UNIVERSITAT DE
BARCELONA

Data Driven Approach to Enhancing Efficiency and Value in Healthcare

Richard E. Guerrero Ludueña

References

[1] Official website for PRINCE 2, Projects in Controlled Environments. (2017). Available at https://www.axelos.com/best-practice-solutions/prince2.

[2] O. Y. Al-Jarrah, P. D. Yoo, S. Muhaidat, G. K. Karagiannidis, and K. Taha. Efficient machine learning for big data: A review. *Big Data Research*, 2(3):87–93, 2015.

[3] H. Allaoua, S. Borne, L. Létocart, and R. Wolfler Calvo. A matheuristic approach for solving a home health care problem. *Electronic Notes in Discrete Mathematics*, 41:471–478, 2013.

[4] E. Alpaydin. *Introduction to Machine Learning*. MIT Press, 2014.

[5] R. Aringhieri, M. E. Bruni, S. Khodaparasti, and J. T. van Essen. Emergency medical services and beyond: Addressing new challenges through a wide literature review. 78:349–368, 2017.

[6] S. Armstrong. Hospitals that are leading the way to a digital future. *BMJ*, 356, 2017.

[7] K. J. Aström. *Theory and Applications of Self-Tuning Regulators*, pages 669–680. Springer Berlin Heidelberg, Berlin, Heidelberg, 1975.

[8] O. Atiq, N. Kubiliun, and D. Agrawal. Informed consent for gi endoscopy-do the time and place matter? *Gastroenterol Nurs*, 38(4):305–6, 2015.

[9] K. Basu, V. Debusschere, S. Bacha, U. Maulik, and S. Bondyopadhyay. Nonintrusive load monitoring: A temporal multilabel classification approach. *IEEE Transactions on Industrial Informatics*, 11(1):262–270, 2015.

[10] A. Bavelas. Communication patterns in task oriented groups. *The Journal of the Acoustical Society of America*, 22(6):725–730, 1950.

[11] S. V. Begur, D. M. Miller, and J. R. Weaver. An integrated spatial dss for scheduling and routing home-health-care nurses. *Interfaces*, 27(4):35–48, 1997.

[12] R. Bekkerman. Automatic categorization of email into folders: Benchmark experiments on enron and sri corpora. Report, 2004.

[13] M. Belkin, P. Niyogi, and V. Sindhwani. Manifold regularization: A geometric framework for learning from labeled and unlabeled examples. *J. Mach. Learn. Res.*, 7:2399–2434, 2006.

[14] J. Bell. *Machine Learning: Hands-On for Developers and Technical Professionals.* Wiley, 2014.

[15] R. E. Bellman. Dynamic programming, 1957.

[16] Y. Bengio. Learning deep architectures for ai. *Foundations and Trends in Machine Learning*, 2(1):1–127, 2009.

[17] A. Blum and T. Mitchell. Combining labeled and unlabeled data with co-training, 1998.

[18] C. Blum and A. Roli. Metaheuristics in combinatorial optimization: Overview and conceptual comparison. *ACM Comput. Surv.*, 35(3):268–308, 2003.

[19] S. Boccaletti, V. Latora, Y. Moreno, M. Chavez, and D. U. Hwang. Complex networks: Structure and dynamics. *Physics Reports*, 424(4):175–308, 2006.

[20] P. Bonacich. Power and centrality: A family of measures. *American Journal of Sociology*, 92(5):1170–1182, 1987.

[21] S. Brailsford, L. Churilov, and B. Dangerfield. *Discrete-Event Simulation and System Dynamics for Management Decision Making.* Wiley, 2014.

[22] S. Brailsford and J. H. Klein. The value of modelling and simulation in healthcare - a review of the evidence and some possible ways forward. (2015). Cumberland Initiative publication.

[23] S. Brailsford and J. Vissers. Or in healthcare: A european perspective. *European Journal of Operational Research*, 212(2):223–234, 2011.

[24] S. C. Brailsford, T. B. Bolt, G. Bucci, T. M. Chaussalet, N. A. Connell, P. R. Harper, J. H. Klein, M. Pitt, and M. Taylor. Overcoming the barriers: a qualitative study of simulation adoption in the nhs. *Journal of the Operational Research Society*, 64(2):157–168, 2013.

[25] S. C. Brailsford, P. R. Harper, B. Patel, and M. Pitt. An analysis of the academic literature on simulation and modelling in health care. *Journal of Simulation*, 3(3):130–140, 2009.

[26] U. Brandes. A faster algorithm for betweenness centrality. *Journal of Mathematical Sociology*, 25(163), 2001.

[27] L. Breiman. Statistical modelling: The two cultures. (2001). available at http://projecteuclid.org/euclid.ss/1009213726.

[28] E. Burke, G. Kendall, J. Newall, E. Hart, P. Ross, and S. Schulenburg. *Hyperheuristics: an Emerging Direction in Modern Search Technology*, page 458. International Series in Operations Research and Management Science. Kluwer Academic Publishers, 2003.

[29] Cancer Research UK. Bowel Cancer Statistics. (2017). Available at http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/bowel-cancer.

[30] Cancer Research UK. Worldwide Cancer Statistics. (2017). Available at http://www.cancerresearchuk.org/health-professional/cancer-statistics/worldwide-cancer.

[31] Care Quality Commission. Royal Bournemouth Hospital. Quality Report. (2015). Available at http://www.cqc.org.uk/sites/default/files/new_reports/AAAE3565.pdf. Technical report.

[32] M. Chaieb, J. Jemai, and K. Mellouli. A hierarchical decomposition framework for modeling combinatorial optimization problems. *Procedia Computer Science*, 60:478–487, 2015.

[33] V. Chapela, R. Criado, S. Moral, and M. Romance. *Mathematical Foundations: Complex Networks and Graphs (A Review)*, pages 9–36. Springer International Publishing, Cham, 2015.

[34] S. Cheng, B. Liu, T. O. Ting, Q. Qin, Y. Shi, and K. Huang. Survey on data science with population-based algorithms. *Big Data Analytics*, 1(1):3, 2016.

[35] F. R. K. Chung. *Eigenvalues of Graphs*, pages 1333–1342. Birkhäuser Basel, Basel, 1995.

[36] W. Cleveland. Data science: An action plan for expanding the technical areas of the field of statistics. *International Statistics Review*, 69(1):21–26, 2001.

[37] J. Cohen and I. M. Pike. Defining and measuring quality in endoscopy. *Gastrointestinal Endoscopy*, 81(1):1–2, 2015.

[38] D. Contandriopoulos, M. Lemire, J. L. Denis, and E. Tremblay. Knowledge exchange processes in organizations and policy arenas: a narrative systematic review of the literature. *Milbank Q*, 88(4):444–83, 2010.

[39] B. Copeland. Artificial Intelligence (AI). (2017). Available at https://www.britannica.com/technology/artificial-intelligence.

[40] K. Crammer and Y. Singer. On the learnability and design of output codes for multiclass problems. *Machine Learning*, 47(2):201–233, 2002.

[41] D. Culliford, J. Maskell, A. Judge, C. Cooper, D. Prieto-Alhambra, and N. K. Arden. Future projections of total hip and knee arthroplasty in the uk: results from the uk clinical practice research datalink. *Osteoarthritis and Cartilage*, 23(4):594–600, 2015.

[42] J. A. Danowski. *Mining Organisations' Networks: Multi-Level Approach*, book section Chapter 13, pages 205–230. Hershey, PA : Information Science Reference, c2012., 2012.

[43] S. Dantas, L. Faria, C. M. H. de Figueiredo, and R. B. Teixeira. The partitioned probe problem: Np-complete versus polynomial dichotomy. *Discrete Applied Mathematics*.

[44] G. B. Dantzig, D. R. Fulkerson, and S. M. Johnson. Solution of a large-scale traveling-salesman problem. *Operations Research*, 2:393–410, 1954.

[45] M. Davidian. Aren't we data science? *AmStat News*, July 2013 2013.

[46] L. W. Day, D. Belson, M. Dessouky, C. Hawkins, and M. Hogan. Optimizing efficiency and operations at a california safety-net endoscopy center: a modeling and simulation approach. *Gastrointestinal Endoscopy*, 80(5):762–773, 2014.

[47] J. de Mast, B. Kemper, R. J. M. M. Does, M. Mandjes, and Y. van der Bijl. Process improvement in healthcare: overall resource efficiency. *Quality and Reliability Engineering International*, 27(8):1095–1106, 2011.

[48] A. Dekker. Conceptual distance in social network analysis. *Journal of Social Structure (JoSS)*, 6, 2005.

[49] J. Diesner, T. L. Frantz, and K. M. Carley. Communication networks from the enron email corpus. it's always about the people. enron is no different. *Computational and Mathematical Organization Theory*, 11(3):201–228, 2005.

[50] L. Donoho. 50 years of data science. Report, Stanford University, 2015.

[51] M. Dorigo and T. Stützle. *Ant Colony Optimization*. Bradford Company, 2004.

[52] R. Durbin and D. Willshaw. An analogue approach to the travelling salesman problem using an elastic net method. *Nature*, 326(6114):689–691, 1987.

[53] D. v. Dyk, M. Fuentes, M. I. Jordan, M. Newton, B. K. Ray, D. T. Lang, and H. Wickham. Asa statement on the role of statistics in data science. *AmStat News*, 2015.

[54] C. H. Ellenbecker, L. Samia, M. J. Cushman, and K. Alster. *Patient Safety and Quality in Home Health Care*, book section Chapter 13. Agency for Healthcare Research and Quality (US), Rockville (MD), 2008.

[55] F. Endel and H. Piringer. Data wrangling: Making data useful again. *IFAC-PapersOnLine*, 48(1):111–112, 2015.

[56] V. Černý. Thermodynamical approach to the traveling salesman problem: An efficient simulation algorithm. *Journal of Optimization Theory and Applications*, 45(1):41–51, 1985.

[57] L. Euler. Solutio problematis ad geometriam situs pertinentis. 1741.

[58] European Commission. The European Union Explained: Public Health. (2014). Available at http://ec.europa.eu/health//sites/health/. Technical report.

[59] D. Evenden, P. R. Harper, S. C. Brailsford, and V. Harindra. System dynamics modeling of chlamydia infection for screening intervention planning and cost-benefit estimation. *IMA Journal of Management Mathematics*, 16(3):265–279, 2005.

[60] A. Fletcher and D. Worthington. What is a 'generic' hospital model?—a comparison of 'generic' and 'specific' hospital models of emergency patient flows. *Health Care Management Science*, 12(4):374, 2009.

[61] P. Fonseca. Using specification and description language to define and implement discrete event simulation models. *Proceedings of the 2010 Summer Computer Simulation Conference*, pages 419–426, 2010.

[62] P. Fonseca. *Formal Languages for Computer Simulation: Transdisciplinary Models and Applications*. IGI Global, 2013.

[63] P. Fonseca, J. Casanovas, and J. Montero. Flexible discrete events simulation of clinical trial using leansim. *Physical review*, pages 1519–1526, 2004.

[64] I. Fraser, W. Encinosa, and S. Glied. Improving efficiency and value in health care: Introduction. *Health Services Research*, 43(5 Pt 2):1781–1786, 2008.

[65] W. J. Frawley, G. Piatetsky-Shapiro, and C. J. Matheus. Knowledge discovery in databases: an overview. *AI Mag.*, 13(3):57–70, 1992.

[66] L. Freeman. A set of measures of centrality based on betweenness. *Sociometry*, 40(1):35–41, 1977.

[67] L. Freeman. Centrality in social networks: conceptual clarification. *Social Networks*, 1(3):215–239, 1979.

[68] M. Fukushima. Solving inequality constrained optimization problems by differential homotopy continuation methods. *Journal of Mathematical Analysis and Applications*, 133(1):109–121, 1988.

[69] N. Furian, M. O'Sullivan, C. Walker, S. Vössner, and D. Neubacher. A conceptual modeling framework for discrete event simulation using hierarchical control structures. *Simulation Modelling Practice and Theory*, 56:82–96, 2015.

[70] M. R. Garey and D. S. Johnson. *Computers and Intractability: A Guide to the Theory of NP-Completeness*. W. H. Freeman and Co., 1979.

[71] G. Gaut, M. Steyvers, Z. E. Imel, D. C. Atkins, and P. Smyth. Content coding of psychotherapy transcripts using labeled topic models. *IEEE Journal of Biomedical and Health Informatics*, 21(2):476–487, 2017.

[72] Z. F. Gellad, C. P. Thompson, and J. Taheri. Endoscopy unit efficiency: Quality redefined. *Clinical Gastroenterology and Hepatology*, 11(9):1046–1049.e1, 2013.

[73] M. Gendreau. *An Introduction to Tabu Search*. International Series in Operations Research and Management Science. Kluwer Academic Publishers, 2003.

[74] M. Gendreau and J.-Y. Potvin. *Handbook of metaheuristics*. International series in operations research and management science: 146. New York : Springer, c2010. 2nd ed., 2010.

[75] A. Ghaheri, S. Shoar, M. Naderan, and S. S. Hoseini. The applications of genetic algorithms in medicine. *Oman Medical Journal*, 30(6):406–416, 2015.

[76] F. Glover. Future paths for integer programming and links to artificial intelligence. *Comput. Oper. Res.*, 13(5):533–549, 1986.

[77] F. Glover, M. Laguna, and R. Martí. *Scatter search*, pages 519–537. Springer-Verlag New York, Inc., 2003.

[78] F. Glover, M. Laguna, and R. Marti. *Approximation Algorithms and Metaheuristics*. 2017.

[79] D. E. Goldberg. *Genetic Algorithms in Search, Optimization and Machine Learning*. Addison-Wesley Longman Publishing Co., Inc., 1989.

[80] M. Goodson. Data science and statistics: different worlds? In *Debate hosted at the Royal Statistical Society*.

[81] I. Gould. *IFIP Guide to Concepts and Terms in Data Processing*. North-Holland, 1971.

[82] D. Gu, J. Li, X. Li, and C. Liang. Visualizing the knowledge structure and evolution of big data research in healthcare informatics. *International Journal of Medical Informatics*, 98:22–32, 2017.

[83] Y. Gu, Y. Chen, J. Liu, and X. Jiang. Semi-supervised deep extreme learning machine for wi-fi based localization. *Neurocomputing*, 166:282–293, 2015.

[84] L. Guo, B. Jin, R. Yu, C. Yao, C. Sun, and D. Huang. Multi-label classification methods for green computing and application for mobile medical recommendations. *IEEE Access*, 4:3201–3209, 2016.

[85] A. K. Gupta and N. Sardana. Naive bayes approach for predicting missing links in ego networks. In *2016 IEEE International Symposium on Nanoelectronic and Information Systems (iNIS)*, pages 161–165.

[86] F. A. Harandi and V. Derhami. A reinforcement learning algorithm for adjusting antecedent parameters and weights of fuzzy rules in a fuzzy classifier. *Journal of Intelligent and Fuzzy Systems*, 30(4):2339–2347, 2016.

[87] J. He, H. Gu, and Z. Wang. Multi-instance multi-label learning based on gaussian process with application to visual mobile robot navigation. *Information Sciences*, 190:162–177, 2012.

[88] Healthcare at Home. Addressing the hospital capacity problem: The Recovery at Home Solution. (2013). Available at www.hah.co.uk/wp-content/themes/HealthCareatHome/img/pdfs/Recovery_at_home_report_2905.pdf. Technical report.

[89] Healthcare at Home. Building the case for clinical care in the home at scale. Final report of the expert panel. (2015). Available at https://hah.co.uk/wp-content/uploads/Virtual-Hospital-Report_AW_Final2.pdf.

[90] Healthcare at Home. Virtual wards: bringing the hospital home. (2015). https://www.hah.co.uk/wp-content/uploads/Virtual-Hospital-Report_AW_Final2.pdf. Technical report.

[91] D. Heath and D. Ventura. Improving multilabel classification by avoiding implicit negativity with incomplete data. *Computational Intelligence*, 30(3):535–561, 2014.

[92] D. Heider, R. Senge, W. Cheng, and E. Hüllermeier. Multilabel classification for exploiting cross-resistance information in hiv-1 drug resistance prediction. *Bioinformatics*, 29(16):1946–1952, 2013.

[93] G. E. Hinton, S. Osindero, and Y.-W. Teh. A fast learning algorithm for deep belief nets. *Neural Computation*, 18(7):1527–1554, 2006.

[94] J. Holland. *Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control, and artificial intelligence.* University of Michigan Press, 1975.

[95] W. L. Hosch. Machine learning, August 11, 2009 2009.

[96] M. Huberman. Predicting conceptual effects in research utilization: Looking with both eyes. *Knowledge in Society*, 2(3):6–24, 1989.

[97] M. Huberman. Linkage between researchers and practitioners: A qualitative study. *American Educational Research Journal*, 27(2):363–391, 1990.

[98] M. Huberman. Research utilization: The state of the art. *Knowledge and Policy*, 7(4):13–33, 1994.

[99] International Business Machines Corporation (IBM). What is Big Data Analytics?. (2017). Available at https://www-01.ibm.com/software/data/infosphere/hadoop/what-is-big-data-analytics.html.

[100] M. Jacomy, T. Venturini, S. Heymann, and M. Bastian. Forceatlas2, a continuous graph layout algorithm for handy network visualization designed for the gephi software. *PLOS ONE*, 9(6):e98679, 2014.

[101] JAG Joint Advisory Group on GI Endoscopy. BSG Quality and Safety Indicators for Endoscopy. (2006). Available at https://goo.gl/REtYLw.

[102] K. Jeong and D. T. Phillips. Operational efficiency and effectiveness measurement. *International Journal of Operations and Production Management*, 21(11):1404–1416, 2001.

[103] M. I. Jordan and T. M. Mitchell. Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245):255–60, 2015.

[104] N. Jothi, N. A. Rashid, and W. Husain. Data mining in healthcare – a review. *Procedia Computer Science*, 72:306–313, 2015.

[105] A. A. Juan, J. Faulin, S. E. Grasman, M. Rabe, and G. Figueira. A review of simheuristics: Extending metaheuristics to deal with stochastic combinatorial optimization problems. *Operations Research Perspectives*, 2:62–72, 2015.

[106] K. Karalas, G. Tsagkatakis, M. Zervakis, and P. Tsakalides. Land classification using remotely sensed data: Going multilabel. *IEEE Transactions on Geoscience and Remote Sensing*, 54(6):3548–3563, 2016.

[107] J. Karnon, J. Stahl, A. Brennan, J. J. Caro, J. Mar, and J. Möller. Modeling using discrete event simulation: A report of the ispor-smdm modeling good research practices task force-4. *Value in Health*, 15(6):821–827, 2012.

[108] N. K. Kaushal, K. Chang, J. G. Lee, and V. R. Muthusamy. Using efficiency analysis and targeted intervention to improve operational performance and achieve cost savings in the endoscopy center. *Gastrointestinal Endoscopy*, 79(4):637–645, 2014.

[109] K.-J. Kim and S.-B. Cho. Meta-classifiers for high-dimensional, small sample classification for gene expression analysis. *Pattern Analysis and Applications*, 18(3):553–569, 2015.

[110] S. Kirkpatrick, J. Gelatt, C. D., and M. P. Vecchi. Optimization by simulated annealing. *Science*, 220(4598):671–80, 1983.

[111] D. König. *Theory of Finite and Infinite Graphs*, pages 45–421. Birkhäuser Boston, Boston, MA, 1936.

[112] D. Knoke and J. Kuklinski. *Network Analysis*. SAGE Publications, 1982.

[113] A. Kolesov, D. Kamyshenko, M. Litovchenko, E. Smekalova, A. Golovizin, and A. Zhavoronkov. On multilabel classification methods of incompletely labeled biomedical text data. *Computational and Mathematical Methods in Medicine*, 2014:1–11, 2014.

[114] P. Kora and P. Yadlapalli. Crossover operators in genetic algorithms: A review. *International Journal of Computer Applications; New York*, 162(10):34–36, 2017.

[115] Y. Koren. Drawing graphs by eigenvectors: theory and practice. *Computers and Mathematics with Applications*, 49(11-12):1867–1888, 2005.

[116] D. Koschützki, K. A. Lehmann, L. Peeters, S. Richter, D. Tenfelde-Podehl, and O. Zlotowski. *Centrality Indices*, pages 16–61. Springer Berlin Heidelberg, 2006.

[117] P. Kostkova, H. Brewer, S. de Lusignan, E. Fottrell, B. Goldacre, G. Hart, P. Koczan, P. Knight, C. Marsolier, R. A. McKendry, E. Ross, A. Sasse, R. Sullivan, S. Chaytor, O. Stevenson, R. Velho, and J. Tooke. Who owns the data? open data for healthcare. *Frontiers in Public Health*, 4:7, 2016.

[118] S. Kotsiantis. Supervised machine learning: A review of classification techniques. *Informatica*, 31:249–268, 2007.

[119] K. Krabbenhoft and L. Damkilde. A general non-linear optimization algorithm for lower bound limit analysis. *International Journal for Numerical Methods in Engineering*, 56(2):165–184, 2003.

[120] H. M. Krumholz and J. Waldstreicher. The yale open data access (yoda) project — a mechanism for data sharing. *New England Journal of Medicine*, 375(5):403–405, 2016.

[121] A. J. Kulkarni, M. F. Baki, and B. A. Chaouch. Application of the cohort-intelligence optimization method to three selected combinatorial optimization problems. *European Journal of Operational Research*, 250(2):427–447, 2016.

[122] S. Kurtz, K. Ong, E. Lau, F. Mowat, and M. Halpern. Projections of primary and revision hip and knee arthroplasty in the united states from 2005 to 2030. *J Bone Joint Surg Am*, 89(4):780–5, 2007.

[123] G. Laporte. The traveling salesman problem: An overview of exact and approximate algorithms. *European Journal of Operational Research*, 59(2):231–247, 1992.

[124] M. Latapy. Main-memory triangle computations for very large (sparse (power-law)) graphs. *Theoretical Computer Science*, 407(1):458–473, 2008.

[125] E. L. Lawler and D. E. Wood. Branch-and-bound methods: A survey. *Operations Research*, 14(4):699–719, 1966.

[126] C. Li and D.-H. Li. An extension of the fletcher–reeves method to linear equality constrained optimization problem. *Applied Mathematics and Computation*, 219(23):10909–10914, 2013.

[127] M. Liberatore and W. Luo. Informs and the analytics movement: The view of the membership. *Interfaces*, 41(6):578–589, 2011.

[128] G. J. Lim, A. Mobasher, J. F. Bard, and A. Najjarbashi. Nurse scheduling with lunch break assignments in operating suites. *Operations Research for Health Care*, 10:35–48, 2016.

[129] G.-H. Lin, D. Zhang, and Y.-C. Liang. Stochastic multiobjective problems with complementarity constraints and applications in healthcare management. *European Journal of Operational Research*, 226(3):461–470, 2013.

[130] Z. Liu, Y. Cui, and W. Li. A classification method for complex power quality disturbances using eemd and rank wavelet svm. *IEEE Transactions on Smart Grid*, 6(4):1678–1685, 2015.

[131] J. C. Long, F. C. Cunningham, and J. Braithwaite. Bridges, brokers and boundary spanners in collaborative networks: a systematic review. *BMC Health Services Research*, 13(1):158, 2013.

[132] D. S. Mankowska, F. Meisel, and C. Bierwirth. The home health care routing and scheduling problem with interdependent services. *Health Care Management Science*, 17(1):15–30, 2014.

[133] E. Marcon, S. Chaabane, Y. Sallez, T. Bonte, and D. Trentesaux. A multi-agent system based on reactive decision rules for solving the caregiver routing problem in home health care. *Simulation Modelling Practice and Theory*, 74:134–151, 2017.

[134] A. Marin and B. Wellman. *Social Network Analysis: An Introduction*. SAGE Publications, 2011.

[135] M. Marshall, C. Pagel, C. French, M. Utley, D. Allwood, N. Fulop, C. Pope, V. Banks, and A. Goldmann. Moving improvement research closer to practice: the researcher-in-residence model. *BMJ Quality and Safety*, 23(10):801–805, 2014.

[136] M. Maruthappu, H. S. Sood, and B. Keogh. The nhs five year forward view: implications for clinicians. *BMJ: British Medical Journal*, 349, 2014.

[137] Massachusetts Institute of Technology. MIT Critical Data. (2017). Available at http://criticaldata.mit.edu/about/.

[138] C. Mateus, I. Marques, and M. E. Captivo. Local search heuristics for a surgical case assignment problem. *Operations Research for Health Care*.

[139] B. Mathieu, H. Sebastien, and J. Mathieu. Gephi: An open source software for exploring and manipulating networks. *International AAAI Conference on Web and Social Media; Third International AAAI Conference on Weblogs and Social Media*, 2009.

[140] Z. Min-Ling and Z. Zhi-Hua. Multilabel neural networks with applications to functional genomics and text categorization. *IEEE Transactions on Knowledge and Data Engineering*, 18(10):1338–1351, 2006.

[141] T. M. Mitchell. *Machine Learning*. McGraw-Hill series in computer science. New York : McGraw-Hill, c1997., 1997.

[142] C. Mitton, C. E. Adair, E. McKenzie, S. B. Patten, and B. W. Perry. Knowledge transfer and exchange: Review and synthesis of the literature. *The Milbank Quarterly*, 85(4):729–768, 2007.

[143] A. Monleón, C. Puig, O. Vall, M. Ríos, A. Chiandetti, and O. García Algar. Prediction of childhood asthma using conditional probability and discrete event simulation. *International Journal of Statistics in Medical Research*, 2:181–191, 2013.

[144] A. S. M. Mosa, I. Yoo, and L. Sheets. A systematic review of healthcare applications for smartphones. *BMC Medical Informatics and Decision Making*, 12(1):67, 2012.

[145] A. Moskowitz, J. McSparron, D. J. Stone, and L. A. Celi. Preparing a new generation of clinicians for the era of big data. *Harvard medical student review*, 2(1):24–27, 2015. 25688383[pmid] Harv Med Stud Rev.

[146] T. B. Murdoch and A. S. Detsky. The inevitable application of big data to health care. *JAMA*, 309(13):1351–1352, 2013. 10.1001/jama.2013.393.

[147] S. Nakajima. *TPM Development Program: Implementing Total Productive Maintenance*. Productivity Press, 1989.

[148] National Clinical Homecare Association. Clinical Homecare Explained: Overview. (2017). Available at http://www.clinicalhomecare.co.uk/about-the-ncha/overview.

[149] National Institute for Health Research (NIHR). Collaborations for Leadership in Applied Health Research and Care (CLAHRCs). (2017). Available at https://www.nihr.ac.uk/about-us/how-we-are-managed/our-structure/infrastructure/collaborations-for-leadership-in-applied-health-research-and-care.htm.

[150] P. Naur. *Concise Survey of Computer Methods*. Petrocelli Books, 1974.

[151] NHS Digital. Supporting Open Data and Transparency. (2017). Available at http://content.digital.nhs.uk/transparency.

[152] NHS England. Academic Health Science Networks. (2017). Available at https://www.england.nhs.uk/ourwork/part-rel/ahsn/.

[153] NHS England. Next Steps on the NHS Five Year Forward View. (2017). Available at https://www.england.nhs.uk/five-year-forward-view/next-steps-on-the-nhs-five-year-forward-view/.

[154] NHS England, Public Health England, Health Education England, Monitor, Trust Development Authority and Care Quality Commission. Five Year Forward View. (2014). Available at https://www.england.nhs.uk/wp-content/uploads/2014/10/5yfv-web.pdf.

[155] NHS Wessex Strategic Clinical Networks. A Strategic Vision for Cancer. (2015). Available at http://www.wessexscn.nhs.uk/files/1614/2719/9910/Strategic_Vision_for_Cancer.pdf. Technical report.

[156] S. Nickel, M. Reuter-Oppermann, and F. Saldanha-da Gama. Ambulance location under stochastic demand: A sampling approach. *Operations Research for Health Care*, 8:24–32, 2016.

[157] S. Nickel, M. Schröder, and J. Steeg. Mid-term and short-term planning support for home health care services. *European Journal of Operational Research*, 219(3):574–587, 2012.

[158] R. Oechsner, M. Pfeffer, L. Pfitzner, H. Binder, E. Müller, and T. Vonderstrass. From overall equipment efficiency (oee) to overall fab effectiveness (ofe). *Materials Science in Semiconductor Processing*, 5(4):333–339, 2002.

[159] I. H. Osman and J. P. Kelly. *Meta-Heuristics: An Overview*, pages 1–21. Springer US, Boston, MA, 1996.

[160] E. Otte and R. Rousseau. Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science*, 28(6):441–453, 2002.

[161] S. Palmer and D. J. Torgerson. Definitions of efficiency. *BMJ*, 318(7191):1136, 1999.

[162] C. Papadimitriou and K. Steiglitz. *Combinatorial Optimization: Algorithm and Complexity*. Prentice Hall, 1982.

[163] Parliament of the United Kingdom. Health and Social Care Act 2012, c.7.. (2017). Available at http://www.legislation.gov.uk/ukpga/2012/7/contents/enacted.

[164] A. Patel, G. Pavlou, R. E. Mujica-Mota, and A. D. Toms. The epidemiology of revision total knee and hip arthroplasty in england and wales: a comparative analysis with projections for the united states. a study using the national joint registry dataset. *Bone Joint J*, 97-b(8):1076–81, 2015.

[165] K. K. Patel, S. Cummings, J. Sellin, L. Scott, and H. B. El-Serag. Applying lean design principles to a gastrointestinal endoscopy program for uninsured patients improves health care utilization. *Clinical Gastroenterology and Hepatology*, 13(9):1556–1559.e4, 2015.

[166] J. L. Pitarch, C. G. Palacín, C. De Prada, B. Voglauer, and G. Seyfriedsberger. Optimisation of the resource efficiency in an industrial evaporation system. *Journal of Process Control*, 56:1–12, 2017.

[167] M. Pitt, T. Monks, S. Crowe, and C. Vasilakis. Systems modelling and simulation in health service design, delivery and decision making. *BMJ Quality and Safety*, 25(1):38–45, 2016.

[168] M. Porter and E. Teisberg. *Redefining Health Care: Creating Value-based Competition on Results*. Harvard Business School Press, 2006.

[169] M. E. Porter. What is value in health care? *New England Journal of Medicine*, 363(26):2477–2481, 2010.

[170] C. Prell. *Social Network Analysis: History, Theory and Methodology.* Sage Publications Ltd., 2011.

[171] G. Qu, H. Wu, C. T. Hartrick, and J. Niu. Local analgesia adverse effects prediction using multi-label classification. *Neurocomputing*, 92:18–27, 2012.

[172] G. Rabadi. *Heuristics, Metaheuristics and Approximate Methods in Planning and Scheduling.* Springer International Publishing, 2016.

[173] S. Rahman, T. Laosirihongthong, and A. S. Sohal. Impact of lean strategy on operational performance: a study of thai manufacturing companies. *Journal of Manufacturing Technology Management*, 21(7):839–852, 2010.

[174] I. Raymond L. Smith and S. D. Roberts. Sensitivity analysis for a whole hospital system dynamics model, 2014.

[175] G. Reinelt. Tsplib: A traveling salesman problem library. *ORSA Journal on Computing*, 3(4):376–384, 1991.

[176] A. Rios, R. Vanderpool, P. Shaw, and R. Kavuluru. A multi-label classification approach for coding cancer information service chat transcripts. In *FLAIRS Conference.*

[177] S. Robinson. *Simulation: The Practice of Model Development and Use.* Wiley, Chichester, 2004.

[178] S. Robinson and C. Brugha. Or58 - second uk or society debate on operational research: The future of or is analytics? In *OR58 Annual Conference.*

[179] J. M. Rodríguez, D. Serrano, T. Monleón, and J. Caro. Discrete-event simulation models in the economic evaluation of health technologies and health products. *Gaceta Sanitaria*, 22(2):151–161, 2008.

[180] S. Russell and P. Norvig. *Artificial Intelligence: A Modern Approach.* Prentice Hall Press, 2009.

[181] B. Rustem. Equality and inequality constrained optimization algorithms with convergent stepsizes. *Journal of Optimization Theory and Applications*, 76(3):429–453, 1993.

[182] G. Sabidussi. The centrality index of a graph. *Psychometrika*, 31(4):581–603, 1966.

[183] R. Sachdeva, T. Williams, and J. Quigley. Mixing methodologies to enhance the implementation of healthcare operational research. *Journal of the Operational Research Society*, 58(2):159–167, 2007.

[184] D. M. Salama and N. M. El-Gohary. Semantic text classification for supporting automated compliance checking in construction. *Journal of Computing in Civil Engineering*, 30(1):1–14, 2016.

[185] J. S. Saleema, B. Sairam, S. D. Naveen, K. Yuvaraj, and L. M. Patnaik. Prominent label identification and multi-label classification for cancer prognosis prediction. In *TENCON 2012 IEEE Region 10 Conference*, pages 1–6.

[186] A. L. Samuel. Some studies in machine learning using the game of checkers. *IBM Journal of Research and Development*, 3(3):210–229, 1959.

[187] A. Sapountzi and K. E. Psannis. Social networking data analysis tools and challenges. *Future Generation Computer Systems*, 2016.

[188] SAS Institute Inc. Machine Learning: What it is and why it matters. (2017). Available at https://www.sas.com/en_gb/insights/analytics/machine-learning.html.

[189] A. Schulz, E. Loza Mencía, and B. Schmidt. A rapid-prototyping framework for extracting small-scale incident-related information in microblogs: Application of multi-label classification on tweets. *Information Systems*, 57:88–110, 2016.

[190] H. Schwartz. *Multi-Agent Machine Learning: A Reinforcement Approach*. Wiley, 2014.

[191] J. Scott. *What is Social Network Analysis?* Bloomsbury Publishing, 2012.

[192] J. Scott. *Social Network Analysis*. SAGE Publications, 2017.

[193] A. Sáez, J. Sánchez-Monedero, P. A. Gutiérrez, and C. Hervás-Martínez. Machine learning methods for binary and multiclass classification of melanoma thickness from dermoscopic images. *IEEE Transactions on Medical Imaging*, 35(4):1036–1045, 2016.

[194] S. Shalev-Shwartz and S. Ben-David. *Understanding Machine Learning: From Theory to Algorithms*. Cambridge University Press, 2014.

[195] A. Sharma, R. Kumar, B. K. Panigrahi, and S. Das. Termite spatial correlation based particle swarm optimization for unconstrained optimization. *Swarm and Evolutionary Computation*, 33:93–107, 2017.

[196] C. Shaw. How can hospital performance be measured and monitored? Report, WHO Regional Office for Europe, 2003.

[197] C. Si, J. An, T. Lan, T. Ußmüller, L. Wang, and Q. Wu. On the equality constraints tolerance of constrained optimization problems. *Theoretical Computer Science*, 551:55–65, 2014.

[198] D. Singh and S. Agrawal. Self organizing migrating algorithm with quadratic interpolation for solving large scale global optimization problems. *Applied Soft Computing*, 38:1040–1048, 2016.

[199] P. Smith. *Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects*. Cambridge University Press, 2009.

[200] B. G. Sobolev, V. Sanchez, and C. Vasilakis. Systematic review of the use of computer simulation modeling of patient flow in surgical care. *Journal of Medical Systems*, 35(1):1–16, 2011.

[201] K. Sörensen, M. Sevaux, and F. Glover. A history of metaheuristics. In *OR2016: annual international conference of the german operations research society*.

[202] W. Steeb. *The Nonlinear Workbook: Chaos, Fractals, Cellular Automata, Neural Networks, Genetic Algorithms, Gene Expression Programming, Support Vector Machine, Wavelets, Hidden Markov Models, Fuzzy Logic with C++, Java and SymbolicC++ Programs*. World Scientific, 2011.

[203] D. B. Taichman, P. Sahni, A. Pinborg, L. Peiperl, C. Laine, A. James, S.-T. Hong, A. Haileamlak, L. Gollogly, F. Godlee, F. A. Frizelle, F. Florenzano, J. M. Drazen, H. Bauchner, C. Baethge, and J. Backus. Data sharing statements for clinical trials. *BMJ*, 357, 2017.

[204] E.-G. Talbi. *Metaheuristics: from design to implementation*. Hoboken, N.J. : John Wiley and Sons, c2009., 2009.

[205] G. Tang, J. Pei, and W.-S. Luk. Email mining: tasks, common techniques, and tools. *Knowledge and Information Systems*, 41(1):1–31, 2014.

[206] N. Taylor, R. Clay-Williams, E. Hogden, J. Braithwaite, and O. Groene. High performing hospitals: a qualitative systematic review of associated factors and practical strategies for improvement. *BMC Health Services Research*, 15(1):244, 2015.

[207] The Institute for Operations Research and the Management Sciences. Operations Research and Analytics. (2017). Available at https://www.informs.org/Explore/Operations-Research-Analytics.

[208] The OR Sociecty. What is OR?. (2017). Available at http://www.learnaboutor.co.uk/.

[209] I. H. Ting, T.-P. Hong, and L. S.-L. Wang. *Social network mining, analysis, and research trends : techniques and applications*. Hershey, PA : Information Science Reference, c2012., 2012.

[210] C. Tison, J. M. Nicolas, F. Tupin, and H. Maitre. A new statistical model for markovian classification of urban areas in high-resolution sar images. *IEEE Transactions on Geoscience and Remote Sensing*, 42(10):2046–2057, 2004.

[211] C.-W. Tsai, M.-C. Chiang, A. Ksentini, and M. Chen. Metaheuristic algorithms for healthcare: Open issues and challenges. *Computers and Electrical Engineering*, 53:421–434, 2016.

[212] G. Tsoumakas and I. Katakis. Multi-label classification: An overview. *Int J Data Warehousing and Mining*, 2007:1–13, 2007.

[213] J. W. Tukey. The future of data analysis. *The Annals of Mathematical Statistics*, 33(1):1–67, 1962.

[214] A. M. Turing. Computing machinery and intelligence. *Mind*, 49:433–460, 1950.

[215] T. W. Valente, K. Coronges, C. Lakon, and E. Costenbader. How correlated are network centrality measures? *Connections (Toronto, Ont.)*, 28(1):16–26, 2008. 20505784[pmid] Connect (Tor).

[216] C. L. Ventola. Mobile devices and apps for health care professionals: Uses and benefits. *Pharmacy and Therapeutics*, 39(5):356–364, 2014. ptj3905356[PII] 24883008[pmid] P T.

[217] J. Viana, S. C. Brailsford, V. Harindra, and P. R. Harper. Combining discrete-event simulation and system dynamics in a healthcare setting: A composite model for chlamydia infection. *European Journal of Operational Research*, 237(1):196–206, 2014.

[218] V. Ward, A. House, and S. Hamer. Developing a framework for transferring knowledge into action: a thematic analysis of the literature. *Journal of health services research and policy*, 14(3):156–164, 2009.

[219] S. Wasserman and K. Faust. *Social Network Analysis: Methods and Applications*. Cambridge University Press, 1994.

[220] D. J. Watts and S. H. Strogatz. Collective dynamics of /'small-world/' networks. *Nature*, 393(6684):440–442, 1998. 10.1038/30918.

[221] G. M. Weber, K. D. Mandl, and I. S. Kohane. Finding the missing link for big biomedical data. *JAMA*, 311(24):2479–2480, 2014. 10.1001/jama.2014.4228.

[222] G. Wegryn, J. Camm, D. Dittmann, D. Kleinmuntz, J. Levis, T. May, A. Robinson, and R. Rose. Panel discussion on or vs analytics: Experts weigh in on the case for change. In *2015 INFORMS Annual Meeting*.

[223] J. Wiens and B. C. Wallace. Editorial: special issue on machine learning for health and medicine. *Machine Learning*, 102(3):305–307, 2016.

[224] D. P. Williamson and D. B. Shmoys. *The Design of Approximation Algorithms*. Cambridge University Press, 2011.

[225] B. Wittenmark. *Self-Tuning Regulators*. John Wiley and Sons, Inc., 2001.

[226] J. Wu, H. Li, S. Cheng, and Z. Lin. The promising future of healthcare services: When big data analytics meets wearable technology. *Information and Management*, 53(8):1020–1033, 2016.

[227] J. Wu, H. Li, L. Liu, and H. Zheng. Adoption of big data and analytics in mobile healthcare market: An economic perspective. *Electronic Commerce Research and Applications*, 22:24–41, 2017.

[228] X. Xie, L. Yang, and W.-S. Zheng. Learning object-specific dags for multi-label material recognition. *Computer Vision and Image Understanding*, 143:183–190, 2016.

[229] Y. Xu, L. Jiao, S. Wang, J. Wei, Y. Fan, M. Lai, and E. I. Chang. Multi-label classification for colon cancer using histopathological images. *Microsc Res Tech*, 76(12):1266–77, 2013.

[230] H. Yang and E. Lee. *Healthcare Analytics: From Data to Knowledge to Healthcare Improvement*. Wiley, 2016.

[231] B. Yu. Let us own data science. *IMS bulletin (online)*, 01/10/2014 2014.

[232] M. Zaghian, W. Cao, W. Liu, L. Kardar, S. Randeniya, R. Mohan, and G. Lim. Comparison of linear and nonlinear programming approaches for "worst case dose" and "minmax" robust optimization of intensity-modulated proton therapy dose distributions. *Journal of Applied Clinical Medical Physics*, 18(2):15–25, 2017.

[233] M. L. Zhang and Z. H. Zhou. A review on multi-label learning algorithms. *IEEE Transactions on Knowledge and Data Engineering*, 26(8):1819–1837, 2014.

[234] N. Zhang and S. Ding. Unsupervised and semi-supervised extreme learning machine with wavelet kernel for high dimensional data. *Memetic Computing*, pages 1–11, 2016.

[235] L. Zhou, S. Pan, J. Wang, and A. V. Vasilakos. Machine learning on big data: Opportunities and challenges. *Neurocomputing*, 2017.