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## Tutorial 9

Monday, December 14, 2015

**Problem 1.** (One-dimensional trust region problem) Consider the one-dimensional, real-valued trust region problem.

$$\begin{aligned} & \text{minimize} && ax^2 + 2bx \\ & \text{subject to} && x^2 \leq 1. \end{aligned}$$

- a) Determine all pairs  $(a, b)$  for which the problem is non-convex.

In the following the problem shall be non-convex.

- b) Calculate the dual function  $L_D(\lambda)$
- c) Give the optimal parameter  $\lambda^*$  which maximizes  $L_D$  and the corresponding value  $d^*$ .
- d) Show that the optimal value of the primal problem  $p^*$  equals  $d^*$ .

**Problem 2.** (Dual problem bounds) For the following optimization problems with optimization variable  $\mathbf{x} \in \mathbb{R}^2$ , compute the dual problem and the maximum lower bound  $d^*$  for the optimal value  $p^*$ .

- a)

$$\begin{aligned} & \text{minimize} && 2x_1^2 + 8x_2^2 \\ & \text{subject to} && 3x_1 + 6x_2 = 10 \end{aligned}$$

- b)

$$\begin{aligned} & \text{maximize} && 2x_1x_2 \\ & \text{subject to} && x_1^2 + x_2^2 = 1 \end{aligned}$$

**Remark:** Convert problem (b) into a minimization problem first.