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Principles and performance of the LI-TIFROM software

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Principles and performance of the LI-TIFROM software



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Problem statement and time-frequency tool

- Linear instantaneous possibly underdetermined mixtures ($a_{ij} \neq 0$):

$$x_i(t) = \sum_{j=1}^N a_{ij} s_j(t) \quad i = 1 \dots P$$
- Fix scale indeterminacies

$$\left. \begin{array}{l} \sigma(\cdot) \text{ a permutation} \\ s'_j(t) = a_{1\sigma(j)} s_{\sigma(j)}(t) \\ b_{ij} = \frac{a_{i\sigma(j)}}{a_{1\sigma(j)}} \end{array} \right\} \Rightarrow x_i(t) = \sum_{j=1}^N b_{ij} s'_j(t) \quad i = 1 \dots P \quad (1)$$
- Time-frequency (TF) tool : Short-Time Fourier Transform

$$(1) \xrightarrow{\text{STFT}} X_i(t, \omega) = \sum_{j=1}^N b_{ij} S'_j(t, \omega) \quad i = 1 \dots P$$
- Our goal? Estimate $B = [b_{ij}]!$

Definitions and assumptions

Definitions

- TF analysis zone: several adjacent TF windows (t_p, ω_l)

They can have any shape...
 ...But we focus on **Constant-frequency TF analysis zones** (T, ω_l) .

- A source $S_k(t, \omega)$ is **isolated** in a **single-source** analysis zone (T, ω_l) if all the sources except $S_k(t, \omega)$ are null in (T, ω_l) .
- A source is **visible** if there exists at least one TF zone where it is isolated.

Assumptions

- All sources are visible (in basic version)
- No TF zone (T, ω_l) where all sources are null everywhere.
- Active sources do not have coherent variations in TF zones.

Original version of LI-TIFROM [1] : principles

- Finding single source TF zones (**low sparsity assumption**):

Stage based on the study of **one** ratio

$$\alpha(t, \omega) \triangleq \frac{X_i(t, \omega)}{X_1(t, \omega)} = \frac{\sum_{j=1}^N a_{ij} S_j(t, \omega)}{\sum_{j=1}^N a_{1j} S_j(t, \omega)}$$

- if S_k isolated in (T, ω_l) , then $\alpha(t_p, \omega_l)$ constant in this zone.
- ⇒ "Best" **single-source zones**: zones where the variance of ratio, $\text{var}[\alpha](T, \omega_l)$, takes the lowest values.
- Estimating columns of the mixing matrix in these zones:
 - if $S_k(t, \omega)$ isolated in (T, ω_l) , then

$$\forall p \in \{1 \dots M\}, \quad \frac{X_i(t_p, \omega_l)}{X_1(t_p, \omega_l)} = \frac{a_{ik}}{a_{1k}} = b_{im}$$
- In practice, an estimated column \hat{b}_{im} :
 - is set as the mean over p of the above ratio,
 - is kept if its distance wrt other estimated columns is "sufficiently" high.
- Estimating the sources:
 - if $N \leq P$, i.e (over-)determined mixtures, no problem!

$$y(t) = B^{-1}x(t)$$
 - if $N > P$, B is not invertible. **Partial separation** proposed instead [1]. In SiSEC 2008, non-convex ℓ_0 norm minimization method [2] used.

Limitations and improvements

Asymmetrical behaviour of the variance of ratios

- Value of $\text{var}[\alpha](T, \omega_l)$ in "real" single-source zone depends on the mixing coefficients a_{ij} .
- When $P > 2$, the performance depends on **the** considered ratio of mixtures.

Symmetrical version of LI-TIFROM [3]

- Consider the ratio $\alpha(t, \omega)$ and its inverse $\beta(t, \omega) \triangleq \frac{1}{\alpha(t, \omega)}$
 - ⇒ **New criterion to find single-source TF zones**:

$$\min \{ \text{var}[\alpha](T, \omega), \text{var}[\beta](T, \omega) \} \quad (2)$$
- Study **all** ratios

$$\alpha_i(t, \omega) \triangleq \frac{X_i(t, \omega)}{X_1(t, \omega)} \text{ and } \beta_i(t, \omega) \triangleq \frac{X_1(t, \omega)}{X_i(t, \omega)}$$
 - ⇒ **Extended criterion of (2)**:

$$\min \{ MVAR[\alpha](T, \omega_l), MVAR[\beta](T, \omega_l) \}$$
 where $MVAR[\alpha](T, \omega_l)$ mean over i of $\text{var}[\alpha_i](T, \omega_l)$.

Performance of the Symmetrical LI-TIFROM

- Determined case (software user guide examples):
 - ⇒ $N = 2$ English speech source signals, $A = \begin{bmatrix} 1 & 0.9 \\ 0.8 & 1 \end{bmatrix}$
 - Mean SIR: 82.0 dB
 - ⇒ $N = 4$ English speech source signals, $A = [0.9^{|i-j|}]_{ij}$
 - Mean SIR: 43.0 dB
- Underdetermined case (SiSEC 2008):
 - ⇒ Several configurations (3 or 4 sources, mixed in 2 observations) involving speech or music sources
 - ⇒ Fast estimation of the mixtures: $\simeq 20$ s.GHz/test
 - Mean MER: 80.9 dB
 - Mean SDR: 10.3 dB
 - Mean SIR: 18.1 dB
 - Mean SAR: 11.4 dB

Software future development

- ✓ Hidden sources [1]
- ✓ Clustering methods [4]
- ✓ Extension to more general mixtures [4, 5]
- ✗ Complete separation of the sources in underdetermined BSS

WWW

- LI-TIFROM 1.0 package freely available:
<http://www.ast.obs-mip.fr/li-tifrom>
- Team's BSS softwares freely available:
<http://www.ast.obs-mip.fr/bss-softwares>

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