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Interactive system for universal functional optimization

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1 Introduction

The UFO system was developed for solving both dense medium-size and sparse large-scale optimization problems. This system can be used for formulation and solution of particular optimization problems, for preparation of specialized optimization subroutines and for designing and testing new optimization methods.

The UFO system uses a macroprocessor with a special input language for generating the UFO control program. This means that arrays in the control program has (variable) dimensions induced by the problem solved and the problem description can have an arbitrary structure.

2 The system UFO

The UFO system can be used for solving various dense or sparse optimization problems:

- Unconstrained or box constrained optimization.
- Optimization with general linear constraints.

- Optimization with general nonlinear constraints.
- Optimization with complementarity constraints.
- Nonsmooth optimization.
- Global optimization.
- Solution to systems of nonlinear functional equations.
- Solution to systems of ordinary differential equations.

The objective function can have various forms:

- General objective function.
- Linear or quadratic objective function.
- Sum of squares or powers.
- Minimax criterion and l_1 or l_∞ norm.
- Integral criterion containing solution to ordinary differential equations.

The problem can be dense, sparse and partially separable. The UFO system contains many optimization methods that can be divided into the following classes:

- Heuristic methods for small-size problems.
- Conjugate gradient methods for large-scale problems.
- Variable metric methods that update an approximation of the Hessian matrix in every iteration.
- Modified Newton methods that use second order derivatives obtained either analytically or numerically or by automatic differentiation.
- Truncated Newton methods for large-scale problems based on difference approximations of directional derivatives.
- Combined Gauss-Newton and variable metric methods for nonlinear least squares.

- Quasi-Newton methods for dense nonlinear least squares and nonlinear equations.
- Simplex or interior point methods for linear and quadratic programming.
- Bundle methods for nonsmooth optimization.
- Recursive quadratic programming and interior point or nonsmooth equation methods for nonlinear programming.
- Primal interior point and smoothing methods for sparse generalized minimax problems.
- Various methods for global optimization.

These methods can be realized in various forms depending on the stepsize selection:

- Line search methods.
- General trust region methods.
- Cubic regularization methods.
- SQP filter methods (for nonlinear programming problems).

Various preconditioned iterative methods can be chosen for direction determination.

Moreover, the system UFO contains several features advantageous for the user:

- Automatic differentiation.
- Facilities for checking problem descriptions.
- Collections of problems for testing optimization methods.
- Graphical environment.
- Interface to the CUTE testing collection.
- Creation of the performance profiles.

3 An example

The use of the UFO system is demonstrated by the folloving transformer design [2]. We have to minimize objective function

$$F(x) = \max_{1 \le i \le 11} f_i(x),$$

$$f_i(x) = \left| 1 - 2 \frac{v_1(x, t_i)}{w_1(x, t_i) + v_1(x, t_i)} \right|,$$

where $v_1(x, t_i)$ and $w_1(x, t_i)$ are complex numbers obtained recursively in such a way that $v_4(x, t_i) = 1$, $w_4(x, t_i) = 10$ and

$$v_k(x, t_i) = \cos(\vartheta_i x_{2k-1}) v_{k+1}(x, t_i) + j \sin(\vartheta_i x_{2k-1}) \frac{1}{x_{2k}} w_{k+1}(x, t_i),$$

$$w_k(x, t_i) = \cos(\vartheta_i x_{2k-1}) w_{k+1}(x, t_i) + j \sin(\vartheta_i x_{2k-1}) x_{2k} v_{k+1}(x, t_i)$$

for $k = 3, 2, 1$. Here $j = \sqrt{-1}$ is the imaginary unit and $\vartheta_i = (\pi/2)\, y_i$, $1 \le i \le 11$, where the points y_i, $1 \le i \le 11$, are shown in the UFO input file.

```
$SET(INPUT)
  $ADD(REAL,'\Y(11)')
  X(1)=2.0D0; X(2)=1.5D0; X(3)=-2.0D0
  X(4)=3.0D0; X(5)=0.8D0; X(6)= 6.0D0
  Y(1)=0.5D0; Y(2)=0.6D0; Y(3)=0.7D0; Y(4)=0.77D0
  Y(5)=0.9D0; Y(6)=1.0D0; Y(7)=1.1D0; Y(8)=1.23D0
  Y(9)=1.3D0; Y(10)=1.4D0; Y(11)=1.5D0
$ENDSET
$SET(FMODELA)
  $ADD(REAL,'\TH\CS\SN')
  $ADD(COMPLEX,'\V(4)\W(4)\C1\C2\C3')
  TH=0.5D0*Y(KA)*3.14159265358979324D0
  V(4)=CMPLX(1.0D0,0.0D0); W(4)=1.0D1*V(4)
  DO I=3,1,-1
```

```
  CS=COS(TH*X(2*I-1)); SN=SIN(TH*X(2*I-1))
  C1=CMPLX(CS,0.0D0); C2=CMPLX(0.0D0,(SN*X(2*I)))
  C3=CMPLX(0.0D0,(SN/X(2*I)))
  V(I)=C1*V(I+1)+C3*W(I+1); W(I)=C2*V(I+1)+C1*W(I+1)
  END DO
  FA=ABS(1.0D0-2.0D0*V(1)/(V(1)+W(1)))
$ENDSET
$NF=6; $NA=11; $NAL=0;
$MODEL='AM'
$CLASS='VM'; $MET=7
$GRAPH='E'; $ISO='Y'; $HIL='Y'; $PATH='Y'
$BATCH
$STANDARD
```

The results of the development are illustrated by using the following two pictures obtained by the UFO graphical environment.

The system UFO can also be used for testing and comparing various optimization methods. The next figures show performance profiles [1] for interior point [3] and nonsmooth equation [4] methods in the Newton (MN) and the variable metric (VM) realizations. These performance profiles were obtained using the UFO system.

References

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