



## 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

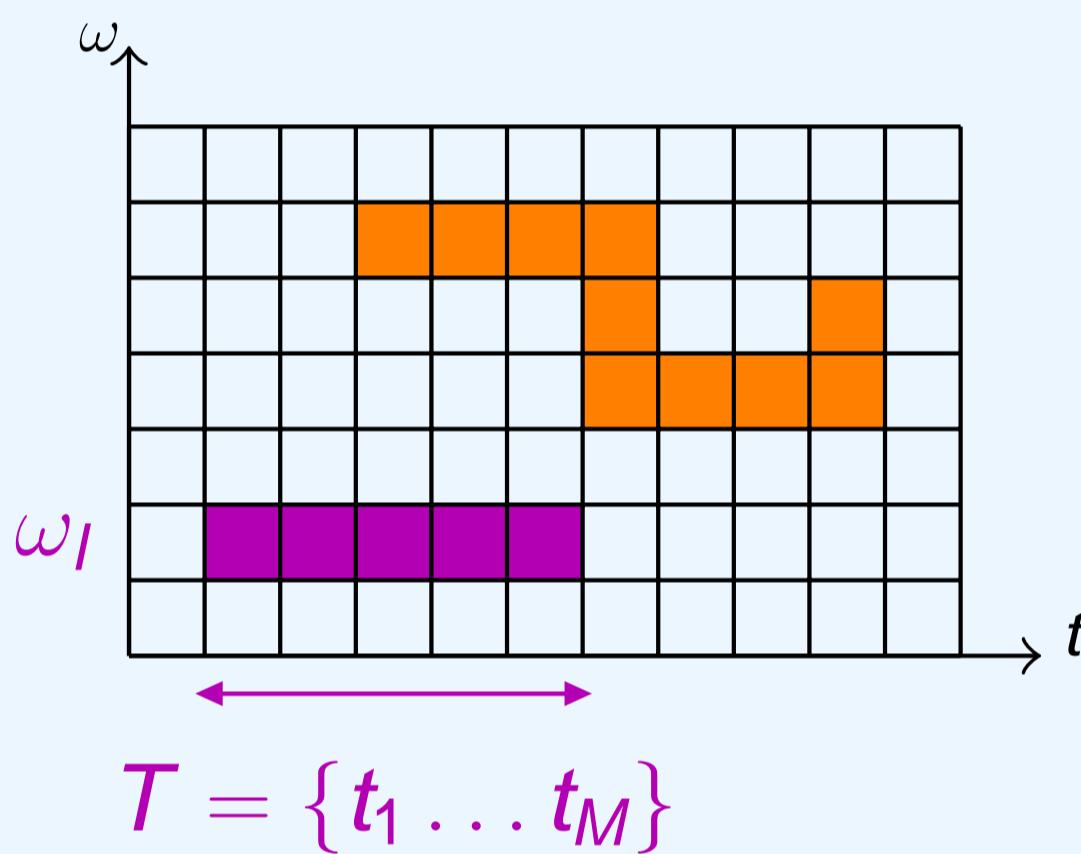
$$(1) \xrightarrow{\text{STFT}} X_i(t, \omega) = \sum_{j=1}^N b_{ij} S'_j(t, \omega) \quad i = 1 \dots P$$

- Our goal? Estimate  $B = [b_{ij}]$ !

### Definitions and assumptions

#### Definitions

- TF analysis zone: several adjacent TF windows  $(t_p, \omega_l)$



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

- A source  $S_k(t, \omega)$  is isolated in a single-source analysis zone  $(T, \omega_l)$  if all the sources except  $S_k(t, \omega)$  are null in  $(T, \omega_l)$ .
- 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  $(T, \omega_l)$  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  $(T, \omega_l)$ , 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  $(T, \omega_l)$ , 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  $\ell_0$  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>

### References

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