Graph Spectral Clustering of Artefacts In Radio Interferometric Images
Matthieu Simeoni *,†, Paul Hurley ‡
*IBM Zurich Research Laboratory, Rüschlikon
† École Polytechnique Fédérale de Lausanne (EPFL), Lausanne
‡ Western Sydney University, Australia

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Abstract — Raw radio interferometric images are severely blurred by strong convolution artefacts. In this work, we propose an unsupervised learning method for clustering such artefacts. We use spectral clustering on a kinship graph: each pixel interpreted as a node, linked by edges weighted according to their spatial correlation. Actual celestial sources are then identified within each clusters.

1. Sky Covariance Function
Assume a point source field \( S \), with randomly fluctuating amplitudes
\[
S(r) = \sum_{q=1}^{Q} \xi_q \delta(r - r_q), \quad \forall r \in S^2
\]
The radio telescope measurements are given by
\[
y := \sum_{q=1}^{Q} \xi_q \begin{bmatrix} e^{-\frac{2\pi i}{\lambda} (r_q, p_1)} \\ \vdots \\ e^{-\frac{2\pi i}{\lambda} (r_q, p_L)} \end{bmatrix} = \sum_{q=1}^{Q} \xi_q \varphi(r_q).
\]
Evidence of the steering vector in the data reveal likely positions of the underlying sources:
\[
\hat{S}(r) = \langle y, \varphi(r) \rangle = \varphi(r)^H y, \quad r \in \Theta.
\]
Dirty field is characterized by its covariance kernel
\[
\hat{k}(r, s) := \mathbb{E} \left[ \hat{S}(r) \hat{S}^*(s) \right] = \varphi(r)^H \Sigma \varphi(s).
\]

2. The Parenting Problem
Radio astronomers only look at intensity field (variance). It is polluted by strong convolution artefacts: each source leaks its energy in the field. In practice, we observe regions of dominance.

3. Kinship Graph & Spectral Clustering
We define a kinship graph, linking each sky direction (node) according to their degree of kinship (correlation). The goal is to cluster this kinship network to recover the region of dominances. We use spectral clustering. Parent sources are identified as nodes with maximal degree.

4. Experimental Results

- True sky.
- Dirty image.
- Kinship graph.
- True ROD.
- Recovered ROD.
- Accuracy (86.7 %)