

INDEX

- *charts, 108, 115
- ACE, 44, 56, 91
 - availability, 56
 - real-time support extensions, 51
- Acrobatic maneuver, *see* High-performance maneuver.
- Active controller model, 229, 233, 237
- Active models, 95–7, 101
- Active multimodel architecture, 86, 95–97
- Active plant model, 229, 232–233, 236
- Active state model, 201–204, 222
- Actuator:
 - chattering, 228
 - control limits, 238–239
 - dynamics, 302
 - faults, 356–357, 364
 - saturation, 304
 - update:
 - in Giotto, 130
- Adaptive control, 3, 5–6, 32, 106, 203, 225, 228. *See also* Fault-adaptive control.
- Adaptive limit detection, 239–247
- Adaptive resource management, 29–30, 69–70, 74–75, 268
 - in OCP, 39–40, 46, 57–58, 61, 63, 86, 397
- Advanced Realtime Control Systems, 69
- Advanced Regional Prediction System (ARPS), 187
- Advanced Rotorcraft Technologies, 176
- Aerosonde (UAV), 17, 22
- Afghanistan, 21
- Aggressive maneuvers, *see* High-performance maneuvers.
- Agilent Technologies, 120
- Air Force Research Laboratory (AFRL), 8, 61, 81, 251
- Air traffic control, 381
- Airborne warning and control systems (AWACS) aircraft, 23
- Airbus, 383
- Aircraft carrier, 14, 19, 23
- Aircraft fuel management, 35, 349, 366
- Aircraft landing and takeoff, 35, 107, 193, 273, 319, 339, 369, 372, 381–386, 390
- Aircraft model, fixed wing, 30, 59, 100–102, 96, 204, 239
 - DC9-30, 383–384
 - F-15, 217
 - F-16, 32, 255–257
 - in OCP, 49
 - point mass, 382–383
- Albania, 21
- Altus (UAV), 17, 23
- Anytime:
 - algorithms, 30, 85, 87–90, 101, 397
 - CPU assignment controller, 30, 89, 102
 - scheduling, 89–91
- Apache helicopter, 21, 235
- Approximate dynamic programming, 299, 314–315
- Aquila (UAV), 19

- Architecture description language(ADL), 140
- ARCSware, 69
- Artificial control saturation, 238
- Asynchronous:
 - communication, 70
 - hybrid control, 342
 - systems, 33, 254–255, 268–269, 321
- Attitude controller, helicopter UAV, 77–79
- Australia, 22
- Autocertifiable code, 7
- Autoland, *see* Aircraft landing and takeoff.
- Automatic target recognition, 87
- Automatic transmission, 286
- Automation surprises, 382
- Automotive applications, 124
- Automotive engine control, 274
- Autonomous control architecture, 202–203
- Autonomous events, 353
- Autonomy, 7, 11, 14, 23, 66, 275, 395, 397–399
 - in autonomous vehicles, 33, 65, 300
- Autopilot, 94, 99, 370, 381–382
- AV-8B (aircraft), 58
- Aviator visual design simulator(AVDS), 49, 58, 266
- Avionics, 19, 55, 372, 395–397, 404
 - in Georgia Tech UAV, 80
 - limitations of current systems, 396
 - modes, 95
- B-17 (aircraft), 10
- Balkans, 19, 21
- Bang-bang control, relation to hybrid systems, 276
- Basis functions, 98, 100, 162–163
- Bekka Valley, 19
- Bellman equation, 313–314
- Biological inspiration, 402
- Bisimulation, 284–285, 327
- Blending local mode controller, 227, 229, 232, 235–236
- Block diagram components, 71
- Boeing, 39, 42, 47, 51, 58, 60, 65, 69, 75, 81, 91, 101, 249, 255, 366
- Boeing Phantom Works, 29, 40, 56, 59, 73, 77, 82
- Bold Stroke, 39–43, 60, 255
 - layered architecture, 42
 - TAO extensions, 51
- Bond graph, 106, 114, 347, 351
- Bosnia, 15, 16, 21
- Boundary condition, 319
- BQ-7 (UAV), 10
- Brevel (UAV), 12
- B-splines, 98, 162–163, 169
- Bug (UAV), 10
- Cadence Design Systems, 120
- Calculus of variations, 176, 183
- Caltech, 31, 149
- Caltech ducted fan, 31, 163–172
 - model, 164–165
- CAN, 124, 137
- Carrier, *see* Aircraft carrier.
- Catastrophic failure, 7
- Center of Excellence in Rotorcraft Technology, 238
- Certification, 7, 400
- Charon, 278
- China, 12, 15
- CIRCA, 88
- Client-server, 258, 260
- Client-side caching, 53–54
- Coasting time, 311–312, 318
- Code generation, 4, 33, 48, 60, 69, 120, 125, 255, 263, 265, 266–268, 404
 - for distributed platforms, 136–139
 - under WCET constraints, 140
- Collision avoidance, 7, 35, 369, 376–378
- Collocation, 149, 160–163
- Commercial off-the-shelf (COTS), 22, 396
- Communication:
 - asynchronous, 29
 - between ground and UAV, 60
 - real-time, 30, 125
 - among vehicles, 29, 401
- Communication delay, 102, 118–119, 172
- Communication protocol, 119–120
- Compaq Alpha, 164
- Component-based:
 - architecture, 65, 68
 - design environment, 105, 109
- Conflict resolution, 369, 372, 378–381
- Constrained optimization, 161, 202
- Continuous-time domain, Ptolemy II, 112, 114
- Control architecture, hierarchical, 29
- Control Lyapunov function, 149, 151–155, 177–178
 - cost-to-go, 184, 186
 - definition, 154
 - terminal cost, 158–159
- Control mode, 5–6, 279, 326–339
 - definition, 328
 - graph, 327, 333
- Control quanta, 307
- Control reconfiguration, 29, 34–35, 364–365

- blender approach, 365
- state initialization approach, 365
- Control saturation, 238, 299, 301, 307, 309
- Control system configuration:
 - limitations of current practice, 67–68
 - tooling limitations, 68–69
- Control system development process, 8
- Control/software codesign, 5
- Controlled events, 352
- Controller modeling language, 353–354
- Controller switching, *see* Switching control.
- Controller tuning, 364
- Controls API, 43, 47–48, 51, 56–60, 63, 75–76, 403
- ControlShell/NDDS, 69
- Convex optimization, 35, 369, 388
- Convex polyhedra, 283
- Cooperative, coordinated control, 6–7, 23, 172, 179, 370, 400–403
 - with OCP, 41
 - using Giotto, 133–136
- CORBA, 6, 29, 41, 51, 54, 63, 73, 81, 101
 - IDL interface, 79
 - knowledge required of, for OCP, 266
 - middleware in Bold Stroke, 42, 60
 - services in OCP, 44–45
- Cornell University, 32
- Correct-by-construction code, 7
- Cost to go, 156, 184, 190, 193
 - upper bound for, 159, 178, 186
- CPU times, 168–172, 190, 198, 377
- CPU utilization, 86, 88
- Creckerelle (UAV), 12
- Cruise missile, 16
- Curse of dimensionality, 369

- DARPA, *see* Defense Advanced Research Projects Agency.
- DARPA/ITO, 8, 366
- DARPA/IXO, 61
- Data transfer protocol, 67
- Dataflow model, 30, 105–108
 - for signal processing, 113, 115
- Dataflow model domain, Ptolemy II, 112
- DC9-30, 383–384
- Deadlock, 260–261
- Defense Advanced Research Projects Agency (DARPA), 3, 7–8, 28, 30, 40–41, 56–57, 60–61, 81, 85–86, 88, 91, 120, 123, 226, 249–250, 254–255, 269, 344, 349, 369, 395, 404–405
- Defense Airborne Reconnaissance Office, 12
- Desert Storm, *see* Operation Desert Storm.

- Design tools, 24, 403–404
- Desired transition model, 229, 232, 236
- Differential flatness, 31, 149, 152–154
- Differential games, 173
- Differential GPS, 80
- Discrete-event domain, Ptolemy II, 112
- Discrete-event dynamical system, 30, 34, 275, 277, 289–294
 - approximation of continuous plant, 290–295
- Discrete-event model, 347, 361–364
- Distributed:
 - control systems, 107
 - hard real-time control, 131–133
 - heterogeneous platforms, 133
 - object computing, 4–5, 65, 70–72
 - real-time distributed computing, 70
 - platforms, 124
 - scheduling, 137
- Domain-polymorphism, 110
- Doppler radar, 187
- Drag reduction, 401
- DragonFly (UAV), 390
- Dryden model, 217
- DSPACE, 164, 257
- Ducted fan, 149, 153–154. *See also* Caltech ducted fan.
- Dymola, 278
- Dynamic inversion, 264–265
- Dynamic programming, 314. *See also* Approximate dynamic programming.
- Dynamic reconfiguration, 3, 64, 69–70, 73–7, 397
- Dynamic scheduling, 47–48, 57–58, 61, 69–70, 73–75
 - lacking in commercial tools, 69
- Dynamic trim, 239–246

- Ellipsoid sets, 211–217, 220–222
- Elliptic maneuver, 175, 193–194. *See also* High-performance maneuver.
- Embedded and Hybrid Systems program, 8
- Embedded control systems, 4–6, 108–109, 123–145, 274, 325–326, 339–342
 - bold Stroke connections, 41
 - design methodology for, 30
 - hybrid system aspects, 33–34
 - SEC motivation, 58
- Embedded processors, 24, 58
- Embedded software:
 - in mission computing, 42
- Embedded software development, 124
 - in OCP, 48
- Embedded system laboratory, 58

- Energy optimization, 7
- Engine speed control, 187
- England, 10
- Environmental models, 5, 30
- EP-3 (aircraft), 15
- Esterel (programming language), 113, 140
- Estimation, 4–5, 201–224
 - cooperative, 222
 - joint and dual, 204–205
 - nonlinear, 205–216
 - robust, 205–210
 - stability, 209–210
 - stochastic, 205–210. *See also* Parameter estimation.
- ETH Zürich, 131
- Ethernet, 72, 133
- Euler-Lagrange equations, 181
- Event channel, 44, 73–75, 79, 91
- Event-based communication, 73–74
- Event service, 73
- Evolutionary computing/optimization, 85, 97–100
- Extended Kalman filter, 166, 201, 205–213, 216, 223
- Extended set membership filter, 201, 211–217, 220–222
- Extensible markup language (XML), 47–48

- F/A-18, 58
- F-15, 58
- F-15-like simulation, 32, 201, 204, 217–222
 - sensors, 218
- F-16:
 - LPV control, 260–263
 - LQR control, 258–260
 - textbook model, 32, 253, 256–257
- F-8, 15
- Façade pattern, 52
- Failure mode, 362
- Failure propagation graph, 347, 357, 361–363
- Fault accommodation, 399
- Fault detection and identification/isolation (FDI), 4–5, 78, 80, 347, 356–364, 398
- Fault detection, identification, and reconfiguration (FDIR), 24, 347–351
- Fault diagnosis model-based, 107–109
- Fault isolation, challenge for hybrid systems, 35
- Fault management, 32, 347
- Fault propagation graph, *see* Failure propagation graph.
- Fault signature, 359, 361
- Fault-adaptive control, 347–368
 - architecture, 349–351
 - as hybrid system problem, 34
- Fault-tolerant control, 33, 77, 80, 398
- Fault-tolerant services:
 - in OCP, 60
- Feedback linearizable, 228
- Fighter aircraft:
 - belief that production ending, 24–25
- Finite horizon optimal control, 156–158
- Finite state automaton, 309
- Finite state machine, 105–106, 108–109, 114–117, 273–274, 278, 340–342, 354, 357, 371
 - domain in Ptolemy II, 113
- Finite state sequential automaton, 353
- Firebee (UAV), 11
- Fixed-wing model, *see* Aircraft model, fixed-wing.
- Flight control:
 - memory size, 58
 - rate requirements, 55
 - typical architecture, 46
- Flight envelope, 32, 218, 229, 301, 304, 307–309, 316, 382, 390
- Flight management system:
 - for helicopter, 108
 - not mission critical, 29
- Flight test, 30, 58–60, 63, 79–81, 249
- FlightLab, 176–183, 188
- “Fly safe” zone, 228–229, 238
- Flyability models, 96
- Fly-by-wire, 395
- Flying bombs, 10
- Formation management, 33
- Fox AT (UAV), 12
- Fox TS (UAV), 12
- France, 12, 21
- Full-envelope design, 4
- Furuta inverted pendulum, 105, 116
- Fuzzy logic and control, 32
- Fuzzy neural network, 32, 225, 229–231, 236
- Fuzzy rules, 229–231
- Fuzzy sliding mode control, 228

- Gain scheduling, 5, 107, 227, 236, 307
 - velocity-based, 228
- General Atomics, 17, 23
- General Inter-ORB Protocol (GIOP), 54
- Generic Hybrid Controls API, 63, 76–77, 81
- Generic patterns, *see* Patterns.
- Generic Tilt-Rotor Simulation, 240, 246
- Georgia Institute of Technology, 29, 32, 39–40, 47, 49, 58, 60–61, 63, 69, 77, 79, 82, 226, 238, 249, 255
- Germany, 10, 12, 21

- GIOP-lite, 54
- Giotto, 30, 123–145
 - annotations, 31, 123, 137
 - compiler, 30, 125
 - driver, 128
 - mode, 124, 130
 - mode-switch, 124–125, 130
 - port, 127
 - program, 130
 - annotated, 141–144
 - programming language, 30, 126–131
 - task, 127
- Global Hawk, 13, 23
 - long-distance capability, 22
- Global positioning system (GPS), 14, 18, 80, 205, 390
- Gnat (UAV), 23
- Graphical user interface (GUI), 266–267
- Great Britain, 12, 21
- Guard, in Giotto, 128. *See also* under Hybrid automaton.
- Gulf War, 16, 19, 21

- Hamiltonian, 156–157, 376–377
- Hamilton-Jacobi equation, 35, 369, 375, 377, 386
- Hamilton-Jacobi-Bellman equation, 313–314,
- Hardware-in-the-loop simulation, 48, 71, 80, 249
- HCC, 278
- Helicopter, 11, 14, 64
 - autonomous, 32, 34, 124
 - flight management system, 108
 - remote controlled, 30, 198
 - RPM change margin, 77
 - three-degree-of-freedom, 34
 - UAV technology requirements, 68
- Helicopter control, 116, 175–200
 - multimodal, 334–339
- Helicopter model:
 - high-fidelity, 178–180
 - in OCP, 49, 77
 - linearized, 151, 240, 244–246
 - nonlinear, 325, 334–335
 - simplified, 32, 225, 235
- Hellfire-C (missile), 22
- Heron (UAV), 11
- Heterochronous dataflow (HDF), 115
- Heterogeneous modeling and design, 105–122
- Hierarchical architecture, 6–7, 402
- High-confidence systems, 7–8, 321, 325, 344, 399–400
- High-g maneuver, 240, 248–9
- High-performance maneuver, 24, 32, 74, 149, 165–168, 175, 226, 239, 308, 395, 398, 401–402. *See also* High-g maneuver; Elliptic maneuver.
- High-resolution TV, 11
- Hitachi, 120
- Honeywell, 30, 39, 69, 249, 264
- Honeywell Labs, 40, 46, 61, 75, 255, 263
- Hunter (UAV), 11, 20–21
- Hybrid automaton, 33, 114, 273, 278–285, 325, 340–341, 371–373, 380
 - flow condition, 279
 - guard, 280, 373
 - invariant condition, 280
 - parallel composition, 280
 - run, 280
 - state, 280
- Hybrid bond graph, 35, 347, 351–353, 355, 358
- Hybrid control system, 23, 64, 300, 342
- Hybrid controls layer, 29, 71
- Hybrid dynamical system, *see* Hybrid system.
- Hybrid maneuver automaton, *see* Maneuver automaton.
- Hybrid observer, 35, 347, 355–360
- Hybrid state, 311
- Hybrid system, 4–5, 28, 33, 105–106, 273–298, 369–392
 - analysis and design approaches, 277–278
 - for diagnostics, 357–361
 - graphical environment, 351
 - in Ptolemy II, 114
 - models, 33, 35, 274–276, 350–351
 - OCP support, 46
 - software tools, 33–35, 277–278
 - stability and design, 285–289
 - supervisory control, 289–294
 - verification, 273
- HyTech, 278

- IEEE, 44
- Imprecise computation, 89
- India, 12
- Indirect adaptive control, 225, 232
- Inertial sensor, 390
- Information technology:
 - growth of, 27
 - lack of impact in control, 35
- Inner-loop control, 29, 77, 94, 151, 165, 169, 239
- Integer linear program, 125
- Intel processor, 126, 133
- Intelligent control, 225–252, 275
- Intelligent highway systems, 7
- Intercontinental Ballistic Missile (ICBM), 20

- Interface automaton, 119
- Internet Inter-ORB Protocol (IIOP), 54
- Internet Protocol, 54
- Interoperability, 6–7, 54, 64–65, 73
- Inter-ORB Protocol (IOP), 54
- Interprocess communication, 319
- Interrupt handling, 319
- Interval mathematics, 211–212, 214, 223
- Inverted pendulum controller, 107, 116–119
- Iran, 12
- Iraq, 12, 15, 21
- Israel, 11–12, 19, 21
- Israel Aircraft Industries, 11
- Israeli Air Force, 11, 21
- IT revolution, 396, 404
- Italy, 12

- Japan, 12
- Jitter, 86, 118
- Joint Program Office, 20

- Kalman filter, 105, 205, 208, 356
 - mode-switched, 35. *See also* Unscented Kalman filter; Extended Kalman filter.
- Kosovo, 15, 17, 21
 - after-Action Review, 21
- Kronos, 278

- Landing. *see* Aircraft landing and takeoff.
- Landing gear forces, 191–193
- Lax-Friedrichs, 376
- Leader-follower formation, 132
- Learning algorithm, 230–231
- Lebanon, 21
- Legacy components, 68
- Lego Mindstorms, 126, 133
- Level set, 369, 374–376
- Level set function, 374
- Local level set algorithm, 372
- Lie algebra, 302, 306
- Limit detection and avoidance, 32, 225, 238–249
- Linear:
 - hybrid automaton, 33, 35, 273, 278, 281–284, 374
 - matrix inequality, 288–289
 - parameter varying (LPV) controller, 32, 253, 260–263, 307
 - quadratic regulator (LQR), 32, 165–166, 176, 180–183, 190, 198, 235–236, 253, 258–260
- Linear switched system, 288
- Linux, 44, 57, 80. *See also* Real-time Linux
- Load factor, 246–249
- Lwner-John ellipsoid, 389
- Lucent, 133

- Lustre (programming language), 140
- Lyapunov functions, 154, 286–289. *See also* Control Lyapunov functions; Multiple Lyapunov functions.
- Lyapunov linearization, 236
- Lyapunov stability, 286
- Lyapunov theorems, 329

- Maneuver, definition, 308
- Maneuver automaton, 34, 299, 301, 310–315, 319
 - controllability, 312
 - definition, 310
 - as dynamical system, 311
 - robust maneuver automaton, 312
- Maneuver library, 34, 301, 318
- Maneuver space, 301, 311–315
- Maneuver-based control, 299–323
- Mason's gain rule, 361
- MathModelica, 278
- Matlab, 32, 39, 68, 71, 124, 190, 319, 377
 - as hybrid system tool, 277
- Mex function, 253, 258
 - OCP integration, 43, 57, 253, 257–266
 - use in traditional development process, 48
- MatrixX, 48, 124
- Maxdet problems, 388
- Maximum volume ellipsoid (MVE), 369, 387–389
- Medium-range forecast model (MRF), 187
- Medium-Range UAV, 20
- Membership function, 229–231, 237
- Message-oriented middleware, 256
- MetaH language, 140
- Mexico, 17
- Microsoft, 50
- Microsoft Visual C++ integration with OCP, 50, 268
- Microsoft Visual Debugger integration with OCP, 50
- Micro-UAVs, 17
- Middleware, 6, 40–43, 55, 73, 85, 255, 397
 - forms of, 256
 - in OCP, 40–45, 49, 55–60, 73
 - requirements for high-performance control, 86
- Military off-the-shelf (MOTS), 22
- Minimum-time control, 315–317
- Mirach 150, 12
- Mirach 26, 12
- Mission computing, 42
- Mission intelligence flow, 226
- Mission planning, 80, 88, 179, 187
- Mixed-integer program, 173
- Modal models, 114–115

- Mode partitioning, 402
- Mode selection, 80
- Mode switching, 34, 105, 326–267, 342, 379, 378–386. *See also* Multimodal control.
- Mode transitions, 6, 35, 66, 76, 80, 193, 225–237, 266, 325, 331, 336, 347, 350, 384
 - in OCP, 46–47, 57
- Modeling with hybrid bond graphs, 352, 355–361
- Mode-based design, 402
- Model checking, 321
- Model fidelity, 32, 89
- Model helicopter flight control, 131
- Model identification, *see* System identification.
- Model predictive control (MPC), 31, 149–152, 175–200, 202, 398–399
 - ducted fan implementation, 168–172
 - impact in process industries, 31, 398
- Model-based fault diagnosis, 107–109, 399
- Model-free fault diagnosis, 399
- Modelica, 277–278
- Model-integrated computing, 353
- Model-inversion-based controller, 238
- Model-predictive neural control, 175–200
 - stability of, 186
- Models of computation, 30, 105–106, 110, 119, 321, 325–326, 340–342, 397
 - continuous time, 112
 - dataflow, 112–113
 - discrete event, 112
 - finite-state machines, 113–114
 - in Ptolemy II, 81, 112–114
 - synchronous data flow (SDF), 113
 - synchronous/reactive, 113
 - timed multitasking, 113
- Modes:
 - in avionics systems, 95
 - in Giotto, 124
 - of operation, 33, 227, 300, 370–386, 390
- Moore’s Law, 86
- Motion planning, 34, 299–323
- Motion primitive, 299, 305–309
 - definition, 306
 - selection, 315–318
- Motorola, 257
- Multimodal control, 6–7, 33–34, 60–61, 76, 108, 116–119, 140, 225, 325–345, 376, 385
 - consistent mode switching, 331
- Mode switching problem, 329
- Mode switching solution, 334
- Multimodel control, 85–103
- Multimodel language, 401
- Multimodels, 5–6
- Multiple Lyapunov functions, 34, 286, 288
- Multiresolution models, 85
- Multiresolution optimization, 97–100
- Multiscale representations, 85
- Multivehicle control, 201–214, 221–222, 400–402
- Multivehicle systems, 6, 59, 101, 344
- NASA, 17
- NASA Ames, 278
- NASA Langley, 256
- National Defense Authorization Act, 18
- National Oceanic and Atmospheric Administration, 187
- National Science Foundation (NSF), 8, 61, 123
- National Semiconductor, 120
- NATO, 15–16, 21
- Nellis Air Force Base, 22
- Neural control, 175–200
- Neural network, 5, 31–32, 175–200, 225, 238–246
- Neurodynamic programming, *see* Approximate dynamic programming.
- Newfoundland, 22
- Newton-Euler equations, 334–335
- “No fly” zone, 15
- Nondeterminism:
 - in asynchronous systems, 397
 - in computing times, 86
 - consequence of discretization, 34, 292–293, 362
- Nonlinear programming, 31, 160, 163
- Nonlinear Trajectory Generation (NTG), 163–169
- Nonperiodic task, 75, 89
- Nonzero, 280
- Novatel, 80
- NPSOL, 163
- NSF, *see* National Science Foundation.
- Object Management Group, 73
- Object request broker (ORB), 51, 54, 56, 81, 256, 269
- Object-oriented architecture/design, 40, 109, 261
- Observer, 242, 244. *See also* hybrid observer.
- OCP, *see* open control platform.
- Omola, 278
- OmSim, 278
- One-step-ahead control, 228
- Online control customization, 5, 149–174, 253–270
- Open system architecture, 4, 6–7, 23, 64, 68
- Open control platform, 29, 39–62, 63–84, 86, 101, 198, 226, 249, 253–270, 396–397
 - anytime scheduling, 91
 - architecture, 45

- Open control platform (*Continued*)
 - asynchronous architecture, 397
 - availability, 56
 - benefit for embedded systems, 40
 - builds, 56
 - controls API, 39
 - examples delivered, 56
 - extensions needed, 397
 - flight demonstration, 58–60, 63, 79–81
 - goals, 41
 - hybrid systems support, 46
 - integration with Matlab/Simulink, 32, 257–268
 - major components, 43
 - memory footprint, 58
 - operating systems supported, 57–58
 - other APIs needed, 403
 - real-time optimizations, 51–55
 - significant innovations, 57
 - simulation environment, 49–50
 - timer service, 55
 - tool integration, 50–51
 - UAV models included, 49
- Operation Allied Force, 18, 21
- Operation Deliberate Force, 16
- Operation Desert Storm, 17, 21
- Optimal control, 5, 154–158
- Optimal value function, 157
- Optimality principle, 313
- Optimization-based control, 147–172
 - stability, 155–159
- ORB, *see* Object request broker.
- Ordered binary decision diagram (OBDD), 362–363
- Oregon Graduate Institute, 31
- Outer-loop command generation, 263
- Outer-loop control, 77
- Outrider Tactical UAV, 20

- Palo Alto Research Center, 33
- Parameter estimation, 35, 347, 357–361
- Patterns, 52, 77, 81
- PD control, *see* Proportional-derivative control.
- Pentium, 58
- Pentium II, 59, 299, 319
- Persistent excitation, 357
- Petri nets, 119, 273–277
- Philips, 120
- Phoenix (UAV), 12
- PID control, *see* Proportional-integral-derivative control.
- Piecewise linear, 295, 351, 361
- Piecewise polynomial, 160, 166
- Pioneer (UAV), 11, 14, 19, 21

- Planning integration with control, 33, 275, 289, 402–403
- Platform-independence, 30, 397, 403
- Plug-and-play, 39, 64–69, 399
- Policy iteration, 314
- Polyhedral overapproximation, 35, 369, 386–389
- Polyhedral partition, 283, 289
- Polyhedral pruning, 388–389
- Polymorphic execution, 110
- Polytope set, 211, 216, 388
- Port-based object, 119
- Portugal, 22
- POSIX, 44
- PowerPC, 58
- Precision-guided weapons, 16, 18
- Predator (UAV), 12–13, 17–18, 20–21
 - first flight, 21
 - missile-equipped, 22
 - open system architecture, 23
 - submarine operation, 22
- Predictive control, 5, 7. *See also* Model predictive control (MPC).
- Preemption, 75, 113
- Programmable logic controller (PLC), 33, 274
- Programmer's model for embedded systems, 123
- Proportional-derivative (PD) control, 169
- Proportional-integral-derivative (PID) control, 13, 107, 350–351, 364, 399
- Prowler (UAV), 23
- Proxy message passing, 319
- Pseudo-control hedging, 32, 238, 247, 250
- Ptolemy II, 30, 39, 105–122, 340–344
 - actors, 109
 - code generation, 120
 - directors, 110
 - domain, 110
 - hybrid systems, 114–115, 277
 - OCP integration, 43, 51, 57
- Ports, 109
 - receivers, 110
 - token, 110
- Ptolemy project, 81
- Ptolemy project homepage, 120
- Publish/subscribe, 44, 51, 253, 262, 265
 - data transfer in OCP, 256

- Q-learning, 314
- QNX, 44, 80, 319
- QNX Neutrino, 390
- Qualitative diagnostic analysis, 352
- Qualitative reasoning, 35, 347, 358–359
- Quality of service, 7, 46, 48, 57, 63, 74–76, 86–87

- Quantization of dynamics, 321
- Quorum, 88
- Race conditions, 262
- Radar tracking, 206, 220–222
- Radio silence, 401
- Ranger (UAV), 11
- Rasmussen Simulation Technologies, 49
- Rate-monotonic analysis, 90
- Rate-monotonic scheduling, 128
- Reachability, 5, 35, 282–284, 309, 325–332, 338, 369–392
 - predecessor set, 330
- Reachable set, 336, 372
- Real-time:
 - adaptive resource management, 46, 85–103
 - communication, 30, 125
 - enterprise, 108
 - event service, 63, 73
 - innovations, 69
 - Linux, 319
 - operating system (RTOS), 4, 6, 44, 50, 58, 105, 109, 113, 118, 125–126, 133, 137, 140, 397
 - separation from design environment, 403
 - system architecture, 34
 - workshop, 48, 257, 268, 319
- Receding horizon control, 151, 158–60, 165–171, 177–178, 183, 186, 398
- Reconfigurable control/systems, 7, 29, 63–84, 354
- Reconfigurable controls API, 75–76
- Reconfiguration dynamic, 3–6
 - flight demonstration, 60
 - OCP support, 46–48
 - transition management, 70, 76–77
- Rectangular automaton, 33, 282
- Recurrent neural network, 228
- Recursive least squares (RLS), 228
- Reinforcement learning, 314
- Relative degree, 162
- Relative equilibria, 34, 303, 305–307, 309, 316
- Remote control, 10, 18, 60, 395
- Remote procedure call, 256
- Replication, 73, 75, 81
- Requirements creep in UAV programs, 19, 22
- Resource management, OCP, 46
 - multiprocessor extensions, 60
- Reuse, 42, 64–70, 76–77, 120
- Riccati equation, 31, 155, 169, 175–200
- Robot control, 132–136
- Robust control, 3, 6, 203, 211
- Robustness-performance tradeoff, 398
- Rotor collective controller, 63, 77–79
- Rotor rotation speed controller, 63–64
- Rotorcraft, 32, 60, 64
 - models in OCP, 49
- Route planning and optimization, 85, 91–100.
 - See also* Trajectory planning and optimization.
- RPM controller, 77–79
- RQ-8A Fire Scout (UAV), 14
- RT CORBA, 6, 29, 43–44, 46, 51, 60, 255
- RTARM, 46, 88
 - integration with anytime scheduling, 91
- RTSim, 257
- Runtime adaptation, 70
- Russia, 12
- Safety-critical system, 42, 113, 124, 139, 326, 369–371, 382, 400
- Sailboat steering, 307
- Schedulability, 88, 266
- Scheduling, 30, 40, 113, 120, 125, 267
 - anytime tasks, 89–91
 - for distributed platform, 123, 136–139
 - in OCP, 46, 48, 52–53
- Scope (programming language), 178
- Scotland, 22
- Scout (UAV), 11
- SCUD missiles, 17
- Searcher (UAV), 11
- Seeker (UAV), 12
- Senate Armed Services Committee, 18, 21
- Sensor faults, 356–357, 364
- Sensor losses, 221–222
- Sensor noise, 205, 317
- Sensor ports, in Giotto, 130, 133
- Sensors effects on state transitions, 132
 - for F-15-like simulation, 217–218
 - inertial, 390
 - jitter-free sampling, 55
 - new additions to system, 67, 74
- Sequential quadratic programming, 163
- Serbia, 15, 21
- Shift (programming language), 278
- Sigma-Pi neural network, 243
- Signal (programming language), 113, 140
- Silver Arrow, 11
- Sim2ocp tool, 33, 254, 266–268
- Simulation environment, 30, 85, 100–103
 - of OCP, 43
- Simulink, 32, 33, 39, 57, 68, 106, 257, 319, 403
 - as hybrid system tool, 277
 - OCP integration, 43, 49–51, 57–58, 253–255, 258–262, 265–268
 - problem with asynchronous system, 33, 254–255, 268–269

- S functions, 253, 265–266
 - use in traditional development process, 48
 - vendor support, 257
- Sliding mode control, 227–228
 - relation to hybrid systems, 276
 - smart weapons, 16
- Software architecture for real-time control, 28
- Software composition, 4, 340
- Software Enabled Control (SEC) program,
 - 3–8, 28, 31, 40, 57–61, 81, 85–86, 91, 123, 173, 226, 238, 249–250, 254–255, 269, 344, 349, 366, 369, 396–399, 404–405
 - baseline fixed-wing UAV model, 257
 - Broad Agency Announcement (BAA), 58
- Somalia, 21
- South Africa, 12
- Southeast Asia, 11
- Southern Cross II, 22
- Soviet Union, 19
- Specification and Description Language (SDL), 115
- S-procedure, 289
- Stability for switching control, 326
 - of formations, 401
 - of MPC, 31
- Stability augmentation, 404
- Stabilizing control, 150–151, 155–159,
 - 165–168, 309, 314–316
- Stanford University, 35, 58, 390
- State estimation, *See* Estimation.
- Statecharts, 108, 115, 354
- State-dependent Riccati equation (SDRE)
 - controller, 32, 175–200
 - design/derivation, 180–183
- Stateflow, 106
 - as hybrid system tool, 277
- Submarine, 10, 22
- Suppression of enemy air defense (SEAD), 15,
 - 18, 24
- Swarm, UAVs, 7
- Switched bond graph, 114
- Switching control, 34, 107, 307, 347, 364–365
 - managing transients, 365
- Stability, 326
- Symmetry, 303–304, 308, 311, 313–318
- Synchronous dataflow (SDF), 113, 117, 120,
 - 269
- Synchronous events, 53
- Synchronous reactive language, 140
- Synchronous/reactive domain, Ptolemy II,
 - 113, 115
- Synthetic aperture radar (SAR), 13, 19
- Syria, 21
- System identification, 4–5, 88, 176, 203
- T-45 (aircraft), 58
- Tactical UAV (TUAV), 14
- Takagi-Sugeno fuzzy model, 225, 229
- TAO, 44, 46, 56
 - availability, 56
 - optimizations for real-time, 51, 54
 - real-time event service, 51
- Task scheduler, 88
- TCP/IP, 54, 262
- TDMA network, 137
- Technical University of Budapest, 34
- Temporal causal graph, 352
- Terminal cost factor, in MPC, 31
- Terrain following, 96, 98
- Terrain model, 97
- Texas Instruments, 164, 257
- The Mathworks, 48, 58, 69, 268
- Thermostat, 275–276, 278–279
- Thermostat/furnace example, 293–295
- Three-degree-of-freedom helicopter, 299, 301,
 - 315–321
- Thrust vectoring, 153, 164–165
- Timed automaton, 278, 282, 374
- Timed causal graphs, 358–361
- Timed multitasking domain, Ptolemy II,
 - 113, 118
- Timer service, in OCP, 55
- Time-scale separation, 402
- Time-triggered architecture (TTA), 123–124
- Time-triggered system, 30, 123–124, 139–140,
 - 342, 397
- TMAN helicopter model, 248
- Train-gate controller, 280–284
- Trajectory controller, helicopter, 77–79
- Trajectory equivalence, 305–306
- Trajectory generation decoupling with
 - tracking, 150
 - using differential flatness, 160–163
- Trajectory planning and optimization, 30, 88,
 - 108, 202, 220–223
 - MPC-based, 31, 94
 - multiresolution, 97–100. *See also* Route planning and optimization.
- Trajectory tracking, 99, 319
- Transaction processing monitor, 256
- Transmission control protocol (TCP), 54
- Trim control, 181
- Trim surface, 307
- Trim trajectory, 34, 299, 306–313, 316–317
- TTCAN, 124
- Turbulence, 196
- Two-degree-of-freedom control, 150–151, 165
- Two-tank system, 35, 347, 349, 352, 362
- Type checking, 120

- U.S. Air Force, 12, 15, 18, 20, 58, 60
- U.S. Army, 10–12, 20–22
- U.S. Coast Guard, 17
- U.S. Congress, 12, 18
- U.S. Department of Defense, 14, 20, 24
- U.S. Department of Energy, 17
- U.S. Marines, 11, 14, 17, 20
- U.S. Navy, 14, 17, 19–21
- U.S. Strategic Air Command, 11
- UAV Joint Program Office, 12
- UCAV, 14, 22, 58, 60
- Uncertainty bounds, 203–204, 210, 211
- Uncertainty model, 203–204
- Uninhabited aerial vehicles (UAV), 9–26, 28, 32, 39, 63–67, 217, 221–223, 226–227, 255, 327, 390, 395–405
 - advantages over piloted aircraft, 14–18
 - application focus for SEC, 396
 - commercial applications, 23
 - formations, 400
 - hierarchical architecture, 66
 - history, 9–14
 - migration from manned missions, 24
 - models in OCP, 49
 - ocean crossings, 22
 - operator interface, 23
 - roadmap, 14, 24
 - vision-guided landing, 107
 - weather research and monitoring, 17
 - in World War I, 10
 - in World War II, 10
- Uninhabited autonomous vehicle (UAV), *see* Uninhabited aerial vehicle (UAV).
- United States (U.S.), 11, 17
- University of California, Berkeley, 30, 34, 40, 51, 61, 70, 249, 340, 344
- University of Minnesota, 32, 49, 70
- University of Notre Dame, 33
- University of Pennsylvania, 34
- UNIX, 44
- Unmanned aerial vehicle (UAV), *see* Uninhabited aerial vehicle (UAV).
- Unscented Kalman filter, 32, 201, 206–210, 217, 223
- UPPAAL, 278
- V-1 buzz bomb, 10
- Validation, 7, 72, 376, 397, 400
- Value iteration, 314–315
- Vanderbilt University, 34
- Variable structure control, relation to hybrid systems, 276
- Vehicle control system, 301
- Vehicle health monitoring, 88
- Vehicle model, 76
- Verification, 7, 69, 113, 326, 340, 344, 400
 - of hybrid systems, 273, 276–277, 283, 369–392
 - probabilistic techniques, 400
 - simulation-based, 301
 - tools for hybrid systems, 278
- Verilog, 106
- Vertical takeoff and landing, 23, 65
- Vertical takeoff UAV (VTUAV), 14
- VHDL, 106
- Video games, 27
- Vietnam, 11
- VM, 54
- VxWorks, 44, 80, 126, 133, 140
 - integration with OCP, 50, 58
- V&V, *see* Validation; Verification.
- Washington University, 39, 44, 56, 73, 77
- Wavelet decomposition, 97–98
- Waypoint generator, 253, 264
- Waypoint tracking controller, 32, 263
- Waypoints, 94
- Weapons system, 16
- Weather effects, 88, 92–93, 398. *See also* Turbulence; Wind effects.
- Weather model, 88, 95
- Weather research and monitoring, 17
- WinCon, 319
- Wind effects, 175, 187–188, 194–198, 227
- Wind River, 126, 133, 140
- Windows, 57
- Windows 98, 319
- Windows NT, 44, 101
- Wireless, 68, 72, 124
 - ethernet, 133
- World state server, 101–102
- World War I, 10, 28
- World War II, 10, 15
- Worst-case execution time, 47, 74, 125–127, 267
- Wright-Patterson AFB, 217
- X-cell, 63, 79–80
- Xerox PARC, 278
- XML, *see* Extensible markup language.
- XV-15 (aircraft), 226, 246
- Yamaha (UAV), 58, 78, 80, 249
- Yugoslavia, 15
- Zeno systems, 287