Conic Modeling Cheatsheet

Cones

Quadratic cone $\mathcal{Q}^n$

$$x_1 \geq \sqrt{x_2^2 + \ldots + x_n^2}$$

Rotated quadratic cone $\mathcal{Q}_r^n$

$$2x_1x_2 \geq x_3^2 + \ldots + x_n^2,\ x_1, x_2 \geq 0$$

Power cone $\mathcal{P}_n^{\alpha_1,\ldots,\alpha_m},\ \alpha_i > 0,\ \sum \alpha_i = 1$

$$x_1^{\alpha_1} \cdot \ldots \cdot x_m^{\alpha_m} \geq \sqrt{x_{m+1}^2 + \ldots + x_n^2},\ x_1, \ldots, x_m \geq 0$$

Exponential cone $K_{\exp}$

$$x_1 \geq x_2 e^{x_3/x_2},\ x_2 \geq 0$$

Simple bounds

$t \geq x^2$	$(0.5, t, x) \in \mathcal{Q}_r^3$
$\lvert t\rvert \leq \sqrt{x}$	$(0.5, x, t) \in \mathcal{Q}_r^3$
$t \geq \lvert x\rvert$	$(t, x) \in \mathcal{Q}^2$
$t \geq 1/x,\ x > 0$	$(x, t, \sqrt{2}) \in \mathcal{Q}_r^3$
$t \geq \lvert x\rvert^p,\ p > 1$	$(t, 1, x) \in \mathcal{P}_3^{1/p, 1-1/p}$
$t \geq 1/x^p,\ x > 0,\ p > 0$	$(t, x, 1) \in \mathcal{P}_3^{1/(1+p), p/(1+p)}$
$\lvert t\rvert \leq x^p,\ x > 0,\ p \in (0,1)$	$(x, 1, t) \in \mathcal{P}_3^{p, 1-p}$
$t \geq \lvert x\rvert^p/y^{p-1}, y > 0$	$(t, y, x) \in \mathcal{P}_3^{1/p, 1-1/p},\ p > 1$
$t \geq x^T x/y,\ y > 0$	$(0.5t, y, x) \in \mathcal{Q}_r^{n+2}$
$t \geq e^x$	$(t, 1, x) \in K_{\exp}$
$t \leq \log x$	$(x, 1, t) \in K_{\exp}$
$t \geq 1/\log x,\ x > 1$	$(u, t, \sqrt{2}) \in \mathcal{Q}_r^3$ $(x, 1, u) \in K_{\exp}$
$t \geq a_1^{x_1} \cdots a_n^{x_n},\ a_i > 0$	$(t, 1, \sum x_i \log a_i) \in K_{\exp}$
$t \geq 1/(x_1^{a_1} \cdots x_n^{a_n})$, $x_i > 0, a_i > 0$	$(t, x, 1) \in \mathcal{P}_{n+2}^{\frac{1}{a+1}, \frac{a_1}{a+1}, \ldots, \frac{a_n}{a+1}}$, $a = \sum a_i$
$\lvert t\rvert^b \leq x_1^{a_1} \cdots x_n^{a_n}$, $x_i > 0, a_i > 0, \sum a_i < b$	$(1, x, t) \in \mathcal{P}_{n+2}^{s, \frac{a_1}{b}, \ldots, \frac{a_n}{b}}$, $s = 1 - \sum a_i/b$
$t \geq a + \frac{b}{cx+d}$, $cx + d > 0, b > 0$	$(t - a, cx + d, \sqrt{2b}) \in \mathcal{Q}_r^3$
$t \geq xe^x,\ x \geq 0$	$(t, x, u) \in K_{\exp}$ $(0.5, u, x) \in \mathcal{Q}_r^3$
$t \geq \log(1 + e^x)$	$u + v \leq 1$ $(u, 1, x - t) \in K_{\exp}$ $(v, 1, -t) \in K_{\exp}$

Means and averaging

Log-sum-exp $t \geq \log(\sum e^{x_i})$	$(z_i, 1, x_i - t) \in K_{\exp}$ $\sum z_i \leq 1$
Log-sum-inv $t \geq \log(\sum 1/x_i),\ x_i > 0$	$(z_i, 1, y_i - t) \in K_{\exp}$ $(x_i, 1, -y_i) \in K_{\exp}$ $\sum z_i \leq 1$
Harmonic mean $0 \leq t \leq n(\sum 1/x_i)^{-1}$, $x_i > 0$	$(z_i, x_i, t) \in \mathcal{Q}_r^3$ $\sum z_i = nt/2$
$\lvert t\rvert \leq \sqrt{xy},\ x, y > 0$	$(x, y, \sqrt{2}t) \in \mathcal{Q}_r^3$
Geometric mean $\lvert t\rvert \leq x_1^{\alpha_1} \cdots x_n^{\alpha_n},\ x_i > 0$ $\alpha_i > 0, \sum \alpha_i = 1$	$(x, t) \in \mathcal{P}_{n+1}^{\alpha_1, \ldots, \alpha_n}$

Entropy

$t \leq -x \log x$	$(1, x, t) \in K_{\exp}$
$t \geq x \log(x/y)$	$(y, x, -t) \in K_{\exp}$
$t \geq \log(1 + 1/x)$ $x > 0$	$(x + 1, u, \sqrt{2}) \in \mathcal{Q}_r^3$ $(1 - u, 1, -t) \in K_{\exp}$
$t \leq \log(1 - 1/x)$ $x > 1$	$(x, u, \sqrt{2}) \in \mathcal{Q}_r^3$ $(1 - u, 1, t) \in K_{\exp}$
$t \geq x \log(1 + x/y)$ $x, y > 0$	$(y, x + y, u) \in K_{\exp}$ $(x + y, y, v) \in K_{\exp}$ $t + u + v = 0$

Convex quadratic problems

Let $\Sigma \in \mathbb{R}^{n \times n}$, symmetric, p.s.d.
Find $\Sigma = LL^T$, $L \in \mathbb{R}^{n \times k}$ (Cholesky factor).
Then $x^T \Sigma x = \|L^T x\|_2^2$.

$t \geq \frac{1}{2} x^T \Sigma x$	$(1, t, L^T x) \in \mathcal{Q}_r^{k+2}$
$t \geq \sqrt{x^T \Sigma x}$	$(t, L^T x) \in \mathcal{Q}^{k+1}$
$\frac{1}{2} x^T \Sigma x + p^T x + q \leq 0$	$(1, -p^T x - q, L^T x) \in \mathcal{Q}_r^{k+2}$
$\max_x c^T x - \frac{1}{2} x^T \Sigma x$	$\max c^T x - r$ $(1, r, L^T x) \in \mathcal{Q}_r^{k+2}$
$c^T x + d \geq \|Ax + b\|_2$	$(c^T x + d, Ax + b) \in \mathcal{Q}^{m+1}$

Norms, $x \in \mathbb{R}^n$

$\|\cdot\|_1,\ t \geq \sum \lvert x_i\rvert$	$(z_i, x_i) \in \mathcal{Q}^2,\ t = \sum z_i$
$\|\cdot\|_2,\ t \geq (\sum x_i^2)^{1/2}$	$(t, x) \in \mathcal{Q}^{n+1}$
$\|\cdot\|_p,\ p > 1$ $t \geq (\sum \lvert x_i\rvert^p)^{1/p}$	$(z_i, t, x_i) \in \mathcal{P}_3^{1/p, 1-1/p}$ $\sum z_i = t$

Geometry

Bounding ball $\min_x \max_i \|x - x_i\|_2$	$\min r$ $(r, x - x_i) \in \mathcal{Q}^{n+1}$
Geometric median $\min_x \sum \|x - x_i\|_2$	$\min \sum t_i$ $(t_i, x - x_i) \in \mathcal{Q}^{n+1}$
Analytic center $\max_x \sum \log(b_i - a_i^T x)$	$\max \sum t_i$ $(b_i - a_i^T x, 1, t_i) \in K_{\exp}$

Regression and fitting

Regularized least squares $\min_w \|Xw - y\|_2^2 + \lambda \|w\|_2^2$	$\min t + \lambda r$ $(0.5, t, Xw - y) \in \mathcal{Q}_r^{m+2}$ $(0.5, r, w) \in \mathcal{Q}_r^{n+2}$
Max likelihood $\max_p p_1^{a_1} \cdots p_n^{a_n}$	$\max \sum a_i t_i$ $(p_i, 1, t_i) \in K_{\exp}$
Logistic cost function $t \geq -\log(1/(1 + e^{-\theta^T x}))$	$u + v \leq 1$ $(u, 1, -\theta^T x - t) \in K_{\exp}$ $(v, 1, -t) \in K_{\exp}$

Risk-return

$\Sigma \in \mathbb{R}^{n \times n}$ – covariance, $\Sigma = LL^T,\ L \in \mathbb{R}^{n \times k}$

$\max_x \alpha^T x$ s.t. $x^T \Sigma x \leq \gamma$	$\max_x \alpha^T x$ $(\sqrt{\gamma}, L^T x) \in \mathcal{Q}^{k+1}$
$\max_x \alpha^T x - \delta x^T \Sigma x$	$\max_x \alpha^T x - \delta r$ $(0.5, r, L^T x) \in \mathcal{Q}_r^{k+2}$
Risk plus $x^{1.5}$ impact cost $t \geq \delta x^T \Sigma x + \beta \sum \lvert x_i\rvert^{3/2}$	$t \geq \delta r + \beta \sum u_i$ $(0.5, r, L^T x) \in \mathcal{Q}_r^{k+2}$ $(u_i, 1, x_i) \in \mathcal{P}_3^{2/3, 1/3}$
Risk in factor model $\gamma \geq x^T (D + FSF^T) x$ D – specific risk (diag.) $F \in \mathbb{R}^{n \times k}$ – factor loads $S = UU^T$ – factor cov.	$\gamma \geq t + s$ $(0.5, t, \sqrt{D} x) \in \mathcal{Q}_r^{n+2}$ $(0.5, s, U^T F^T x) \in \mathcal{Q}_r^{k+2}$

MOSEK Modeling Cookbook

Linear and conic optimization, cones, duality, semidefinite (SDP) and mixed-integer (MIP) formulations, practical hints, scaling.