Bibliography

Alleyne, A. and Hedrick, J. K.: 1995, Nonlinear adaptive control of active suspensions, *IEEE Transactions on Control Systems Technology* **Vol. 3/1**, pp. 94–101.

Andersson, D. and Eriksson, P.: 2004, Handling and ride comfort optimisation of an inter-city bus, *Vehicle System Dynamics Supplement* **Vol. 41**, pp. 547–556.

Bakker, E., Pacejka, H. B. and Linder, L.: 1989, A new tire model with an application in vehicle dynamics studies, *Society of Automotive Engineers, Technical Paper Series* **Paper no. SAE 890087**.

Balabanov, V. O. and Venter, G.: 2004, Multi-fidelity optimisation of high-fidelity analysis and low-fidelity gradients, 10^{th} *AIAA/ISSMO Symposium on multidisciplinary analysis and optimisation. Albany, NY. 30 August - 1 September* .

Bandler, J. W., Cheng, Q. S., Dakroury, S. A., Mohamed, A. S., Bakr, M. H., Madsen, K. and Søndergaard, J.: 2004, Space mapping: The state of the art, *IEEE Transactions on Microwave Theory and Techniques* **Vol. 52-1**, pp. 337–361.

Bartholomew-Biggs, M., Brown, S., Christianson, B. and Dixon, L.: 2000, Automatic differentiation of algorithms, *Journal of Computational and Applied Mathematics* **Vol. 124**, pp. 171–190.

Baumal, A. E., McPhee, J. and Calamai, P. H.: 1998, Application of genetic algorithms to the optimisation of an active vehicle suspension design,

Computer Methods in Applied Mechanics and Engineering **Vol. 163**, pp. 87–94.

Bischof, C. H., Bücker, H. M., Lang, B., Rasch, A. and Slusanschi, E.: 2005, Efficient and accurate derivatives for a software process chain in airfoil shape optimisation, *Future Generation Computer Systems* **Vol. 21**, pp. 1333–1344.

Boggs, P. T. and Tolle, J. W.: 2000, Sequential quadratic programming for large-scale non-linear optimisation, *Journal of Computational and Applied Mathematics* **Vol. 124**, pp. 123–137.

BS6841: 1987, *Guide to Measurement and Evaluation of Human Exposure to Whole-Body Mechanical Vibration and Repeated Shock*, British Standards Institution.

Dahlberg, T.: 1977, Parametric optimisation of a 1-dof vehicle travelling on a randomly profiled road, *Journal of Sound and Vibration* **Vol. 55-2**, pp. 245–253.

Dahlberg, T.: 1979, An optimised speed controlled suspension of a 2-dof vehicle travelling on a randomly profiled road, *Journal of Sound and Vibration* **Vol. 64-4**, pp. 541–546.

Danchick, R.: 2006, Accurate numerical partials with applications to optimisation, *Applied Mathematics and Computation* **in press, accessed science direct, 18 November 2006**, doi:10.1016/j.amc.2006.05.083.

Eberhard, P., Bestle, D. and Piram, U.: 1995, Optimisation of damping characteristics in non-linear dynamic systems, *First World Congress of Structural and Multidisciplinary Optimisation* pp. 863–870.

Eberhard, P., Schiehlen, W. and Bestle, D.: 1999, Some advantages of stochastic methods in multicriteria optimisation of multibody systems, *Archive of Applied Mechanics* **Vol. 69**, pp. 543–554.

Els, P. S.: 2005, The applicability of ride comfort standards to off-road vehicles, *Journal of Terramechanics* **Vol. 42-1**, pp. 47–64.

Els, P. S.: 2006, *The ride comfort vs. handling compromise for off-road vehicles*, Phd thesis, University of Pretoria, South Africa.

Els, P. S. and Uys, P. E.: 2003, Investigation of the applicability of the Dynamic-Q optimisation algorithm to vehicle suspension design, *Mathematical and Computer Modelling* **Vol. 37**, pp. 1029–1046.

Els, P. S., Uys, P. E., Snyman, J. A. and Thoresson, M. J.: 2006, Gradient-based approximation methods applied to the optimal design of vehicle suspension systems using computational models with severe inherent noise, *Mathematical and Computer Modelling* **Vol. 43-7/8**, pp. 787–801.

Eriksson, P. and Arora, J. S.: 2002, Comparison of global optimisation algorithms applied to a ride comfort optimisation problem, *Structural and Multidisciplinary Optimisation* **Vol. 24**, pp. 157–167.

Eriksson, P. and Friberg, O.: 2000, Ride comfort optimisation of a city bus, *Structural and Multidisciplinary Optimisation* **Vol. 20**, pp. 67–75.

Etman, L. F. P., Vermeulen, R. C. N., van Heck, J. G. A. M., Schoofs, A. J. G. and van Campen, D. H.: 2002, Design of a stroke dependent damper for the front axle suspension of a truck using multibody system dynamics and numerical optimisation, *Vehicle System Dynamics* **Vol. 38-2**, pp. 85–102.

Fiacco, A. V. and McCormick, G. P.: 1968, *Non-linear Programming: Sequential Unconstrained Minimization Techniques*, John Wiley and Sons, Inc, New York.

Genta, G.: 1997, *Motor Vehicle Dynamics, Modelling and Simulation. Series on Advances in Mathematics for Applied Sciences: Volume 43*, World Scientific, New Jersey, USA.

Gerotek: 2006, *Gerotek Testing Facilities, South Africa*, www.gerotek.co.za *accessed 10 April 2006*.

Gobbi, M., Haque, I., Papalambros, P. Y. and Mastinu, G.: 2005, Optimisation and integration of ground vehicle systems, *Vehicle System Dynamics* **43/6-7**, pp. 437–453.

Gobbi, M., Mastinu, G. and Doniselli, C.: 1999, Optimising a car chassis, *Vehicle System Dynamics* **Vol. 32**, pp. 149–170.

Gobbi, M., Mastinu, G., Doniselli, C., Guglielmetto, L. and Pisino, E.: 1999, Optimal and robust design of a road vehicle suspension system, *Vehicle System Dynamics Supplement* **Vol. 33**, pp. 3–22.

Gonsalves, J. P. C. and Ambrósio, J. A. C.: 2005, Road vehicle modelling requirements for optimisation of ride comfort and handling, *Multibody System Dynamics* **13**, pp. 3–23.

Gordon, T. J., Best, M. C. and Dixon, P. J.: 2002, An automated driver based on convergent vector fields, *Proceedings of the Institute of Mechanical Engineers, Part D: Journal of Automotive Engineering* **Vol. 216 Special Issue**, pp. 36–56.

Hock, W. and Schittkowski, K.: 1981, *Test Examples for Nonlinear Programming Codes. Lecture Notes in Economics and Mathematical Systems: Volume 187*, Springer-Verlag, Berlin, Germany.

ISO3888-1: 1999, *Passenger cars - Test track for a severe lane-change manœuvre - Part 1: Double lane-change*, The International Organisation for Standardisation, 06 October 2004.

ISO8608: 1995, *Mechanical Vibration - Road Surface Profiles - Reporting of Measured Data*, The International Organisation for Standardisation, 01 September 1995.

Kim, C. and Ro, P. I.: 1998, A sliding mode controller for vehicle active suspension systems with non-linearities, *Proceedings of International Mechanical Engineers* **Vol. 212 (D)**, pp. 79–92.

Kim, C. and Ro, P. I.: 2001, An accurate model for vehicle handling using reduced-order model techniques, *Society of Automotive Engineering Technical Paper Series* **SAE 2001-01-2520**.

Koziel, S., Bandler, J. W. and Madsen, K.: 2005, Towards a rigorous formulation of the space mapping technique for engineering design, *Circuits and Systems, ISCAS 2005 IEEE International Symposium* **Vol. 23-26 May**, pp. 5605–5608.

Lasdon, L.: 2001, Nonlinear and geometric programming - current status, *Annals of Operations Research* **105**, pp. 99–107.

Mathworks: 2000a, *MATLAB Optimisation Toolbox Users Guide version 2.2*.

Mathworks: 2000b, *MATLAB Release 12 Users guide*.

Miller, L. R.: 1998, Tuning passive, semi-active, and fully active suspension systems, *Proceedings of the 27th Conference on Decision and Control. Austin, Texus. December* .

MSC: 2005, *Getting Started Using MSC.ADAMS View, Version 2005*, MSC-Corporation.

Naudé, A. F.: 2001, *Computer Aided Design Optimisation of Road Vehicle Suspension Systems*, Phd thesis, University of Pretoria, South Africa.

Naudé, A. F. and Snyman, J. A.: 2003a, Optimisation of road vehicle passive suspension systems. Part 1. Optimisation algorithm and vehicle model, *Applied Mathematical Modelling* **Vol. 27**, pp. 249–261.

Naudé, A. F. and Snyman, J. A.: 2003b, Optimisation of road vehicle passive suspension systems. Part 2. Qualification and case study, *Applied Mathematical Modelling* **Vol. 27**, pp. 263–274.

Pacejka, H. B.: 2002, *Tyre and Vehicle Dynamics*, Society of Automotive Engineers, Warrendale, USA.

Papalambros, P. Y.: 2002, The optimisation paradigm in engineering design: promises and challenges, *Computer-Aided Design* **34**, pp. 939–951.

Pilbeam, C. and Sharp, R. S.: 1996, Performance potential and power consumption of slow-active suspension systems with preview, *Vehicle System Dynamics* **Vol. 25**, pp. 169–183.

Proköp, G.: 2001, Modelling human vehicle driving by model predictive online optimisation, *Vehicle System Dynamics* **Vol. 35/1**, pp. 19–53.

Redhe, M. and Nilsson, L.: 2004, Optimisation of the new SAAB 9-3 exposed to impact load using a space mapping technique, *Structural and Multidisciplinary Optimisation* **Vol. 27**, pp. 411–420.

Schuller, J., Haque, I. and Eckel, M.: 2002, An approach for optimisation of vehicle handling behaviour in simulation, *Vehicle System Dynamics Supplement* **Vol. 37**, pp. 24–37.

Sharp, R. S., Casanova, D. and Symonds, P.: 2000, A mathematical model for driver steering control, with design, tuning and performance results, *Vehicle System Dynamics* **Vol. 33**, pp. 289–326.

Snyman, J. A.: 2000, The lfopc leap-frog algorithm for constrained optimisation, *Computers and Mathematics with Applications* **Vol. 40**, pp. 1085–1096.

Snyman, J. A.: 2005a, A gradient-only line search method for the conjugate gradient method applied to constrained optimisation problems with severe noise in the objective function, *International Journal for Numerical Methods in Engineering* **62**, pp. 72–82.

Snyman, J. A.: 2005b, *Practical Mathematical Modelling, An introduction to Basic Optimisation theory and classical and New Gradient-Based Algorithms. Applied Optimisation: Volume 97*, Springer, New York, USA.

Snyman, J. A. and Hay, A. M.: 2002, The Dynamic-Q optimisation method: An alternative to SQP?, *Computers and Mathematics with Applications* **Vol. 44**, pp. 1589–1598.

Theron, N. J. and Els, P. S.: 2005, Modelling of a semi-active hydropneumatic spring-damper unit, *International Journal of Vehicle Design* **accepted for publication**.

Thoresson, M. J.: 2003, *Mathematical optimisation of the suspension system of an off-road vehicle for ride comfort and handling*, Meng thesis, University of Pretoria, South Africa.

Tolsma, J. E. and Barton, P. I.: 1998, On computational differentiation, *Computers in Chemical Engineering* **Vol. 22-4/5**, pp. 475–490.

Uys, P. E., Els, P. S. and Thoresson, M. J.: 2006a, Criteria for handling measurement, *Journal of Terramechanics* **Vol. 43-1**, pp. 43–67.

Uys, P. E., Els, P. S. and Thoresson, M. J.: 2006b, Suspension settings for optimal ride comfort of off-road vehicles travelling on roads with different roughness and speeds, *Journal of Terramechanics* pp. In Press, available on ScienceDirect 11 July 2006.

Uys, P. E., Els, P. S., Thoresson, M. J., Voigt, K. G. and Combrink, W. C.: 2005, Experimental determination of moments of inertia for an off-road vehicle in a regular engineering laboratory, *International Journal of Mechanical Engineering Education* **accepted for publication**.

van Keulen, F. and Toropov, V. V.: 2006, Multipoint approximations for structural optimisation problems with noisy response functions, *Bradford University, webpage: http://0-www.bradford.ac.uk.innopac.up.ac.za/staff/vtoropov/fred/int2a.htm* **accesed 13 September 2006**, pp. 1–8.

Vanderplaats, G.: 1992, *DOT - Design Optimisation Tools. Version 3.0*, VMA Engineering, Colorado Springs, USA.

Vanderplaats, G.: 1999, *DOT - Design Optimisation Tools, Users Manual. Version 5.0*, Vanderplaats Research and Development, Colorado Springs, USA.

Willcox, K.: 2006, Design and optimisation of complex systems, *High Performance Computation for Engineered Systems, Massachusetts institute of technology, webpage: https://0-dspace.mit.edu.innopac.up.ac.za:443/retrieve/4002/HPCES005.pdf* **accesed 18 November 2006**, pp. 1–7.

Appendix A

Auto-Scaling Test Problems

The test problems described here are from the book of Hock and Schittkowski 1981, and used in Chapter 8 to test the automatic scaling theory, before being applied to the vehicle suspension optimisation problem.

A.1 Hock 2

Objective function:

$$f(\mathbf{x}) = 100(x_2 - {x_1}^2)^2 + (1 - x_1)^2 \tag{A.1}$$

Constraints:

$$\begin{aligned} -2 \leq x_1 \leq 2 \\ 1.5 \leq x_2 \leq 3 \end{aligned} \tag{A.2}$$

Starting point:

$$\begin{aligned} \mathbf{x}_0 &= [-2\ 1] \\ f(\mathbf{x}_0) &= 909 \end{aligned} \tag{A.3}$$

Optimum:

$$\begin{aligned} \mathbf{x}^* &= [1.22\ 1.5] \\ f(\mathbf{x}^*) &= 0.05042\ 61879 \end{aligned} \tag{A.4}$$

A.2 Hock 13

Objective function:

$$f(\mathbf{x}) = (x_1 - 2)^2 + {x_2}^2 \tag{A.5}$$

Constraints:

$$\begin{gathered} g(\mathbf{x}) = x_2 + (1 - x_1)^3 \leq 0 \\ -2 \leq x_1 \leq 2 \\ -2 \leq x_2 \leq 2 \end{gathered} \tag{A.6}$$

Starting point:

$$\begin{gathered} \mathbf{x}_0 = [-2 \ \ -2] \\ f(\mathbf{x}_0) = 20 \end{gathered} \tag{A.7}$$

Optimum:

$$\begin{gathered} \mathbf{x}^* = [1 \ 0] \\ f(\mathbf{x}^*) = 1 \end{gathered} \tag{A.8}$$

A.3 Hock 15

Objective function:

$$f(\mathbf{x}) = 100(x_2 - {x_1}^2)^2 + (1 - x_1)^2 \tag{A.9}$$

Constraints:

$$\begin{gathered} g(\mathbf{x}) = 1 - x_1 x_2 \leq 0 \\ g(\mathbf{x}) = -x_1 - {x_2}^2 \leq 0 \\ -2 \leq x_1 \leq 0.5 \\ 1 \leq x_2 \leq 2.5 \end{gathered} \tag{A.10}$$

Starting point:

$$\begin{gathered} \mathbf{x}_0 = [-2 \ 1] \\ f(\mathbf{x}_0) = 909 \end{gathered} \tag{A.11}$$

Optimum:

$$\begin{gathered} \mathbf{x}^* = [0.5 \ 2] \\ f(\mathbf{x}^*) = 306.5 \end{gathered} \tag{A.12}$$

A.4 Hock 17

Objective function:

$$f(\mathbf{x}) = 100(x_2 - {x_1}^2)^2 + (1 - x_1)^2 \tag{A.13}$$

Constraints:

$$\begin{aligned} g(\mathbf{x}) &= x_1 - {x_2}^2 \leq 0 \\ g(\mathbf{x}) &= x_2 - {x_1}^2 \leq 0 \\ -0.5 &\leq x_1 \leq 0.5 \\ -1 &\leq x_2 \leq 1 \end{aligned} \tag{A.14}$$

Starting point:

$$\begin{aligned} \mathbf{x}_0 &= [-2\ 1] \\ f(\mathbf{x}_0) &= 909 \end{aligned} \tag{A.15}$$

Optimum:

$$\begin{aligned} \mathbf{x}^* &= [0\ 0] \\ f(\mathbf{x}^*) &= 1 \end{aligned} \tag{A.16}$$

Appendix B

Vehicle Model Files

Table B.1: Vehicle mass and inertia properties

Body	Mass [kg]	I_{xx}	I_{yy}	I_{zz}
body front	682	909	0	0
body rear	894	952	0	0
tyres	31.5	1.2	1.2	2.0
front axle	166	22.3	0.13	22.3
rear axle	166	22.3	0.13	22.3
steer link	3	0.4	0.4	0

- all other links have 0 mass properties.

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