichannel recording and,  
         338–341  
     surface EMG applications in, 323–341
- Neuromuscular disorders, diagnosis of, 179
- Neuromuscular electrical stimulation (NMES),  
     SEMG-triggered, 448
- Neuromuscular fatigue, 234–235
- Neuromuscular jitter, 37–39
- Neuromuscular regulation, 15–16
- Neuromuscular system, 10  
     microgravity effects on, 423–425
- Newton algorithm, 291
- Noise  
     electronic voltage, 119  
     of electrodes, 110–111
- Noise attenuation, 142
- “Noisy” control information, 458–459
- Nonisometric exercise (NIE), 366, 367
- Nonlinear projection methods, 468
- Nonlinear techniques, 154–155
- Nonparametric approaches, 260–261
- Nonpoint electrodes, 177–179
- Nonpropagating potentials, 180
- Nonpropagating signal components, 97
- Nonreciprocal inhibition, 13
- Nonstationary signals, 260
- Nonstationary stochastic processes, 137
- Normalized standard error of the mean  
     (NSEM), 251
- Nyquist sampling theorem, 45, 121, 274
- Occupational biomechanics, workload  
     assessment in, 388–389
- Ohm’s equation, 215
- On Asymmetry in Sphincters (OASIS) project,  
     411
- Operational amplifier (OA), 116  
     input current noise in, 119

- Operation Everest II (OEII), 421  
 Optical distance sensor, 307–308  
 Orizio, C., 305  
 Orthogonal MRA, 277  
 Orthogonal wavelet transform, 275  
 Oxford intelligent hand, 470  
 Oxygen availability, effect on motor unit recruitment and firing frequency, 10–11
- Pain. *See* Back pain; Chronic pain; Neck pain  
 Parametric based spectral estimators, 135–136  
 Parametric decomposition, 281–286  
 Parametric methods, 136, 150, 260, 293  
   for modeling, 294  
 Parametric search, multimodal, 281–283  
 Parasitic capacitances, 120  
 Parker, P. A., 453  
 Parseval's theorem, 269, 270  
 Partially superimposed MUAPs, 63  
 Partitioning methods, 54–56  
 Pathological fatigue, 335–338  
 Pathophysiologic profile, 388  
 Pattern classification methodologies, 465–466  
 Pattern recognition, feature extraction for, 52–53  
 Pattern-recognition-based control, 463–465  
 Pattern-recognition-based systems, evolution of, 466–468  
 Paynter finite-time integrator, 390  
 PC technology, 44  
 Peak load level, 348  
 Peel-off approach, 63–64, 283  
 Pelvic floor, 412  
   EMG of, 411–417  
   evaluation of, 412–417  
   rehabilitation of, 416  
 Pelvic floor disorders, 404, 413, 414  
 “Pennate” fibers, 330  
 Percentage of determinism (%DET), 158, 159, 161, 373  
 Percentage of recurrence structures (%REC), 158  
 Percentage of the reference voluntary electrical activity (%RVE), 347  
 Percentile frequencies, analysis of, 149  
 %MVC contractions, 50, 347, 351  
 Performance, 68–69  
   amplitude estimator, 141  
 Performance indexes, 68  
 Perineal muscles, needle EMG of, 413, 414  
 Periodogram, 135, 151, 279  
 Peripheral fatigue, 292–293  
 Peripheral motor control system, 11–15  
 Peripheral nervous system (PNS), 323–324  
 pH, intracellular, 16  
 Phase method of CV estimation, 189  
 Phase representation, 33, 284–286  
 Phenomenological intramuscular EMG signal model, 70  
 Phenomenological models, 206  
 Physical parameters, 196  
   effect on EMG variables, 249–250  
 Physical stress, 354  
   chronic, 437  
 Piezoelectric contact sensors, 305, 307, 310  
   MMG detected by, 309–310  
 Plantarflexion, 394, 397  
 Point electrodes, 173–174. *See also* Nonpoint electrodes  
   two-dimensional spatial filters with, 174–177  
 Poisson's equation, 87, 88, 215  
 Polycestral decomposition, 290  
 Polymyography, 324, 327  
 Postural dysfunction, 437–438  
 Postural perturbations, 384  
 Postural tension, 435  
 Postural training, with SEMG feedback, 449  
 Potential distributions, 113, 170–171, 172, 209, 215  
   two-dimensional, 108  
 Powered upper limb prostheses, 453–471  
   conventional myoelectric control and, 460–463  
   emerging MEC strategies and, 463–471  
   intelligent subsystems and, 468–471  
   myoelectric signal and, 455–460  
 Power spectral density (PSD), 101, 134, 161, 162. *See also* PSD estimation  
   surface EMG, 153  
   of a synthesized EMG signal, 294–295  
   time-varying, 137  
 Power training, 372–375  
 Prehension rule, 469  
 Prevention of Neuromuscular Disorders in the Use of Computer Input Devices (PROCID), xvii, 353  
 Principal components analysis, 467–468  
 Probability density function (PDF), 144  
 Progressively dynamic movement, generalization to, 446–448  
 Progressive relaxation, 444–445  
 Projection pursuit, 467  
 Propagating signal components, 97  
 Proportional control, 462

- Prostheses. *See also* Powered upper limb prostheses  
 multifunction, 462–463  
 multifunctional control of, 470  
 myoelectric, 145, 454–455
- PSD estimation, 135, 142. *See also* Power spectral density (PSD)  
 during voluntary contractions, 146  
 using wavelet packets, 279  
 using wavelet shrinkage, 279–280
- Pseudorandom electrical activity, 42
- Psychological stress, 354  
 musculoskeletal disorders and, 355  
 neuroendocrine systems sensitive to, 355  
 trapezius muscle response to, 356–357
- Psychophysiological stress-related hyperactivity, 436–437
- Psychosocial stress, 353
- Quadratic time-frequency methods, 468
- Quadrifilar needle electrode (QNE), 41
- “Quasi-stationary” signal, 144, 293
- Race walking, 371–372
- Radial conductivity, 88
- RADIUS value, selecting, 158–159
- Rainoldi, A., 233, 403, 417, 420, 423
- Ramp contractions, 154
- Random processes, 264  
 cumulants of, 266
- Raster plots, MUAP, 62
- Rate coding, 458, 462  
 motor unit, 6–9
- Reciprocal inhibition, 14
- Recorded signal, frequency content of, 42
- Recording equipment, EMG, 43–45
- Recordings, 72–73  
 high-density multichannel, 338–341
- Recruitment (REC), 101  
 influence on MMG, 316–318
- Recruitment threshold, 9
- Recruitment threshold force, 71
- Recurrence histograms, 66
- Recurrence map (RM), 157, 158
- Recurrence quantification analysis (RQA), 134, 154–162, 373–374  
 application to surface EMG signal analysis, 159–162  
 mathematical basis of, 155–159
- Recurrence representation (RM), 159
- Reference decomposition, 67, 70
- Reference MUs, association with detected MUs, 67–68
- Reference signal, 191
- Reflexes, 11–12
- Reflexive spasm, acute, 439
- Reflex overflow, 14
- Reflex responses, 15
- Rehabilitation medicine, 403–425  
 EMG in back and neck pain, 404–411  
 EMG of the pelvic floor, 411–417  
 hypobaric hypoxia, 420–423  
 microgravity effects on neuromuscular system, 423–425
- Reinnervation, collateral, 33, 34
- Relaxation-based downtraining, 444–445
- Relinearization, 143–144
- Renewal point process, 65
- Renshaw cell mediated inhibition, 14
- Repetitive stimulation, 334
- “Representing efforts,” 435–436
- Ring electrode, 177, 178
- Romberg test, 423
- Root mean square (RMS), 346  
 indicators of, 140  
 value of, 236
- Running, 372
- Satellite potential, 66
- Scaling function, 276–277
- Scanning EMG, 41–42
- Screen quality, 45
- SD signal, 115. *See also* Single differential (SD)
- Segmentation phase performance, 68–69
- “Segmentation” strategy, 408
- Selective muscle stimulation, 93, 94
- Selective recruitment, 9
- SEMG amplifier, input impedance of, 116–118
- SEMG amplitude normalization procedures, 368
- SEMG biofeedback. *See also* SEMG feedback; Surface electromyography (SEMG)  
 in ergonomics, 352  
 techniques of, 443–450
- SEMG decomposition, 301
- SEMG feedback. *See also* SEMG biofeedback; Surface electromyography (SEMG)  
 functional activity performance with, 450  
 postural training with, 449  
 therapeutic exercise with, 449
- SEMG measurements, 338–341
- SEMG models, structure-based, 207–209
- SEMG normalization/calibration, 346–347
- SEMG sensors, recommendations for, 123–127
- SEMG signal conditioning system, 120–121
- SEMG signals. *See also* Surface electromyography (SEMG)

- amplitude of, 335–336
- comparing, 385–386
- rectified and smoothed, 370–371
- SEMG-triggered neuromuscular electrical stimulation (NMES), 448
- Semiperiodic electrical activity, 42
- SENIAM (Surface Electromyography for Noninvasive Assessment of Muscle), xvii, 227, 251, 411
- recommendations for, 127
- standards, 123
- Sensor-muscle coupling, 309–310
- Sensors, 123
  - construction of, 124–125
  - location and orientation of, 125–127
- Sensory-based discrimination, 445–446
- Sensory receptor organs, 13
- Sequential clustering techniques, 56
- Sequential control, 468
- Shiavi, R., 381
- Short-time Fourier transform (STFT), 137, 269–271, 296–297, 467
- Short time synchronization (STS), 208
- Shwedyk model, 294
- Signal amplitude, 116
- Signal decomposition, 281–292
- Signal detection protocol, 49–50
- Signal models, 137–139, 207
- Signal nonstationarity, 59
- Signal processing, 133, 383. *See also*
  - Advanced signal processing techniques
  - SEMG, 345–346
  - statistical, 264–265
- Signals, 45
  - compound, 261–263
  - delay estimation for, 186–187
- Signal sampling, 121–122
- Signal segmentation, 50–52
- Signal theory, 261
- Signal-to-noise ratio (SNR), 141, 142, 144, 298, 459–460
- “Silent areas,” 42
- Simulation. *See* EMG modeling
- Simulation studies, 35, 99, 150
- Simultaneous coordinated control, 468
- Sinc function, 269
- Single bipolar channel, 464
- Single-channel EMG, 134
- Single-channel information extraction
  - techniques, 133–163
  - information extraction in frequency domain, 145–153
  - joint analysis of spectrum and amplitude method, 153–154
  - recurrence quantification analysis, 154–162
  - spectral estimation, 134–137
  - SEMG amplitude estimation, 139–145
  - SEMG signal models, 137–139
- Single-channel SEMG signals, 365
- Single differential (SD), 111, 112. *See also* SD signal
- Single-fiber action potentials (SFAPs), 37, 89, 90, 211, 261, 281, 282–283, 284–285
- simulated, 95, 96, 98
- Single-fiber EMG (SFEMG), 36, 38, 39
- Single-fiber macro electrode, 40
- Single-input, multiple-output (SIMO) model, 291
- Single-input, single-output (SISO) model, 261, 267
- Single-linkage distance metric, 54
- Single-MU action potentials, 192, 193–194
- Single-MU action potential trains, 199
- Single-MU CV estimation, 186
- Single myoelectric channel, 455–458. *See also*
  - Multiple myoelectric channels
  - limitations of, 458–460
- Single-pass supervised classification algorithm, 59
- Single-surface MU action potentials, 93
- “Size principle,” 6–7, 373
- Skeletal muscle fiber membrane, 17
- Skeletal muscles
  - aging and, 10, 417
  - analyzing EMG signals from, 297
  - functional differentiation in, 385
- Skin-AgCl contact, 110
- Skin-electrode contact, stability of, 110
- Skin-electrode interface, 108–109
- Skin impedance, 383. *See also* Electrode-skin impedance
- Slow-twitch (S) motor units, 3, 242
- Slow-twitch muscle fibers, 4
- Slow-twitch muscles, 423
- “Smart terminals,” 323
- Smoothing, 144–145
- Software, EMG machine, 44
- Søgaard, K., 47
- Spaceflight, effects of, 423–424
- Spasm, reflexive, 439
- Spatial filtering, 89, 170–180, 196–197, 250
  - applications of, 179–180
  - 2-D, 217
- Spatial filters. *See also* Two-dimensional spatial filters
  - crosstalk and, 180
  - with nonpoint electrodes, 177–179
  - with point electrodes, 173–174

- Spatial frequencies, 95
- Spatial sampling, 170, 180–185, 197  
two-dimensional, 183–185
- Spectral analysis, 148, 153, 163  
role in muscular fatigue studies, 146  
techniques using, 137
- Spectral changes, evaluating, 134
- Spectral compression, descriptors of, 148–152
- Spectral dips, 89–91, 113–114
- Spectral estimation, 134–137
- Spectral estimators  
Fourier-based, 134–135  
parametric-based, 135–136
- Spectral matching CV estimation, 187–188
- Spectral shape indicators, 280
- Spectral variables, 101, 153
- Spectrograms, 269–271
- Sphincter function, 414
- Spike recordings, intramuscular, 8
- Spikes, defined, 152
- Spike-triggered averaging, 48, 115, 192, 210  
of the force signal, 75  
of the surface EMG signal, 76
- Spinal loading, estimation of, 407
- Spinal motor control, EMG and, 404–408
- Spindles, 12
- Spondylosis, 408
- Square law device, 460–461
- Standard deviation, 71–72
- Stashuk, D. W., 47
- Static contractions, muscle fatigue during, 293–296
- Static hypothesis, 87
- Static load level, 348
- Stationary signals, 260
- “Statistical bandwidth,” 140
- Statistical identification methods, 287–289
- Statistical signal processing, 264–265
- Statistics, second-order, 260. *See also* Higher order statistics
- Steady-state MES, 464
- Stegeman, D., 1, 81, 205, 323
- Sternocleidomastoid (SCM) muscle, 409
- Stimulated contraction, 305–307
- Stochastic processes, 264–269  
spectral estimation of, 134–137  
time-varying PSD of nonstationary, 137
- Stop motors to prevent collision damage rule, 469
- Strength training, 372–375  
aging and, 417
- Stress, 354. *See also* Physical stress  
EMG and, 355–356
- Stressful situations, maladaptive coping to, 436
- Stress-induced muscular tension, 353
- “Stress profiling,” 437
- Stress reaction, 355
- Stress-related hyperactivity, 436–437
- Stretch reflex, 11–12, 13
- Stroop color-word test (CWT), 356
- Structural models, 206, 208, 227
- Subcutaneous tissue layer, thickness of, 250
- Subtractive wavelet transform, 283–284
- Superimposed MUAPs, resolving, 63–64
- Supervised classification, of MUAPs, 58–62
- Supervised classification algorithm, 59–60
- Supervised classification techniques, 49
- Surface-detected signal, 121
- Surface electrodes, 28, 89
- Surface electrode systems, 47–48
- Surface electromyography (SEMG), xvi. *See also* Multi-channel information extraction techniques; SEMG entries; Surface EMG entries  
asymmetrical, 438  
biofeedback applications of, 435–450  
central nervous system disorders and, 324–326  
exercise physiology applications of, 365–377  
hypobaric hypoxia and, 420–423  
load estimation and, 346–347  
muscle damage studies via, 375–377  
musculoskeletal disorders and, 352–353  
in the study of motor performances, 365–377  
time and frequency domain analysis of, 368–369  
versus needle and wire methodology, 382
- Surface EMG amplitude estimation, 139–145
- Surface EMG applications  
in central nervous system disorders, 324–326  
clinical, 332–335  
CMAP and motor nerve conduction, 326–328  
CMAP generation, 328–332  
high-density multichannel recording, 338–341  
in movement and gait analysis, 381–397  
in neurology, 323–341  
pathological fatigue, 335–338
- Surface EMG decomposition, 289–292
- Surface EMG features, developed force and, 97–101
- Surface EMG recordings, 447

- Surface EMG signal(s). *See also* Single-channel information extraction techniques
- A/D conversion and, 121–122
  - applications of spectral analysis of, 153
  - detection and conditioning of, 107–127
  - electrode configuration and, 111–115
  - electrode impedance and, 110–111
  - electrode transfer function and, 108–109
  - EMG filters and, 120–121
  - estimation of PSD of, 146
  - European recommendations on electrodes, 123–127
  - frequency compression of, 410
  - front-end amplifiers and, 115–120
  - models of, 137–139
  - during muscle isometric contraction, 160–161
  - recurrence quantification analysis of, 154–162
  - sampling and, 121–122
  - spike-triggered averaging of, 76
- Surface EMG signal processing, 345–346
- Surface EMG spectral analysis, 227
- Surface EMG variables, 236–238
- factors affecting, 246–251
  - force level and, 248
- Surface mechanomyogram, 305–318
- application of, 318
  - detection techniques and sensor comparison with, 307–310
  - detector comparison, 310–312
  - simulation and, 312
  - versus EMG, 316–318
  - versus force, 313–315
- Surface potential distribution, 88
- Sympathetic-adrenal medullary (SAM) system, 355
- Synchronization, 208
- models of, 221–222
  - of firing instants between motor units, 220–222
- Synchronized trains, 66
- Syntactic pattern classification approach, 465
- Synthesis wavelets, 275
- Synthesized EMG signal
- analyzing, 298
  - estimating PSD of, 294–295
- Synthetic SEMGs, decomposition of, 290–291
- Synthetic waveforms, 71
- System identification, using cumulants, 267–269
- System resolution, selecting, 122
- System sensitivity parameter, 44
- Target muscle activity, isolation of, 443–444
- Temporal frequency, 95
- Temporal relationships, between MUAPTs, 64–66
- Tension discrimination training, 446
- Tension recognition training, 445–446
- Therapeutic exercise, with SEMG feedback, 449
- Three-layer model, 88
- Three-state myoelectric controller, 454
- Threshold-based tension recognition training, 445–446
- Threshold-based uptraining/downtraining, 445
- Thresholding, 280
- Thresholds, clustering algorithms and, 56
- Threshold values, 51–52
- Time and frequency domain analysis, 368–369
- Time delay, estimating, 189–190
- Time domain technique, 149
- Time-frequency distributions, 251
- Time-frequency representations (TFRs), 269–272, 298, 300
- bilinear, 271–272
- Time-frequency resolution, 272, 301
- Time resolution, of EMG equipment, 45
- Time-scale EMG fingerprints, 284
- Time-scale phase representation, 284–286
- Time-scale phase transform (TSFT), 285–286
- Time-varying autoregressive (TVAR) approach, 137
- Time-varying power spectral density, 137
- Totally Modular Prosthetic Arm with high Workability (TOMPAW), 470
- Total workload, stress and, 354
- Training strategies, biofeedback, 443–450
- Trajectories, predefined, 469
- Transfer function, 112–113, 114, 175, 177, 178, 216
- Transmembrane current, 82, 84
- Transmembrane ion channels, 209
- Trapezius muscle, psychological stress and, 356–357
- Tripole equations, 210
- Trontelj, J. V., 27
- True positives/negatives, 68–70
- Trunk movement studies, 406–407
- Trunk muscle recruitment, 405
- Trunk muscles, 404–408
- Tubular system (T-system), 17, 20
- Two-dimensional Fourier transform, 178, 212–213, 217
- Two-dimensional spatial filters, 174–177
- Two-dimensional spatial sampling, 183–185

- Type I muscle fibers, 3–5  
Type II muscle fibers, 3, 5–6, 9
- Ultrasonography, 375, 376
- Upper limb prostheses. *See* Powered upper limb prostheses
- Upper motor neurone disorders, 298
- Up-sampling, 275
- Uptraining, 443, 445
- Utah arm, 462
- van Dijk, J. G., 323
- Variance-to-signal (V/S) ratio, 391, 392
- Ventilatory studies, 15–16
- Video-oriented biofeedback systems, 436
- Visual feedback, 443
- Viterbi algorithm, 60
- Voltage turns, number of, 33
- Volume conduction, 214–215
- Volume conductor, 81, 87–89, 101  
finiteness of, 89  
spatial low-pass filter characteristics of, 170, 171
- Voluntary contraction(s)  
aging and, 420  
diminished ability for, 336–337  
effect on EMG signal features, 247–248  
mechanomyogram during, 305–307  
muscle fatigue during, 222–224, 238–242  
muscle surface oscillations and, 306–307  
PSD estimation during, 146  
surface EMG frequency content changes during, 152–153
- Walking, versus race walking and running, 370–371
- Wavelet functions, 272–273, 277
- Wavelet packets, 278–279, 301
- Wavelet packet tree, 278
- Wavelet series expansion (WSE), 275
- Wavelet shrinkage, PSD estimation using, 279–280
- Wavelet smoothing techniques, 280
- Wavelet transform (WT), 272–279, 298. *See also* Subtractive wavelet transform  
EMG signal decomposition using, 281–286
- Weakness  
learned, 440–441  
SEMG and, 438
- Weight-lifting, 373–375
- “Weight-shifting,” 440
- Welch method, 279, 294
- Whiplash-associated disorders, 410
- Whitening, 142–143  
of the myoelectric signal, 459–460
- Whitening filter, 142, 143
- White noise, 119
- Wide-sense stationary (WSS), 134
- Wigner-Ville distribution (WVD), 297, 300–301
- Wigner-Ville transform, 271, 298–299
- Window length, optimal, 144–145
- Window shape, 150
- Workload assessment, in occupational biomechanics, 388–389
- Workload concepts, in ergonomics, 344–345
- Work-related musculoskeletal disorders (WMSDs), 345
- WP periodogram, 279
- Wrist rotation rule, 469
- w*-slice method, 290
- WSS stochastic process, 137
- Yao/Fuglevand synchronization model, 221
- Yielding flexion, 394
- Zazula, D., 259
- Zero crossings (ZC), 152, 346
- Zwarts, M. J., 323