Guaranteed Rank Minimization via Singular Value Projections

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Poster No: W56
Affine Constrained Rank Minimization Problem (ARMP)

\[(\text{ARMP}): \min_{X} \text{rank}(X) \]
\[\text{s.t } A(X) = b.\]
\[X \in \mathbb{R}^{m \times n}, \ A : \mathbb{R}^{m \times n} \rightarrow \mathbb{R}^{d}, \ b \in \mathbb{R}^{d}.\]

- \(d \ll mn\) (typically, \(d = 6nk\))
- Applications:
  - Matrix completion: Netflix Challenge
  - Linear time-invariant systems
  - Embedding using missing Euclidean distances
- NP-hard even to approximate within log factor (Meka et al.’08)
(RARMP) : \( \min_X \psi(X) = \frac{1}{2} \| A(X) - b \|_2^2 \),

\[ \text{s.t } X \in C(k) = \{ X : \text{rank}(X) \leq k \}. \]

- SVP: Adapt classical projected gradient
- Efficient projection onto non-convex rank constraint using SVD
- Converges to the optimal solution under certain RIP conditions
- SVP-Newton: Second order adaptation of SVP
Results

- Singular Value Projection (SVP) algorithm
  - Simple analysis for ARMP (with RIP)
  - Partial progress for matrix completion
  - Simple Newton-step based extension: SVP-Newton and SVP-NewtonD

- Experimental Results:
  - Synthetic Datasets with uniform sampling
  - Synthetic Datasets with noise and more realistic power-law sampling
  - MovieLens Dataset

- SVP much faster and more stable than existing methods

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