

References

- [1] R.A. Adams, *Sobolev Spaces*, Academic Press, New York, 1975.
- [2] M. Ainsworth and J.T. Oden, *A Posteriori Error Estimation in Finite Element Analysis*, John Wiley & Sons, Inc., New York, 2000.
- [3] M. Ainsworth, J.T. Oden, and C.Y. Lee, Local *a posteriori* error estimators for variational inequalities, *Numer. Meth. PDE* **9** (1993), 23–33.
- [4] J. Albery, C. Carstensen and D. Zarrabi, Adaptive numerical analysis in primal elastoplasticity with hardening, *Comp. Meths. Appl. Mech. Engng.* **171** (1999), 175–204.
- [5] A.M. Arthurs, *Complementary Variational Principles*, 2nd Edition, Oxford Math. Monographs, Oxford, 1980.
- [6] K. Atkinson and W. Han, *Theoretical Numerical Analysis: A Functional Analysis Framework*, Springer-Verlag, New York, TAM, Volume 39, 2001.
- [7] I. Babuška, The problem of modeling the elastomechanics in engineering, *Computer Methods in Applied Mechanics and Engineering* **82** (1990), 155–182.
- [8] I. Babuška and A.K. Aziz, Survey lectures on the mathematical foundations of the finite element method, in A.K. Aziz, ed., *The Mathematical Foundations of the Finite Element Method with Applications to Partial Differential Equations*, Academic Press, New York, 1972, 3–359.
- [9] I. Babuška, Y. Li, and K.L. Jerina, Reliability of computational analysis of plasticity problems, *Technical Note BN-1123*, IPST, UMCP, March 1991.

- [10] I. Babuška and J. Pitkaranta, The plate paradox for hard and soft simple support, *SIAM J. Math. Anal.* **21** (1990), 551–576.
- [11] I. Babuška and W.C. Rheinboldt, Error estimates for adaptive finite element computations, *SIAM J. Numer. Anal.* **15** (1978), 736–754.
- [12] I. Babuška and W.C. Rheinboldt, *A posteriori* error estimates for the finite element method, *Intern. J. Numer. Methods Engrg.* **12** (1978), 1597–1615.
- [13] I. Babuška and T. Strouboulis, *The Finite Element Method and its Reliability*, Oxford University Press, 2001.
- [14] J. Baranger and K. Najib, Analyse numérique des écoulements quasi-Newtonians dont la viscosité obéit à la loi puissance ou la loi de Carreau, *Numer. Math.* **58** (1990), 35–49.
- [15] J.W. Barrett and W.B. Liu, Finite element error analysis of a quasi-Newtonian flow obeying the Carreau or power law, *Numer. Math.* **64** (1993), 433–453.
- [16] S. Bartels and C. Carstensen, Each averaging technique yields reliable a posteriori error control in FEM on unstructured grids. Part II: Higher order FEM, *Math. Comp.* **71** (2002), 971–994.
- [17] S. Bartels and C. Carstensen, Averaging techniques yield reliable a posteriori finite element error control for obstacle problems. Preprint Nr. 2/2001. Publications of the Max-Planck-Institute for Mathematics in the Sciences, Leipzig, Germany.
- [18] H.S. Bear, *An Introduction to Mathematical Analysis*, Academic Press, San Diego, 1997.
- [19] R. Becker and R. Rannacher, An optimal control approach to *a posteriori* error estimation in finite element methods, in *Acta Numerica 2001*, Cambridge University Press, 1–102.
- [20] T. Belytschko, W.K. Liu and B. Moran, *Nonlinear Finite Elements for Continua and Structures*, Wiley, Chichester, England, 2000.
- [21] C. Bernardi and V. Girault, A local regularization operator for triangular and quadrilateral finite elements, *SIAM J. Numer. Anal.* **35** (1998), 1893–1916.
- [22] R.B. Bird, R.L. Armstrong and O. Hassager, *Dynamics of Polymeric Liquids*, Vol. 1, Fluid Mechanics, Wiley, 1977.

- [23] H. Blum and R. Rannacher, On the boundary value problem of the bi-harmonic operator on domains with angular corners, *Math. Meth. in the Appl. Sci.* **2** (1980), 556–581.
- [24] H. Blum and F.-T. Suttmeier, An adaptive finite element discretisation for a simplified Signorini problem, *CALCOLO* **37** (2000), 65–77.
- [25] H. Blum and F.-T. Suttmeier, Weighted error estimates for finite element solutions of variational inequalities, *Computing* **65** (2000), 119–134.
- [26] V. Bostan and W. Han, Recovery-based error estimation and adaptive solution of elliptic variational inequalities of the second kind, to appear in *Communications in Mathematical Sciences*.
- [27] V. Bostan and W. Han, On a posteriori error analysis of a quasistatic variational inequality, submitted.
- [28] V. Bostan, W. Han and B. D. Reddy, A posteriori error analysis for elliptic variational inequalities of the second kind, in *Computational Fluid and Solid Mechanics 2003*, Proceedings of Second MIT Conference on Computational Fluid and Solid Mechanics, June 17–20, 2003, ed. K.J. Bathe, 1867–1870.
- [29] V. Bostan, W. Han and B. D. Reddy, A posteriori error estimation and adaptive solution of elliptic variational inequalities of the second kind, submitted.
- [30] M. Braack and A. Ern, A posteriori control of modeling errors and discretization errors, *Multiscale Model. Simul.* **1** (2003), 221–238.
- [31] D. Braess, *Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics*, second edition, Cambridge University Press, Cambridge, 2001.
- [32] S.C. Brenner and L.R. Scott, *The Mathematical Theory of Finite Element Methods*, second edition, Springer-Verlag, New York, 2002.
- [33] F. Brezzi and M. Fortin, *Mixed and Hybrid Finite Element Methods*, Springer-Verlag, Berlin, 1991.
- [34] C. Carstensen, Numerical analysis of the primal problem of elastoplasticity with hardening, *Numer. Math.* **82** (1999), 577–597.
- [35] C. Carstensen, Quasi-interpolation and a posteriori analysis in finite element methods, *RAIRO Math. Model. Num.* **33** (1999), 1187–1202.

- [36] C. Carstensen and J. Albery, Averaging techniques for reliable a posteriori FE-error control in elastoplasticity with hardening, *Comput. Methods Appl. Mech. Engrg.* **192** (2003), 1435–1450.
- [37] C. Carstensen and S. Bartels, Each averaging technique yields reliable a posteriori error control in FEM on unstructured grids. Part I: Low order conforming, nonconforming, and mixed FEM, *Math. Comp.* **71** (2002), 945–969.
- [38] C. Carstensen and R. Verfürth, Edge residual dominate a posteriori error estimates for low order finite element methods, *SIAM J. Numer. Anal.* **36** (1999), 1571–1587.
- [39] J. Chen, W. Han, and H. Huang, On the Kačanov method for a quasi-Newtonian flow problem, *Numerical Functional Analysis and Optimization* **19** (1998), 961–970.
- [40] Z. Chen and R.H. Nochetto, Residual type a posteriori error estimates for elliptic obstacle problems, *Numer. Math.* **84** (2000), 527–548.
- [41] P.G. Ciarlet, *The Finite Element Method for Elliptic Problems*, North Holland, Amsterdam, 1978.
- [42] P.G. Ciarlet, *Mathematical Elasticity, Vol. I: Three-Dimensional Elasticity*, North-Holland, Amsterdam, 1988.
- [43] P.G. Ciarlet, Basic error estimates for elliptic problems, in P.G. Ciarlet and J.-L. Lions, eds., *Handbook of Numerical Analysis*, Vol. II, North-Holland, Amsterdam, 1991, 17–351.
- [44] Ph. Clément, Approximation by finite element functions using local regularization, *RAIRO Numerical Analysis* **R-2** (1975), 77–84.
- [45] J. Conway, *A Course in Functional Analysis*, 2nd ed., Springer-Verlag, New York, 1990.
- [46] M. Dauge, *Elliptic Boundary Value Problems in Corner Domains—Smoothness and Asymptotics of Solutions*, Lecture Notes in Mathematics, No. 1341, Springer-Verlag, 1988.
- [47] G. Duvaut and J.-L. Lions, *Inequalities in Mechanics and Physics*, Springer-Verlag, Berlin, 1976.
- [48] R.E. Edwards, *Functional Analysis: Theory and Applications*, Dover Publications, Inc., New York, 1994.

- [49] I. Ekeland and R. Temam, *Convex Analysis and Variational Problems*, North-Holland, Amsterdam, 1976. Reprinted as SIAM's Classics in Applied Mathematics, Volume 28, 1999.
- [50] K. Eriksson, D. Estep, P. Hansbo, and C. Johnson, Introduction to adaptive methods for differential equations, in *Acta Numerica 1995*, Cambridge University Press, 105–158.
- [51] L.C. Evans, *Partial Differential Equations*, AMS, 1998.
- [52] R.S. Falk, Error estimates for the approximation of a class of variational inequalities, *Math. Comp.* **28** (1974), 963–971.
- [53] M. Feistauer, J. Mandel, and J. Nečas, Entropy regularization of the transonic flow problem, *Comment. Math. Univ. Carolin.* **25** (1984), 431–443.
- [54] V.M. Filippov, *Variational Principles for Nonpotential Operators*, Translations of Mathematical Monographs, Vol. 77, AMS, 1989.
- [55] M. Fortin, Old and new finite elements for incompressible flows, *Int. J. Numer. Meth. Fluids.* **1** (1981), 347–364.
- [56] D. French, S. Larsson, and R.H. Nochetto, Pointwise a posteriori error analysis for an adaptive penalty finite element method for the obstacle problem, *Comput. Methods Appl. Math.* **1** (2001), 18–38.
- [57] A. Friedman, *Variational Principles and Free-boundary Problems*, John Wiley & Sons, New York, 1982.
- [58] S. Fučík, A. Kufner, and J. Nečas, Kačanov's method and its application, *Rev. Roumaine de Math. Pures et Appl.*, **20** (1975), 907–916.
- [59] D.Y. Gao, *Duality Principles in Nonconvex Systems*, Kluwer Academic Publishers, Dordrecht, 1999.
- [60] D.Y. Gao, Nonconvex semi-linear problems and canonical duality solutions, Chapter 5 of *Advances in Mechanics and Mathematics II, 2003*, eds. D.Y. Gao and R.W. Ogden, Kluwer Academic Publishers, Dordrecht, pp. 261–312.
- [61] D. Gilbarg and N. Trudinger, *Elliptic Differential Equations of Second Order*, Springer-Verlag, 1977.
- [62] M.B. Giles and E. Süli, Adjoint methods for PDEs: a posteriori error analysis and postprocessing by duality, in *Acta Numerica 2002*, Cambridge University Press, 145–236.

- [63] V. Girault and P.-A. Raviart, *Finite Element Methods for Navier-Stokes Equations, Theory and Algorithms*, Springer, Berlin, 1986.
- [64] H. Gittel, Studies on transonic flow problems by nonlinear variational inequalities, *Z. Anal. Anwendungen* **6** (1987), 449–458.
- [65] R. Glowinski, *Numerical Methods for Nonlinear Variational Problems*, Springer-Verlag, New York, 1984.
- [66] R. Glowinski, J.-L. Lions, and R. Trémolières, *Numerical Analysis of Variational Inequalities*, North-Holland, Amsterdam, 1981.
- [67] P. Grisvard, *Elliptic Problems in Nonsmooth Domains*, Pitman, Boston, 1985.
- [68] W. Han, The best constant in a Sobolev inequality, *Applicable Analysis An International Journal* **41** (1991), 203–208.
- [69] W. Han, Finite element analysis of a holonomic elastic-plastic problem, *Numer. Math.* **60** (1992), 493–508.
- [70] W. Han, The best constant in a trace inequality, *Journal of Mathematical Analysis and Applications* **163** (1992), 512–520.
- [71] W. Han, *A posteriori* error analysis for linearizations of nonlinear elliptic problems and their discretizations, *Math. Meths. Appl. Sci.* **17** (1994), 487–508.
- [72] W. Han, Quantitative error estimates for idealizations in linear elliptic problems, *Math. Meths. Appl. Sci.* **17** (1994), 971–987.
- [73] W. Han, Notes on best constants in some Sobolev’s inequalities, *Analysis Mathematica* **20** (1994), 3–10.
- [74] W. Han and S. Jensen, The Kačanov method for a nonlinear variational inequality of the second kind arising in elastoplasticity, *Chinese Annals of Mathematics* **17B** (1996), 129–138.
- [75] W. Han, S. Jensen, and B.D. Reddy, Numerical approximations of internal variable problems in plasticity: error analysis and solution algorithms, *Numerical Linear Algebra with Applications* **4** (1997), 191–204.
- [76] W. Han, S. Jensen, and I. Shimansky, The Kačanov method for some nonlinear problems, *Applied Numerical Analysis* **24** (1997), 57–79.
- [77] W. Han and B.D. Reddy, On the finite element method for mixed variational inequalities arising in elastoplasticity, *SIAM J. Numer. Anal.* **32** (1995), 1778–1807.

- [78] W. Han and B.D. Reddy, Computational plasticity: the variational basis and numerical analysis, *Computational Mechanics Advances* **2** (1995), 283–400.
- [79] W. Han and B.D. Reddy, *Plasticity: Mathematical Theory and Numerical Analysis*, Springer-Verlag, 1999.
- [80] W. Han, B.D. Reddy, and G.C. Schroeder, Qualitative and numerical analysis of quasistatic problems in elastoplasticity, *SIAM J. Numer. Anal.* **34** (1997), 143–177.
- [81] W. Han and M. Sofonea, *Quasistatic Contact Problems in Viscoelasticity and Viscoplasticity*, American Mathematical Society and International Press, 2002.
- [82] J. Haslinger, I. Hlaváček and J. Nečas, Numerical methods for unilateral problems in solid mechanics, in P.G. Ciarlet and J.-L. Lions, eds., *Handbook of Numerical Analysis*, Vol. IV, North-Holland, Amsterdam, 1996, 313–485.
- [83] I. Hlaváček, J. Haslinger, J. Nečas and J. Lovíšek, *Solution of Variational Inequalities in Mechanics*, Springer-Verlag, New York, 1988.
- [84] R.H.W. Hoppe and R. Kornhuber, Adaptive multilevel methods for obstacle problems, *SIAM J. Numer. Anal.* **31** (1994), 301–323.
- [85] C.O. Horgan, Eigenvalue estimates and the trace theorem, *J. of Math. Anal. and Appl.* **69** (1979), 231–242.
- [86] C.O. Horgan and L.E. Payne, Lower bounds for free membrane and related eigenvalues, *Rendiconti di Matematica* **10** (1990), 457–491.
- [87] H. Huang, W. Han, and J. Zhou, The regularization method for an obstacle problem, *Numer. Math.* **69** (1994), 155–166.
- [88] T.J.R. Hughes, *The Finite Element Method*, Prentice Hall Inc., New Jersey, 1987.
- [89] C. Johnson, *Numerical Solutions of Partial Differential Equations by the Finite Element Method*, Cambridge University Press, Cambridge, 1987.
- [90] C. Johnson, Adaptive finite element methods for the obstacle problem, *Math. Models Methods Appl. Sci.* **2** (1992), 483–487.
- [91] J. Kačúr, J. Nečas, J. Polák, and J. Souček, Convergence of a method for solving the magnetostatic field in nonlinear media, *Aplikace Matematiky* **13** (1968), 456–465.

- [92] R.B. Kellogg and J.E. Osborn, A regularity result for the Stokes problem in a convex polygon, *J. Functional Anal.* **21** (1976), 397–431.
- [93] A.M. Khludnev and J. Sokolowski, *Modelling and Control in Solid Mechanics*, Birkhäuser Verlag, Basel, 1997.
- [94] N. Kikuchi and J.T. Oden, *Contact Problems in Elasticity: A Study of Variational Inequalities and Finite Element Methods*, SIAM, Philadelphia, 1988.
- [95] D. Kinderlehrer and G. Stampacchia, *An Introduction to Variational Inequalities and their Applications*, Academic Press, New York, 1980.
- [96] V.A. Kondrat'ev, Boundary problems for elliptic equations in domains with conical or angular points, *Trans. Moscow Math. Soc.* **16** (1967), 227–313.
- [97] V.A. Kondrat'ev and O.A. Oleinik, Boundary-value problems for partial differential equations in non-smooth domains, *Russian Math. Surveys* **38** (1983), 1–86.
- [98] R. Kornhuber, A posteriori error estimates for elliptic variational inequalities, *Comput. Math. Appl.* **31** (1996), 49–60.
- [99] V.A. Kozlov, V.G. Maz'ya, and J. Rossmann, *Elliptic Boundary Value Problems with Point Singularities*, AMS, Providence, 1997.
- [100] V.A. Kozlov, V.G. Maz'ya, and J. Rossmann, *Spectral Problems Associated with Corner Singularities of Solutions to Elliptic Equations*, AMS, Providence, 2001.
- [101] A. Kufner, O. John, and S. Fučík, *Function Spaces*, Noordhoff International Publishing, A division of A.W. Sijthoff International Publishing Company B.V., Leyden, The Netherlands, 1977.
- [102] A. Kufner and A. Sangig, *Some Applications of Weighted Sobolev Spaces*, Teubner-Texte zur Mathematik, Band 100, Leipzig, 1987.
- [103] J.R. Kuttler and V.G. Sigillito, *Estimating Eigenvalues with A Posteriori / A Priori Inequalities*, Pitman Research Notes in Mathematics Series, Volume 135, London, 1985.
- [104] N.N. Lebedev, *Special Functions & Their Applications*, Dover Publications, Inc., New York, 1972.
- [105] R. Lehmann, Developments at an analytic corner of solutions of elliptic partial differential equations, *J. Math. Mech.* **8** (1959), 727–760.

- [106] J.E. Marsden and T.J.R. Hughes, *Mathematical Foundations of Elasticity*, Prentice-Hall, Englewood Cliffs, New Jersey, 1983.
- [107] V.G. Maz'ya, N.F. Morozov, B.A. Plamenevskii, and L. Stupyalis, *Elliptic Boundary Value Problems*, AMS Translations, Series 2, Volume 123, 1984.
- [108] E. Miersemann, Asymptotic expansions of solutions of the Dirichlet problem for quasilinear elliptic equations of second order near a conical point, *Math. Nachr.* **135** (1988), 239–274.
- [109] S.G. Mikhlin, *Variational Methods in Mathematical Physics*, Oxford, New York, Pergamon Press, 1964.
- [110] N.I. Muskhelishvili, *Some Basic Problems of the Mathematical Theory of Elasticity*, P. Noordoff Ltd, Groningen-Holland, 1953.
- [111] J. Nečas and I. Hlaváček, *Mathematical Theory of Elastic and Elastoplastic Bodies: An Introduction*, Elsevier Scientific Publishing Company, Amsterdam, Oxford, New York, 1981.
- [112] J. Nečas and I. Hlaváček, Solution of Signorini's contact problem in the deformation theory of plasticity by secant modules method, *Aplikace Matematiky* **28** (1983), 199–214.
- [113] B. Noble and M.J. Sewell, On dual extremum principles in applied mathematics, *J. Inst. Math. Appl.* **9** (1972), 123–193.
- [114] R.H. Nochetto, K.G. Siebert, and A. Veiser, Pointwise a posteriori error control for elliptic obstacle problems, *Numer. Math.* **95** (2003), 163–195.
- [115] J.T. Oden, Finite elements: an introduction, in: P.G. Ciarlet and J.L. Lions, eds., *Handbook of Numerical Analysis*, Vol. II, North-Holland, Amsterdam, 1991, pp. 3–15.
- [116] J.T. Oden and S. Prudhomme, Estimation of modeling error in computational mechanics, *J. Comput. Phys.* **182** (2002), 496–515.
- [117] J.T. Oden and J.N. Reddy, *An Introduction to the Mathematical Theory of Finite Elements*, John Wiley, New York, 1976.
- [118] J.T. Oden and K. Vemaganti, Estimation of local modeling error and goal-oriented modeling of heterogeneous materials, Part I: Error estimates and adaptive algorithms, *J. Comput. Phys.* **164** (2000), 22–47.
- [119] J.T. Oden and K. Vemaganti, Estimation of local modeling error and goal-oriented modeling of heterogeneous materials, Part II: A computational environment for adaptive modeling of heterogeneous elastic solids, *Comp. Methods Appl. Mech. Engrg.* **190** (2001), 6663–6684.

- [120] J.T. Oden, K. Vemaganti, and N. Moes, Hierarchical modeling of heterogeneous solids, *Comp. Methods Appl. Mech. Engrg.* **172** (1999), 3–25.
- [121] J.T. Oden and T.I. Zohdi, Analysis and adaptive modeling of highly heterogeneous elastic structures, *Comp. Methods Appl. Mech. Engrg.* **148** (1997), 367–391.
- [122] R.W. Ogden, *Non-linear Elastic Deformations*, Ellis Harwood, Chichester, and John Wiley, New York, 1984.
- [123] J.E. Osborn, Regularity of solutions of the Stokes problem in a polygonal domain, in *Numerical Solution of Partial Differential Equations—III*, Ed. B. Hubbard, Synspade, 1975.
- [124] M.N. Özişik, *Boundary Value Problems of Heat Conduction*, International Textbook Company, Scranton, Pennsylvania, 1968.
- [125] P.D. Panagiotopoulos, *Inequality Problems in Mechanics and Applications*, Birkhäuser, Boston, 1985.
- [126] T.v. Petersdorff and E.P. Stephan, Decompositions in edge and corner singularities for the solution of the Dirichlet problem of the Laplacian in a polyhedron, *Math. Nachr.* **149** (1990), 71–104.
- [127] W. Prager and P.G. Hodge, *Theory of Perfectly Plastic Solids*, Dover Publications, New York, 1968.
- [128] S. Prudhomme, J.T. Oden, T. Westermann, J. Bass, and M.E. Botkin, Practical methods for *a posteriori* error estimation in engineering applications, *Int. J. Numer. Meth. Engrg* **56** (2003), 1193–1224.
- [129] A. Quarteroni and A. Valli, *Numerical Approximation of Partial Differential Equations*, Springer-Verlag, Berlin, 1994.
- [130] B.D. Reddy, Mixed variational inequalities arising in elastoplasticity, *Nonlinear Analysis, TMA* **19** (1992), 1071–1089.
- [131] B.D. Reddy and T.B. Griffin, Variational principles and convergence of finite element approximations of a holonomic elastic-plastic problem. *Numer. Math.* **52** (1988), 101–117.
- [132] J.C. Redondo, The penalized obstacle problem, *Duke Mathematical Journal* **69** (1993), 43–85.
- [133] S.I. Repin, A posteriori error estimation for variational problems with uniformly convex functionals, *Mathematics of Computation* **69** (2000), 481–500.

- [134] S.I. Repin and L.S. Xanthis, A posteriori error estimation for elastoplastic problems based on duality theory, *Computer Methods in Applied Mechanics and Engineering* **138** (1996), 317–339.
- [135] J.E. Roberts and J.-M. Thomas, Mixed and hybrid methods, in P.G. Ciarlet and J.-L. Lions, eds., *Handbook of Numerical Analysis*, Vol. II, North-Holland, Amsterdam, 1991, 523–639.
- [136] R.T. Rockafellar, *Convex Analysis*, Princeton University Press, New Jersey, 1970.
- [137] Ch. Schwab, *p- and hp-Finite Element Methods*, Oxford University Press, 1998.
- [138] M.J. Sewell, Dual approximation principles and optimization in continuum mechanics, *Phil. Trans. Roy. Soc. (London) A* **265** (1969), 319–351.
- [139] V.G. Sigillito, *Explicit A Priori Inequalities with Applications to Boundary Value Problems*, Pitman Research Notes in Mathematics Series, Volume 13, London, 1977.
- [140] E.M. Sparrow and R.D. Cess, *Radiation Heat Transfer*, McGraw-Hill, Washington, 1978.
- [141] I. Stakgold, *Green's Functions and Boundary Value Problems*, John Wiley & Sons, Inc., 1979.
- [142] E. Stein and S. Ohnimus, Anisotropic discretization- and model-error estimation in solid mechanics by local Neumann problems, *Comput. Methods Appl. Mech. Engrg.* **176** (1999), 363–385.
- [143] J. Steinbach, *A Variational Inequality Approach to Free Boundary Problems with Applications in Mould Filling*, Birkhäuser Verlag, Basel, 2002.
- [144] G. Strang and G. Fix, *An Analysis of the Finite Element Method*, Prentice-Hall, Englewood Cliffs, NJ, 1973.
- [145] F.-T. Suttmeier, General approach for a posteriori error estimates for finite element solutions of variational inequalities, *Computational Mechanics* **27** (2001), 317–323.
- [146] B.A. Szabo and I. Babuška, Computation of the amplitude of stress singular terms for cracks and reentrant corners, in *Fracture Mechanics: Nineteenth Symposium, ASTM STP969*, Ed. T.A. Cruse, 1988.
- [147] V. Thomée, *Galerkin Finite Element Methods for Parabolic Problems*, Springer Lecture Notes in Mathematics, No. 1054, 1984.

- [148] V. Thomée, *Galerkin Finite Element Methods for Parabolic Problems*, Springer, 1997.
- [149] P. Tolksdorf, On the Dirichlet problem for quasilinear equations in domains with conical boundary points, *Comm. in PDEs* **8** (1983), 773–817.
- [150] A. Veiser, Efficient and reliable a posteriori error estimators for elliptic obstacle problems, *SIAM J. Numer. Anal.* **39** (2001), 146–167.
- [151] W. Velte, Complementary variational principles, in *Finite Element and Boundary Element Techniques from Mathematical and Engineering Point of View*, Ed. E. Stein and W. Wendland, Springer-Verlag, Wien-New York, 1988.
- [152] R. Verfürth, A posteriori error estimates for nonlinear problems, finite element discretizations of elliptic equations, *Mathematics of Computation* **62** (1994), 445–475.
- [153] R. Verfürth, *A Review of A Posteriori Error Estimation and Adaptive Mesh Refinement Techniques*, Wiley and Teubner, 1996.
- [154] C. Wang, *Applied Elasticity*, McGraw-Hill Book Company, Inc., 1953.
- [155] J. Weisz, A posteriori error estimate of approximate solutions to a special nonlinear boundary value problem, *Zeit. Angew. Math. Mech.* **75** (1995) 1, 79–81.
- [156] N.M. Wigley, Asymptotic expansions at a corner of solutions of mixed boundary value problems, *J. Math. Mech.* **13** (1964), 549–576.
- [157] M.L. Williams, Stress singularities resulting from various boundary conditions in angular corners of plates in extension, *J. Appl. Mech.* **19** (1952), 526–528.
- [158] N. Yan, A posteriori error estimators of gradient recovery type for elliptic obstacle problems, *Adv. Comput. Math.* **15** (2001), 333–362.
- [159] E. Zeidler, *Nonlinear Functional Analysis and its Applications. III: Variational Methods and Optimization*, Springer-Verlag, New York, 1986.
- [160] E. Zeidler, *Nonlinear Functional Analysis and its Applications. IV: Applications to Mathematical Physics*, Springer-Verlag, New York, 1988.
- [161] E. Zeidler, *Nonlinear Functional Analysis and its Applications, II/B Nonlinear Monotone Operators*, Springer-Verlag, New York, 1990.
- [162] O.C. Zienkiewicz, Origins, milestones and directions of the finite element method—a personal view, in P.G. Ciarlet and J.-L. Lions, eds., *Handbook*

- of Numerical Analysis*, Vol. 4, North-Holland, Amsterdam, 1996, pp. 3–67.
- [163] O.C. Zienkiewicz and R.L. Taylor, *The Finite Element Method*, Vol. 1 (Basic Formulation and Linear Problems), McGraw-Hill, New York, 1989.
- [164] O.C. Zienkiewicz and R.L. Taylor, *The Finite Element Method*, Vol. 2 (Solid and Fluid Mechanics, Dynamics and Nonlinearity), McGraw-Hill, New York, 1991.
- [165] O. C. Zienkiewicz and J. Z. Zhu, A simple error estimator and adaptive procedure for practical engineering analysis, *Int. J. Numer. Meth. Engrg.* **24** (1987), 337–357.
- [166] O. C. Zienkiewicz and J. Z. Zhu, The superconvergent patch recovery and a posteriori error estimates. Part 1: The recovery technique, *Int. J. Numer. Meth. Engrg.* **33** (1992), 1331–1364.
- [167] O. C. Zienkiewicz and J. Z. Zhu, The superconvergent patch recovery and a posteriori error estimates. Part 2: Error estimates and adaptivity, *Int. J. Numer. Meth. Engrg.* **33** (1992), 1365–1382.

Index

- $C(\overline{\Omega})$, 7
- $C^\infty(\overline{\Omega})$, 7
- $C_0^\infty(\Omega)$, 7
- $C^m(\overline{\Omega})$, 7
- $C^{0,\beta}(\overline{\Omega})$, 8
- $C^{m,\beta}(\overline{\Omega})$, 8
- $H_0^1(\Omega)$, 13
- $H_{\Gamma_1}^1(\Omega)$, 16
- $H^k(\Omega)$, 10
 - inner product, 10
 - norm, 10
- $H_0^k(\Omega)$, 11
- $H^{-1}(\Omega)$, 13
- $H^{1/2}(\partial\Omega)$, 12
- $L^\infty(\Omega)$, 8
- $L^p(\Omega)$, 8
- $L_{\text{loc}}^p(\Omega)$, 8
- $W^{k,p}(\Omega)$, 9
 - norm, 9
 - seminorm, 15
- $W_0^{k,p}(\Omega)$, 11
- \mathbb{R}^d , 5
 - inner product, 5
 - norm, 5
- \mathbb{S}^d , 5
 - inner product, 5
 - norm, 5

- a posteriori error estimate, 3
- a priori error estimate, 44
- auxiliary function, 66
 - admissible, 73

- best constant, 19
- bilinear form, 18
 - bounded, 18
 - continuous, 18
 - elliptic, 18
 - symmetric, 18

- Céa's inequality, 37
- Carathéodory function, 58
- Cauchy–Schwarz inequality, 6
- Clément-type interpolation, 240
- coercive function, 56
- compact embedding, 14
- conjugate functional, 57
- convergence, 6
 - strong, 6
 - weak, 6
- convex function, 48
 - characterization, 56
 - continuity, 52
 - strictly, 48
 - strongly, 63
- convex set, 47

- density theorems, 11
- directional derivative, 55
- domain, 5
 - Lipschitz, 10
- dual problem, 57
- dual space, 5
- dual variable, 66
 - admissible, 73
- dual-weighted residual technique, 4
- duality pairing, 5
- duality theory, 59

- effective domain, 48
- elliptic variational inequality
 - first kind, 30
 - second kind, 30
- embedding, 13
- energy difference, 61
- epigraph, 49
- equivalent norms, 14
- error estimator, 235
 - gradient recovery-based, 255

- residual-based, 248, 273
- error indicator, 235
- finite element interpolant, 43
- finite element method, 38
 - h - p -version, 38
 - h -version, 38
 - p -version, 38
- finite element space, 41
- finite elements
 - affine-equivalent, 41
- frictional contact problem, 32
- Gâteaux derivative, 55
- Galerkin method, 36
- gradient recovery-based error estimate, 255
- Hölder continuity, 8
- Hahn–Banach theorem, 50
- heat conduction problem, 119
 - coefficient idealization, 121
 - insulation boundary condition, 122
 - linearization, 160
 - temperature boundary condition, 124
- Hencky material, 144
- idealizations in linear problems, 67
 - boundary condition, 100
 - coefficient, 68
 - domain, 106
 - right-hand side, 91
- indicator function, 49, 53
- Kačanov method, 204
 - convergence, 205
 - elastoplasticity, 226
 - quasi-Newtonian flow problem, 219
 - stationary conservation law, 209
- Korn inequality, 34
- Lagrange multiplier, 238
- Lax–Milgram Lemma, 18
- linearization, 127
 - Bingham flow, 176
 - heat conduction problem, 160
 - nonlinear elasticity, 143
 - obstacle problem, 182
 - problem with small parameter, 169
 - quasilinear problem, 173
- Lipschitz continuity, 7
- Lipschitz domain, 10
- lower semicontinuous (l.s.c.), 49
- mathematical model, 1
 - basic, 1
 - idealized, 1
- meas(Ω), 8
- mesh, 39
- mesh parameter, 40
- multi-index notation, 7
- normal derivative, 13
- obstacle problem, 31, 182, 193
- partition, 39
 - regular, 40
- Poincaré inequality, 19
- primal problem, 57
- proper functional, 29
- reference element, 39
- reflexive Banach space, 6
- regularization method, 196
 - a posteriori error estimate, 200
 - convergence, 197
 - elastoplasticity, 226
 - obstacle problem, 193
- residual-based error estimate, 248, 273
- Riesz representation theorem, 6
- Ritz method, 37
- separation of convex sets, 50
- singularity, 25
- smoothness of boundary, 10
- Sobolev space, 9
- strain deviator, 144
- stress deviator, 144
- subdifferential, 53
- subgradient, 53
- sublinear functional, 50
- summation convention, 5
- support, 7
- support functional, 53
- torsion problem, 112
 - normalized Prandtl's stress function, 114
 - Prandtl's stress function, 113
 - warping function, 112
- trace, 12
- triangulation, 39
 - regular, 40
- variational inequality, 29
- weak derivative, 9
- weak formulation, 16
- weakly lower semicontinuous (w.l.s.c.), 49
- Young inequality, 58
 - generalized, 58