NORTHWESTERN
UNIVERSITY

interactive audio lab

REPET: REpeating Pattern Extraction Technique

A Simple Music/Voice Separation Method based on the Extraction of the Underlying Repeating Structure

Zafar RAFII

Plan

I. Introduction

II. REPET Algorithm

1. Repeating period identification
2. Repeating segment modeling
3. Repeating structure extraction

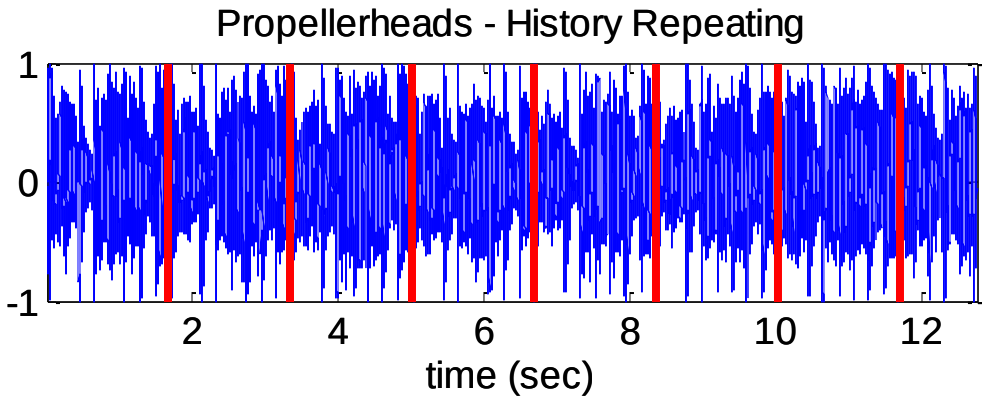
III. Music/Voice Separation

1. Experimental results
2. Audio examples
3. Future work

IV. Conclusion

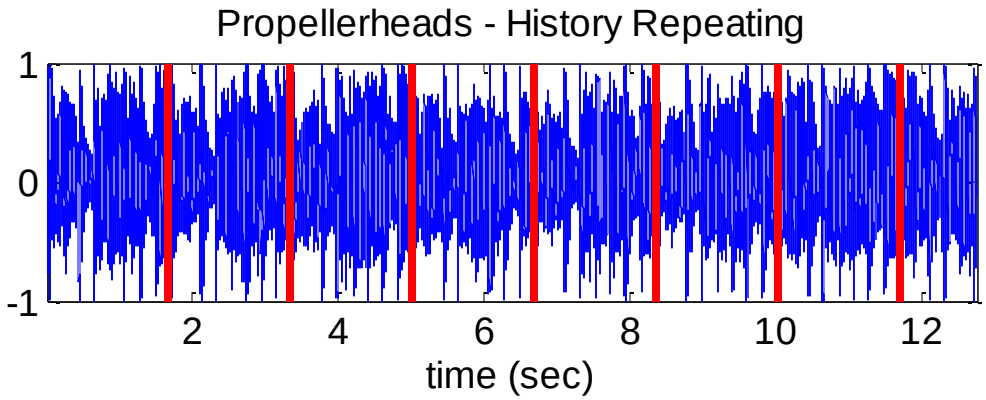
I. Introduction

- **Repetition** is a core principle in music: a musical piece has generally a distinguishable underlying repeating structure



I. Introduction

- Assuming sparsity in time and frequency, there should be (roughly) periodically **repeating** & **non-repeating** t-f bins



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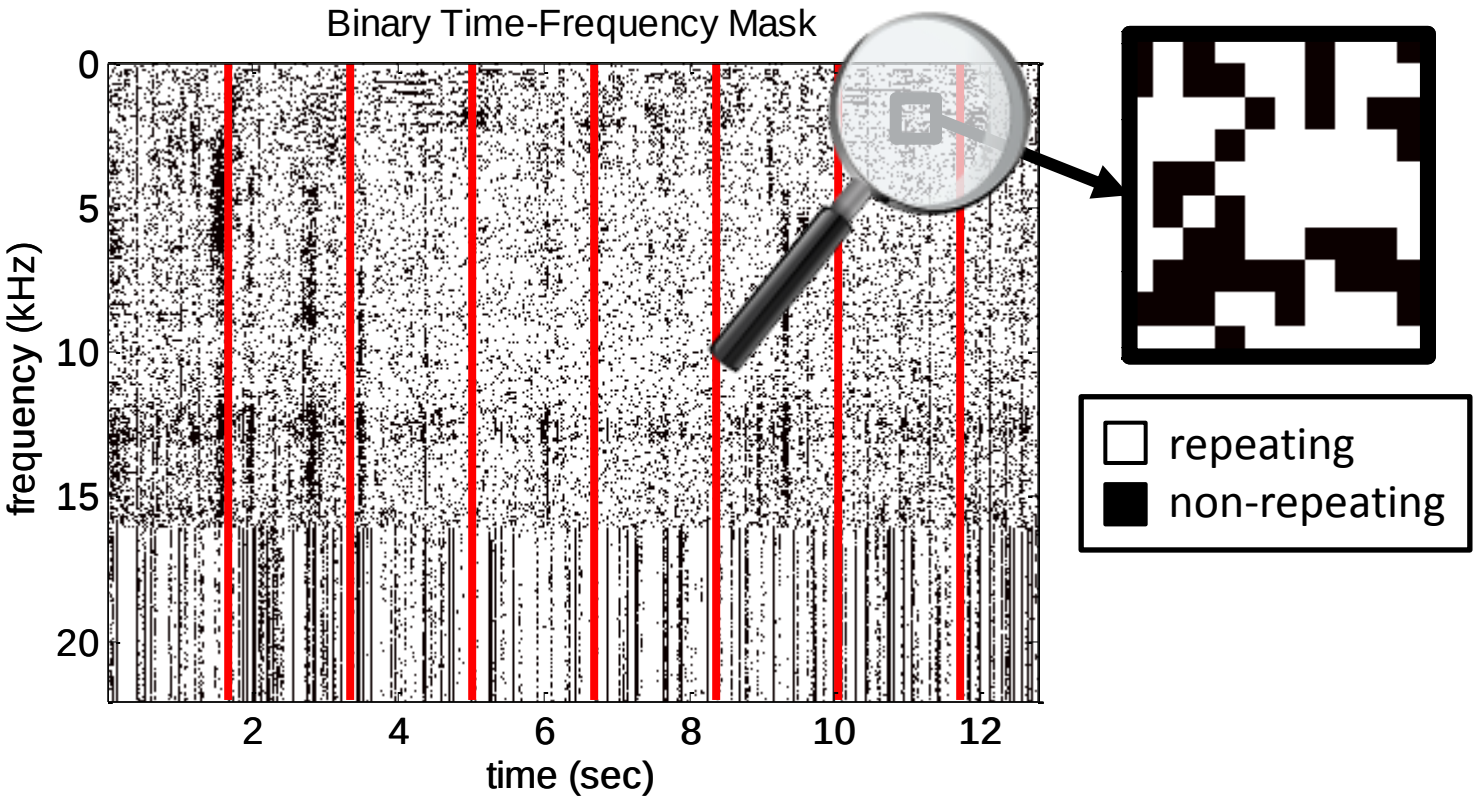


I. Introduction

- **Idea**: identify time-frequency bins periodically repeating in the spectrogram and extract them via binary masking

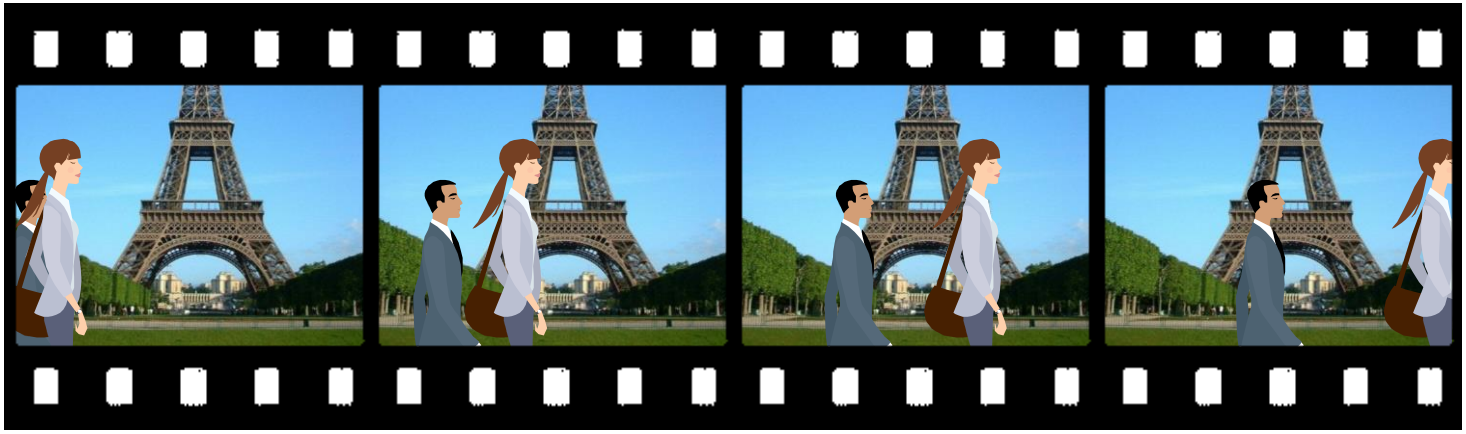
- **Method**: REpeating Patterns Extraction Technique (REPET)
  1. Identify a repeating period
  2. Model a repeating segment
  3. Extract the repeating structure

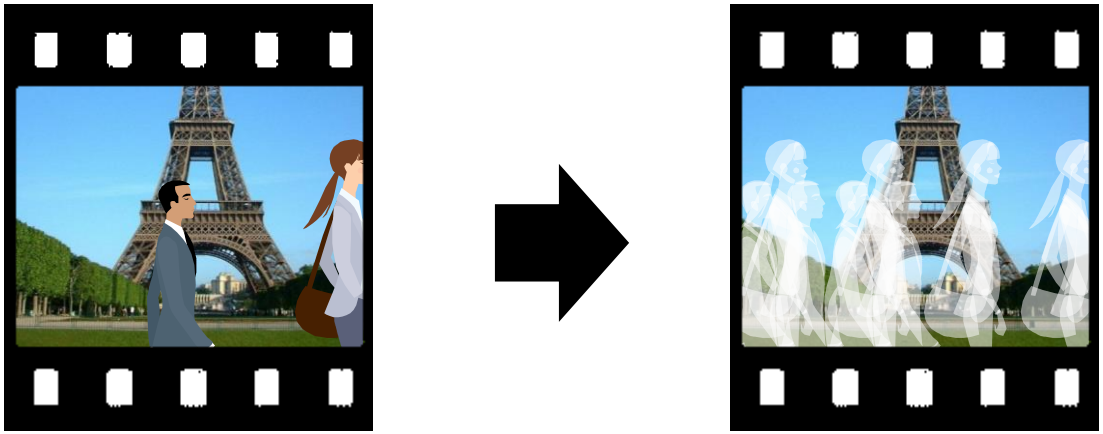
- **Result**: a simple music/voice separation system!
  - The underlying repeating structure ≈ *musical "background"*
  - The overlying non-repeating structure ≈ *vocal "foreground"*

I. Introduction

- Parallel with **background subtraction** in computer vision:

1. Compare frames to estimate a "background model"

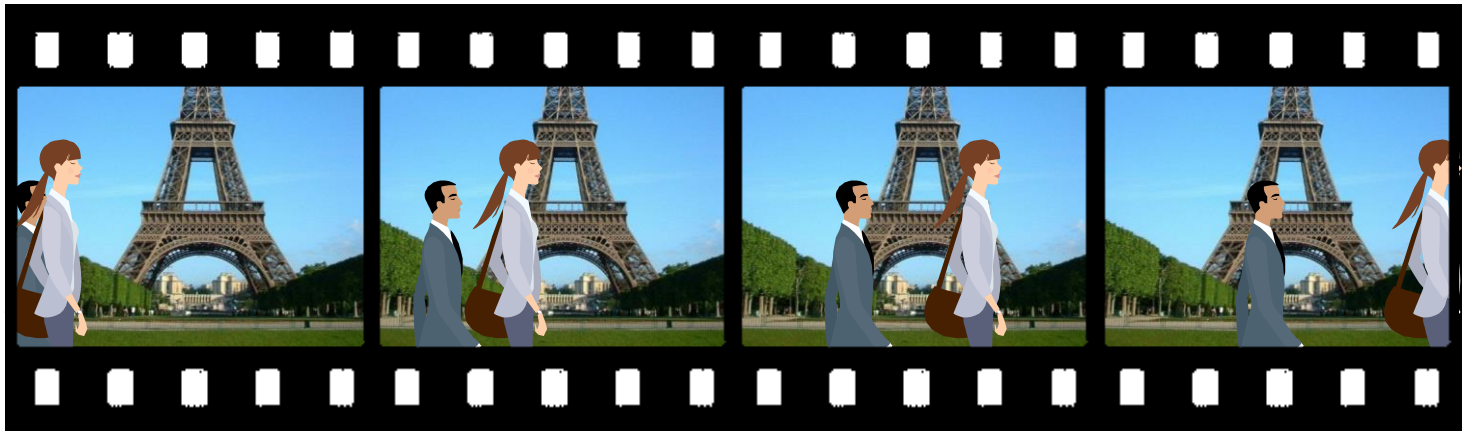




I. Introduction

- Parallel with **background subtraction** in computer vision:

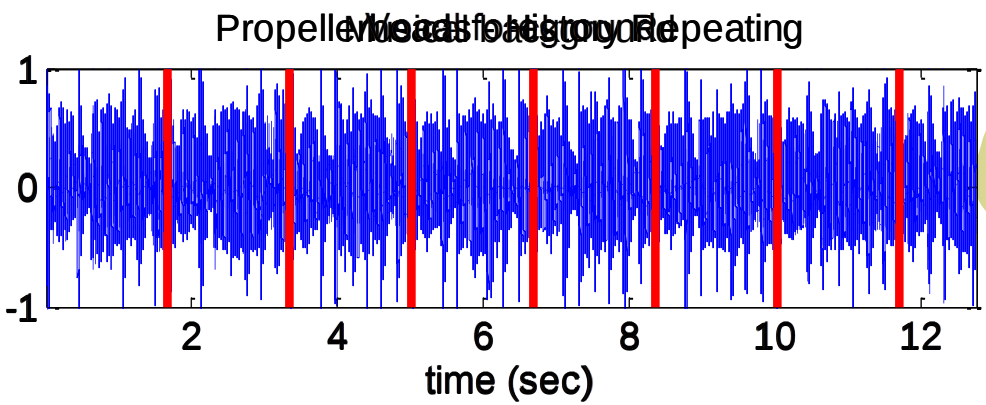
2. Extract the "background" from the "foreground"



I. Introduction

- Parallel with **background subtraction** in computer vision:

→ With audio, we also need to identify a repeating period!



I. Introduction

- **Practical Interest:**
  - Instruments/vocalist identification
  - Music/voice transcription
  - Post production
  - Karaoke

- **Practical Advantages**:
  - Not feature-dependent
  - No complex framework
  - No prior training

- **Intellectual Interest:**
  - Simply based on repetition
  - Musical structure extraction

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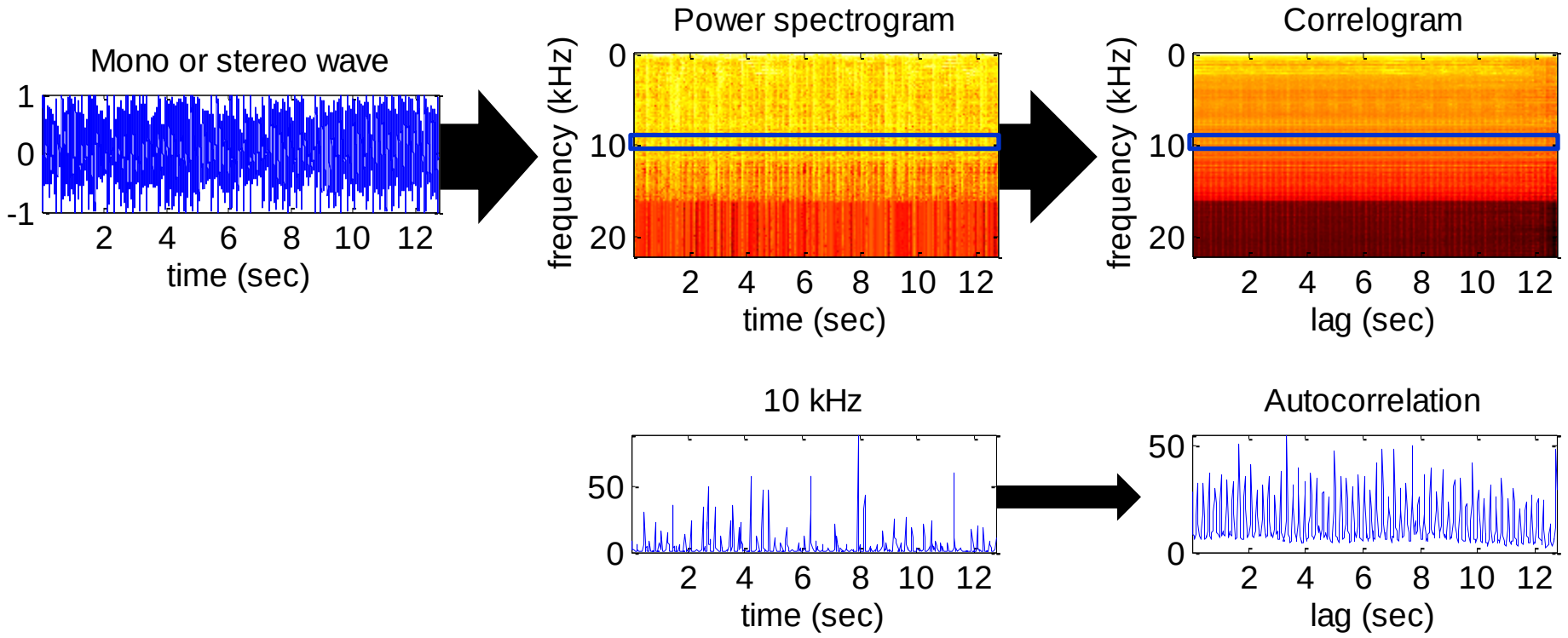
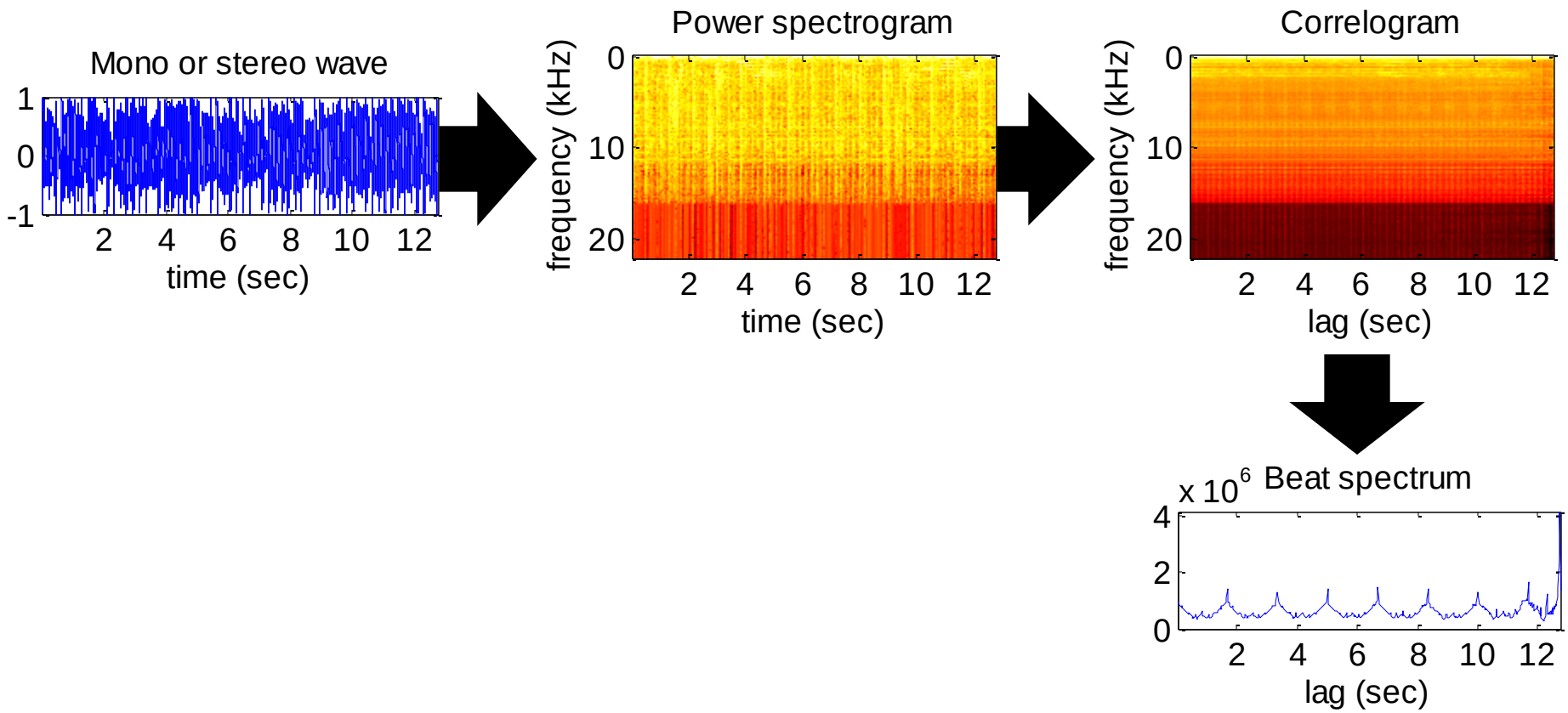
II. REPET – 1. Repeating Period

- A correlogram is calculated from the **autocorrelation** of the rows of the power spectrogram to detect periodicities



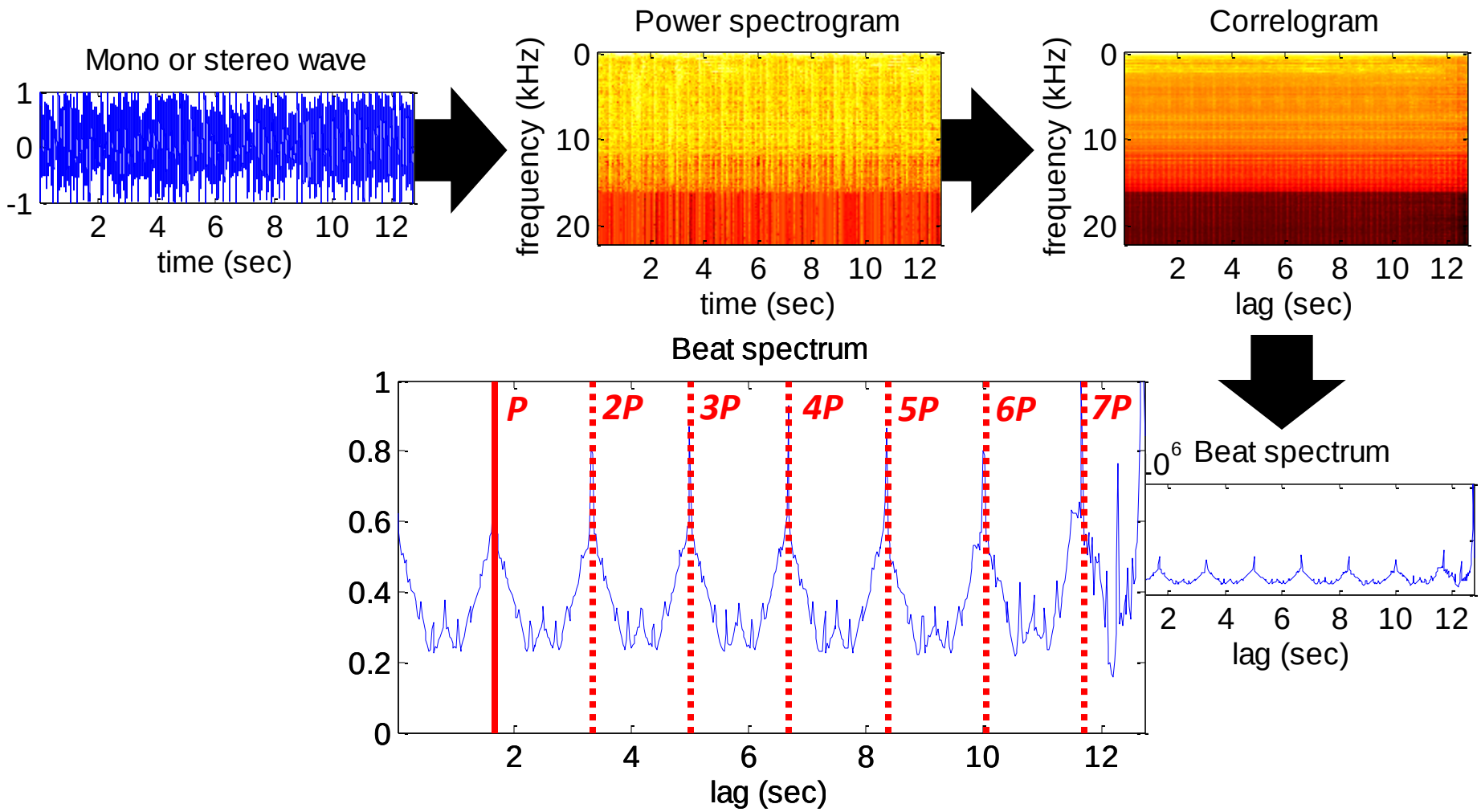
II. REPET – 1. Repeating Period

- By taking the mean of the rows of the correlogram, we obtain the "**beat spectrum**"



II. REPET – 1. Repeating Period

- The beat spectrum reveals the **repeating period *P*** of the underlying repeating musical structure



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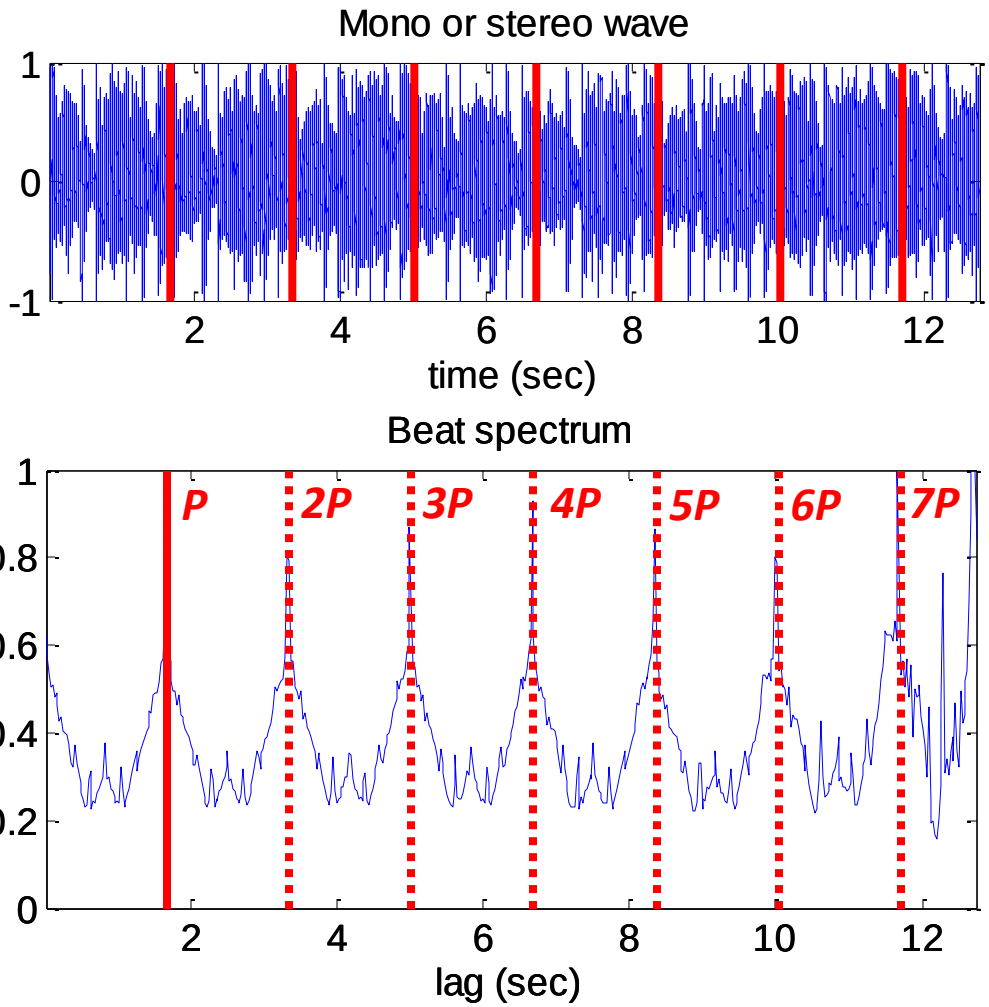

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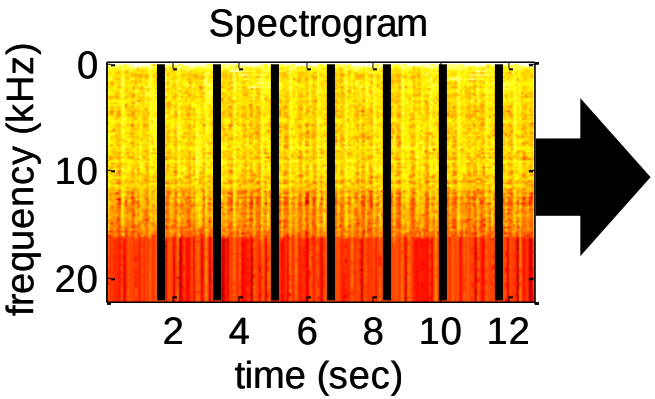
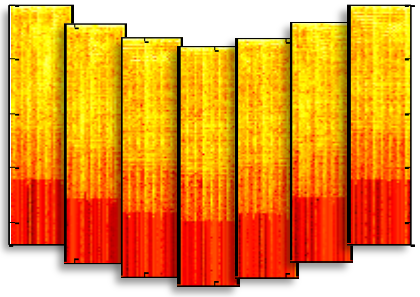
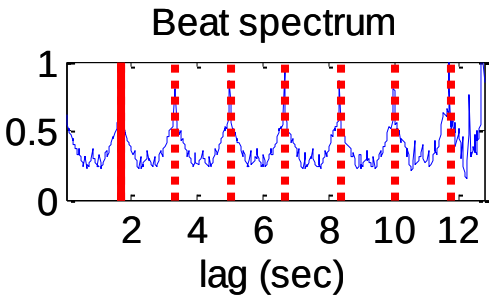
II. REPET – 2. Repeating Segment

- The **repeating period** is used to segment the magnitude spectrogram at period rate

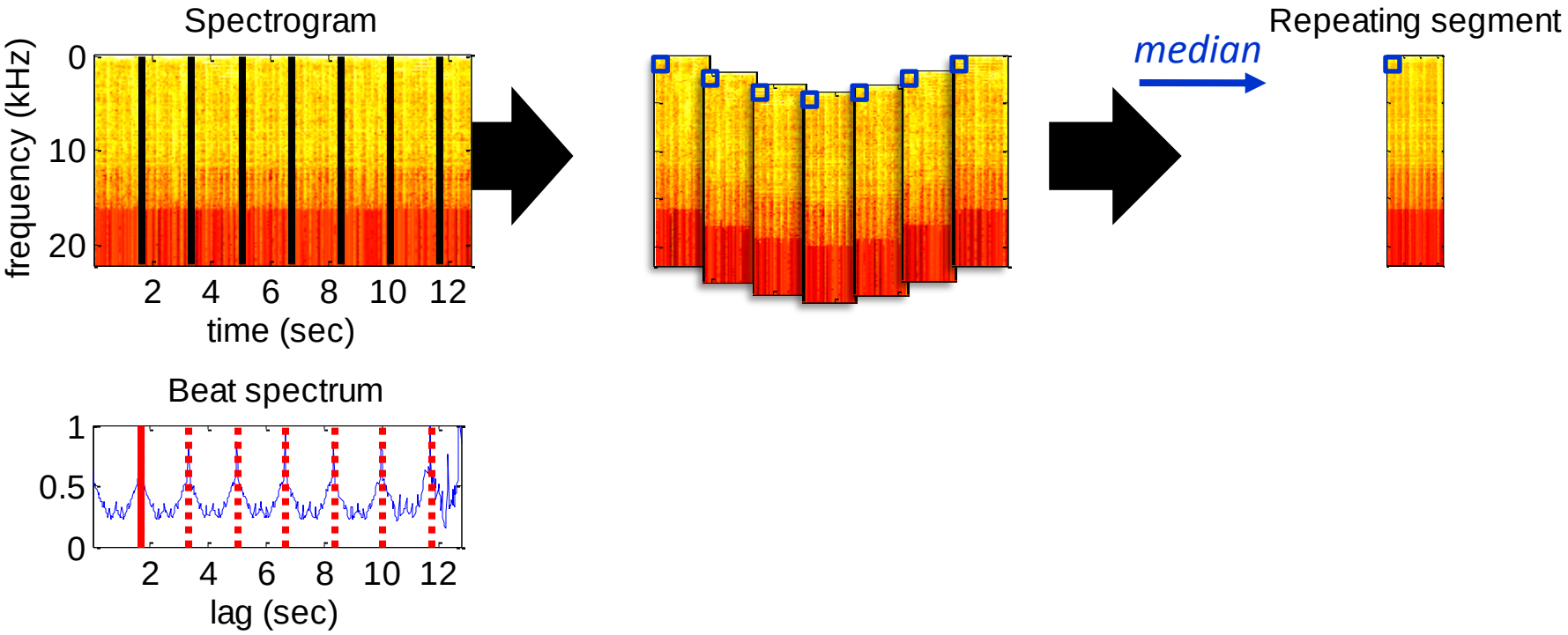






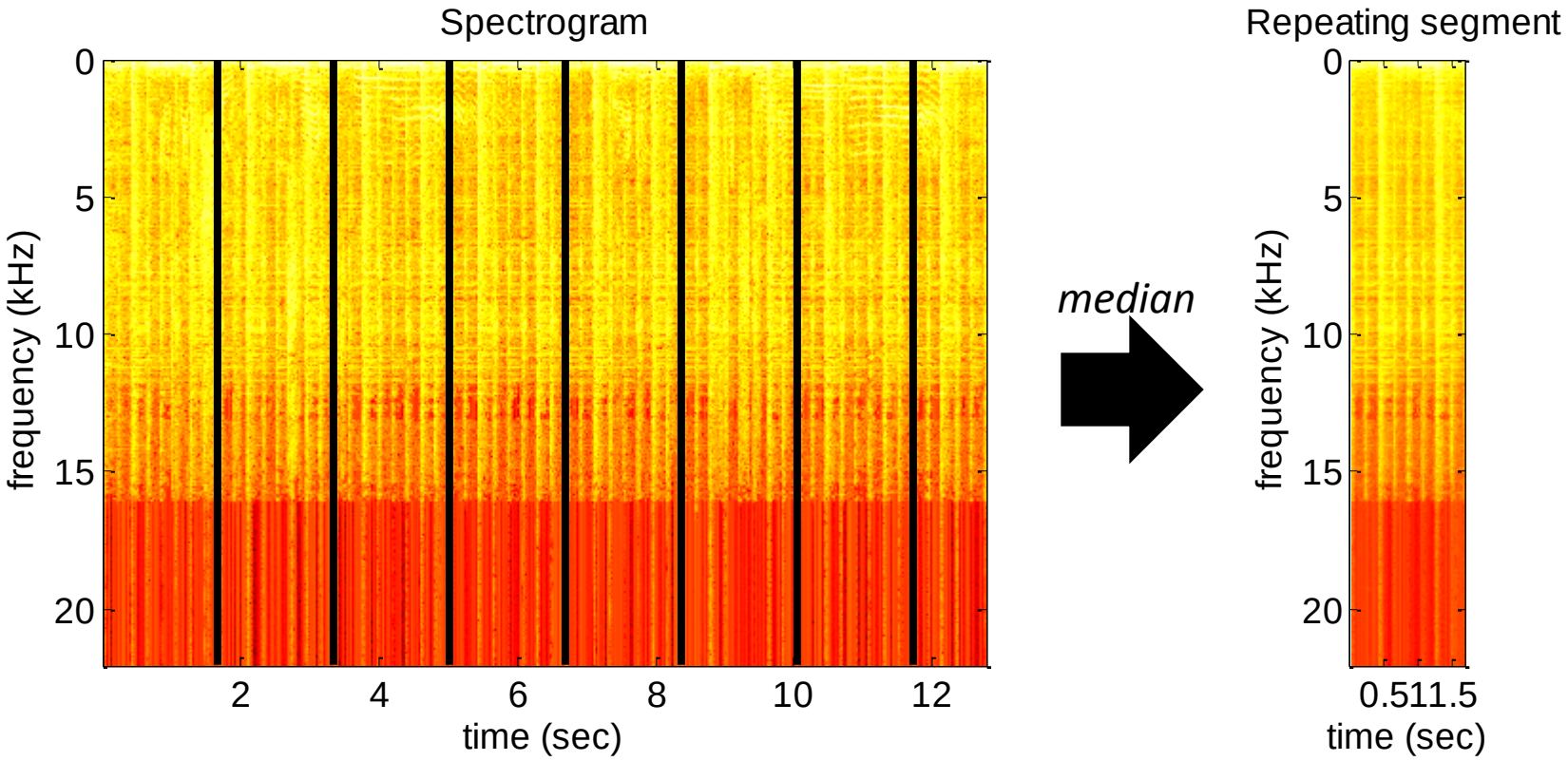
II. REPET – 2. Repeating Segment

- The **repeating segment** is modeled as the median of the segments for every t-f bins



II. REPET – 2. Repeating Segment

- As the middle value of a distribution, the **median** helps to model a smooth repeating segment, eliminating outliers



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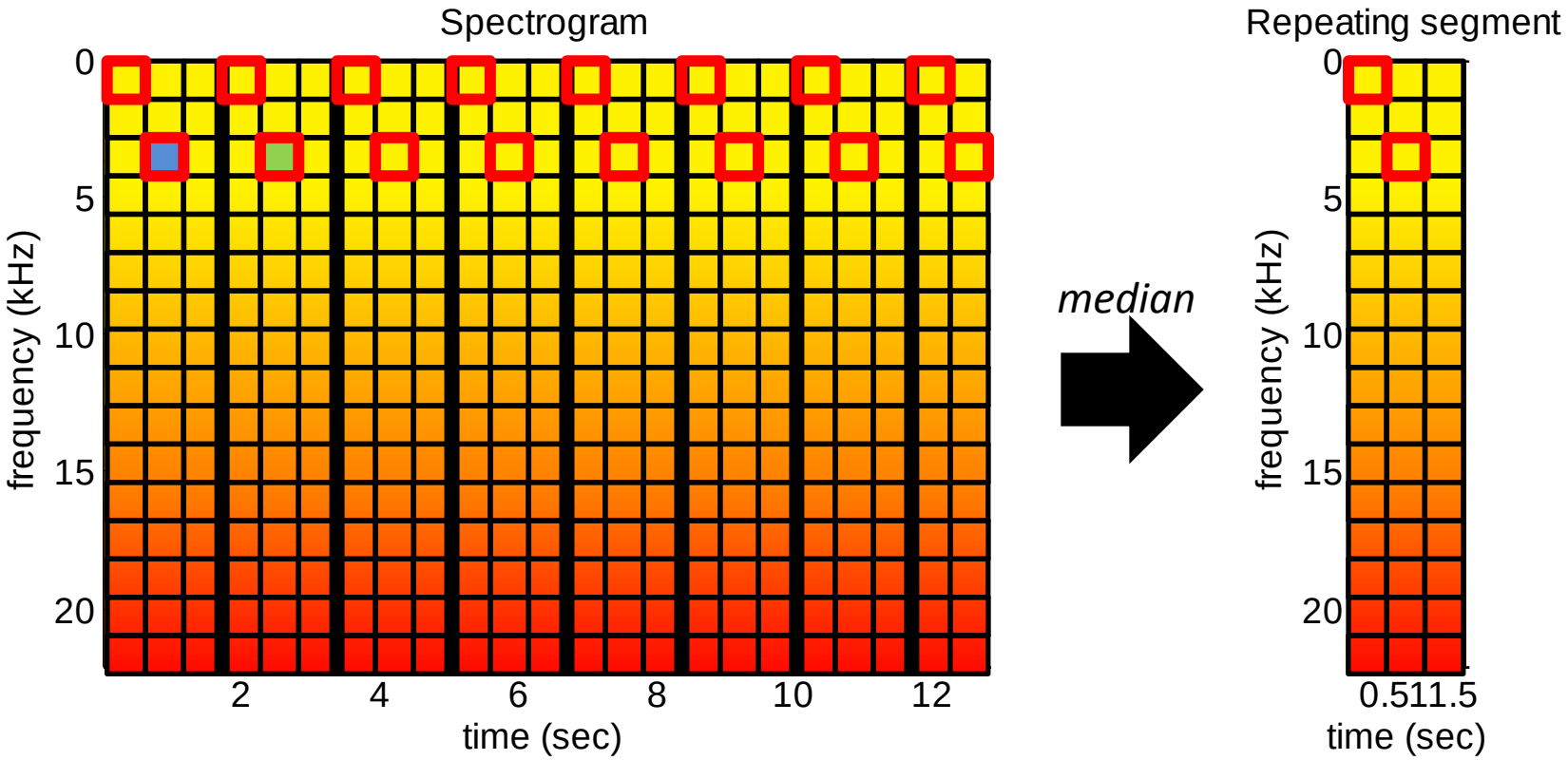

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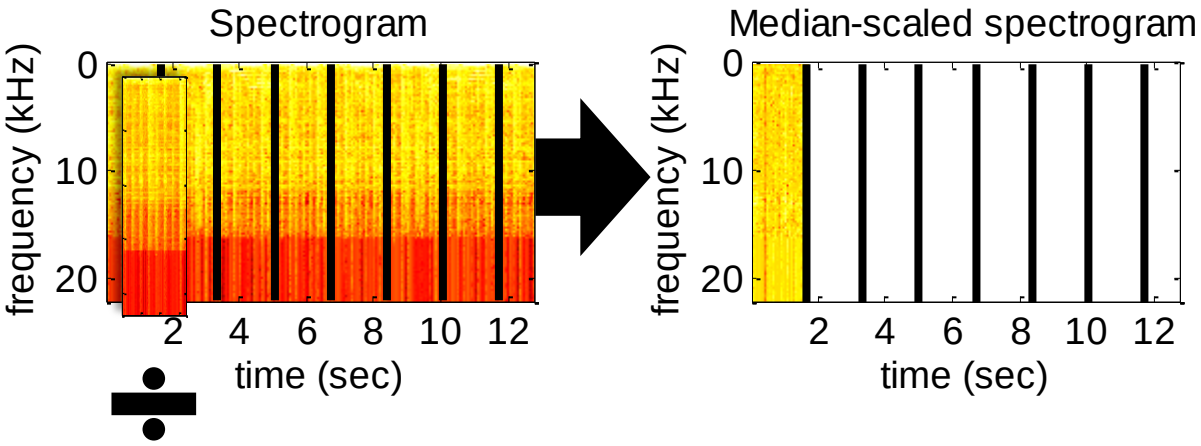
II. REPET – 3. Repeating Structure

- The **repeating segment** is used to divide bin-wise each segment in order to obtain a median-scaled spectrogram



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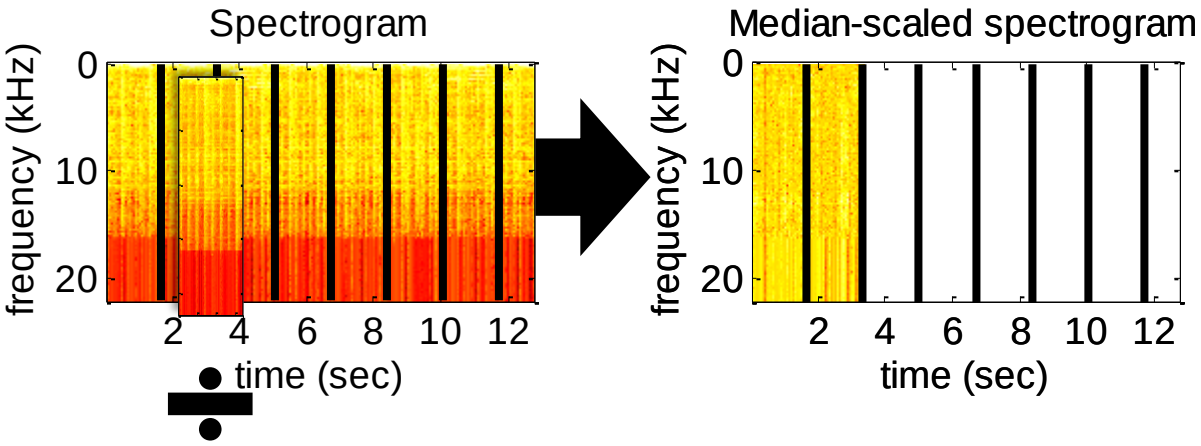

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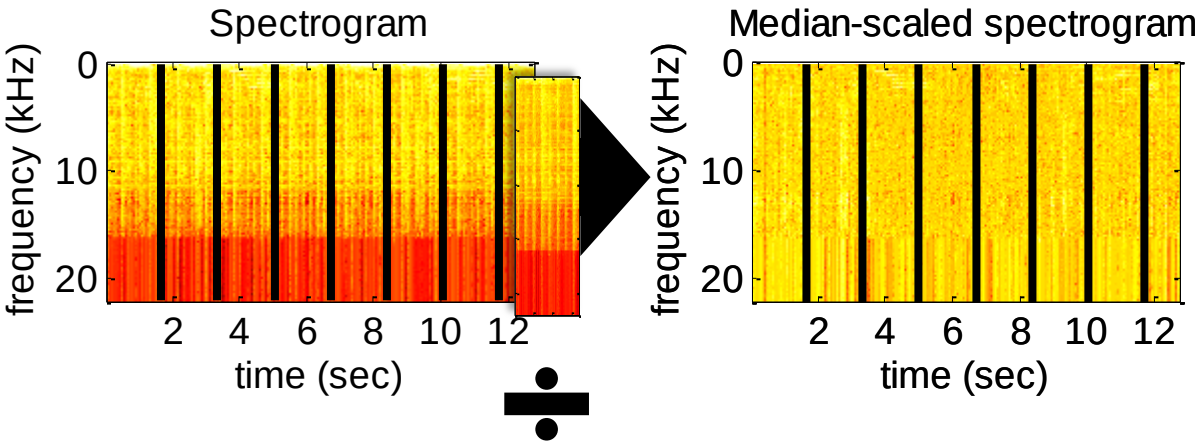
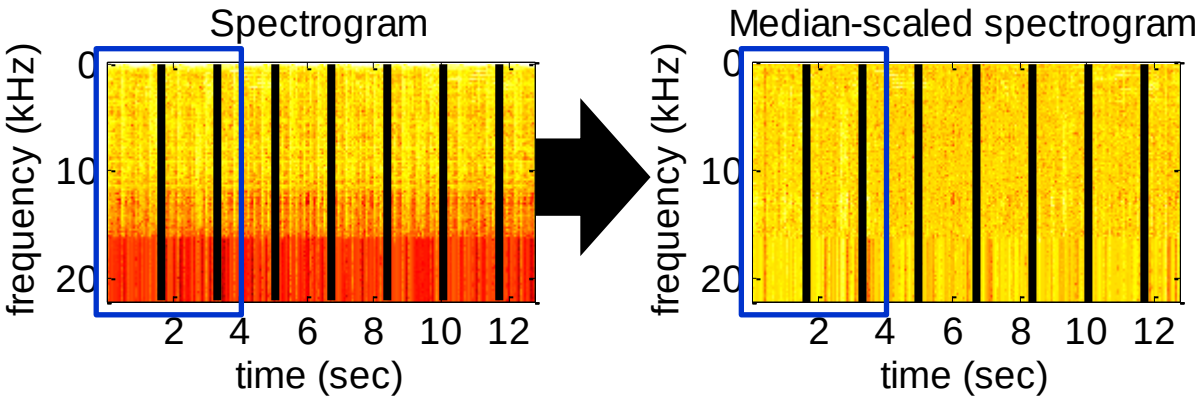


II. REPET – 3. Repeating Structure

- Repeating t-f bins are similar to the repeating segment, so have values around 1 in the median-scaled spectrogram



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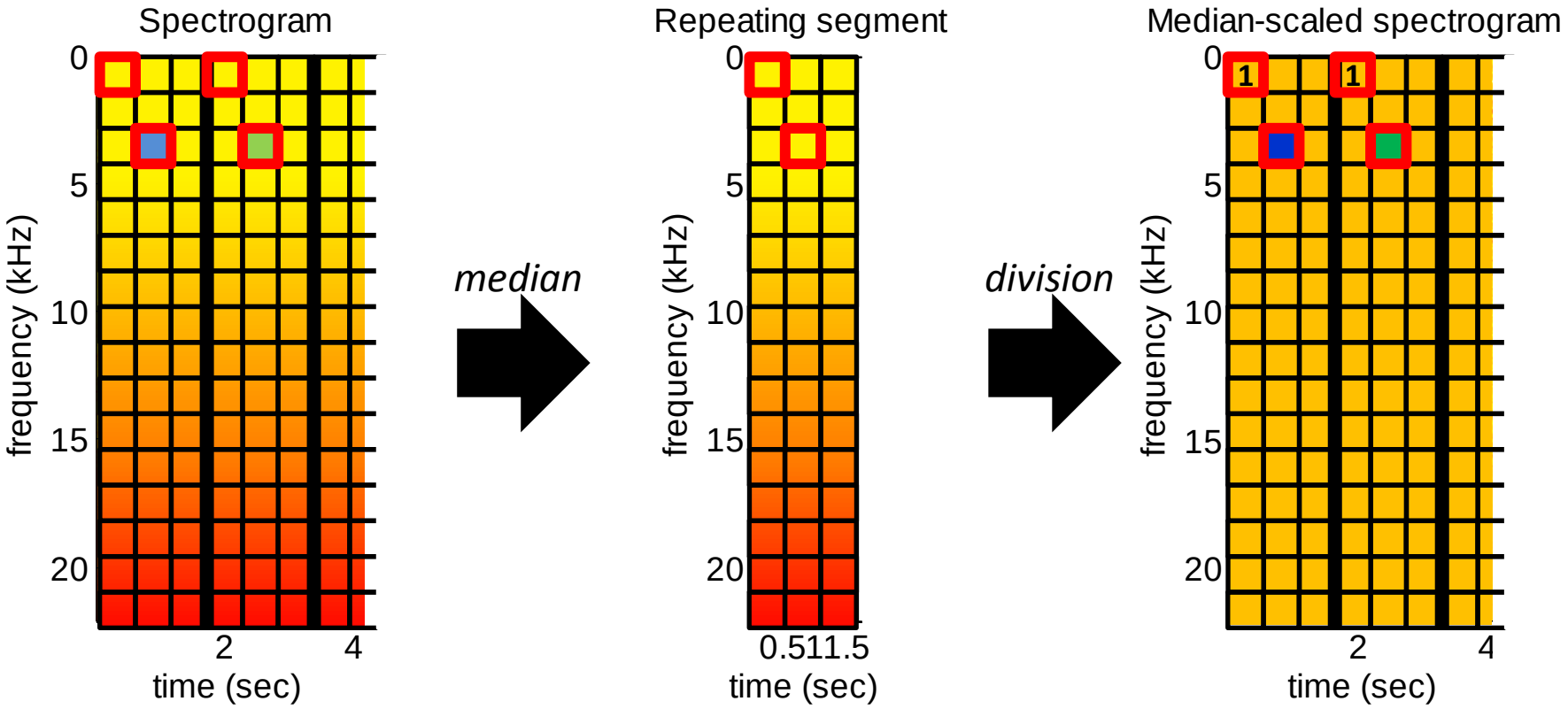
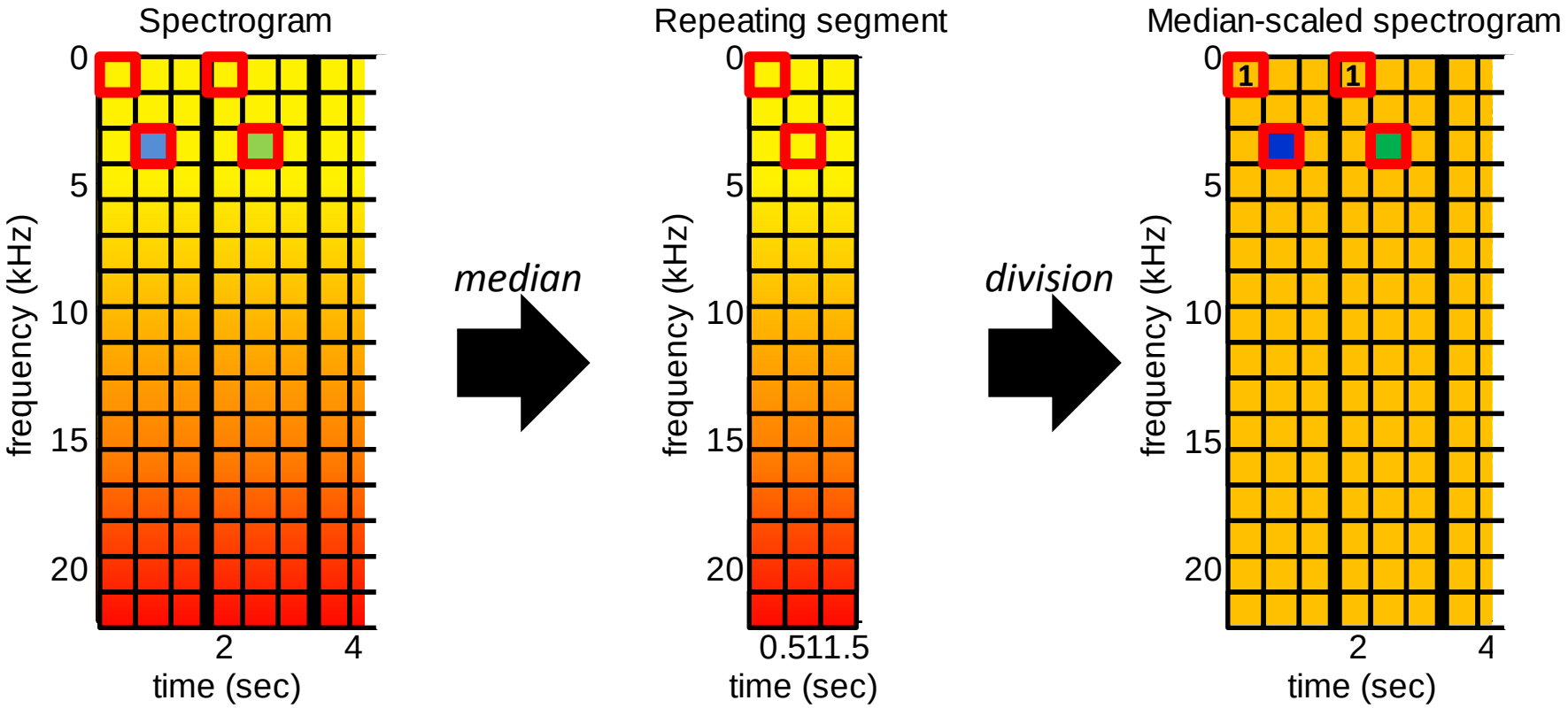


II. REPET – 3. Repeating Structure

- By assigning bins around 1 to the repeating structure (*white*) and the rest to 0 (*black*), we get a **binary t-f mask**



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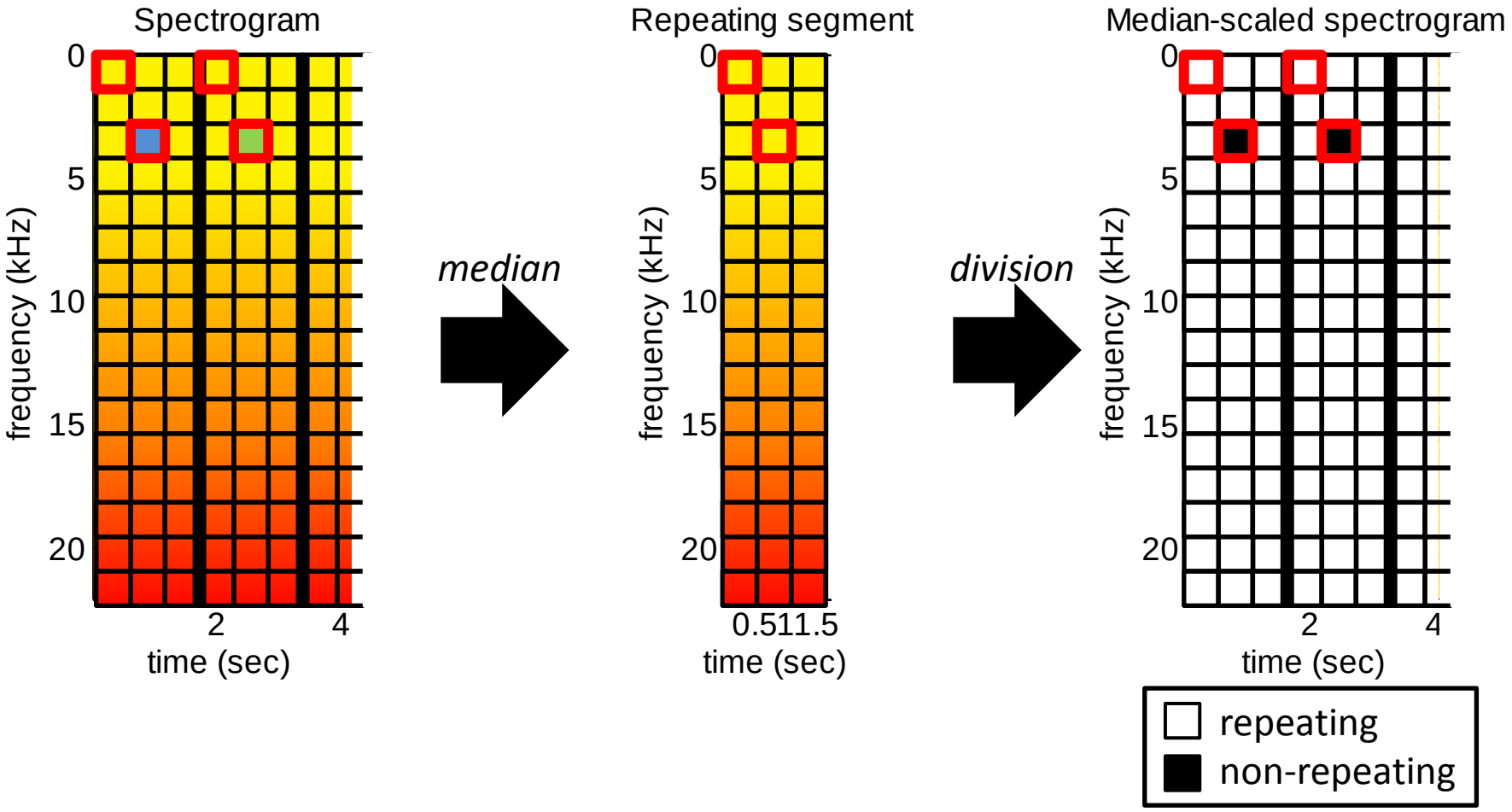

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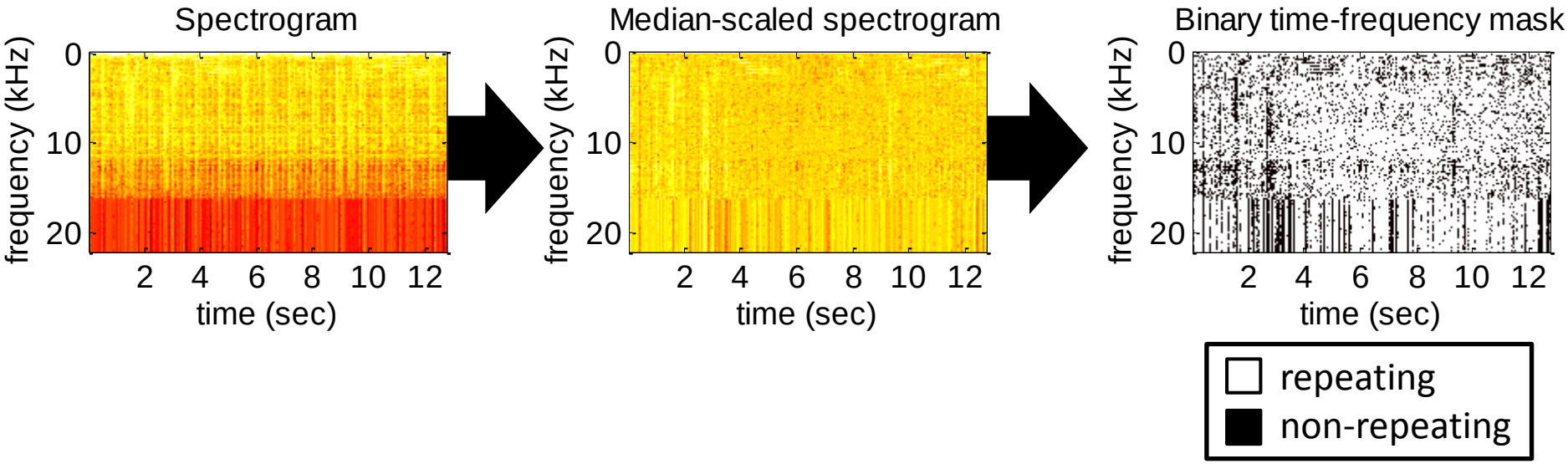
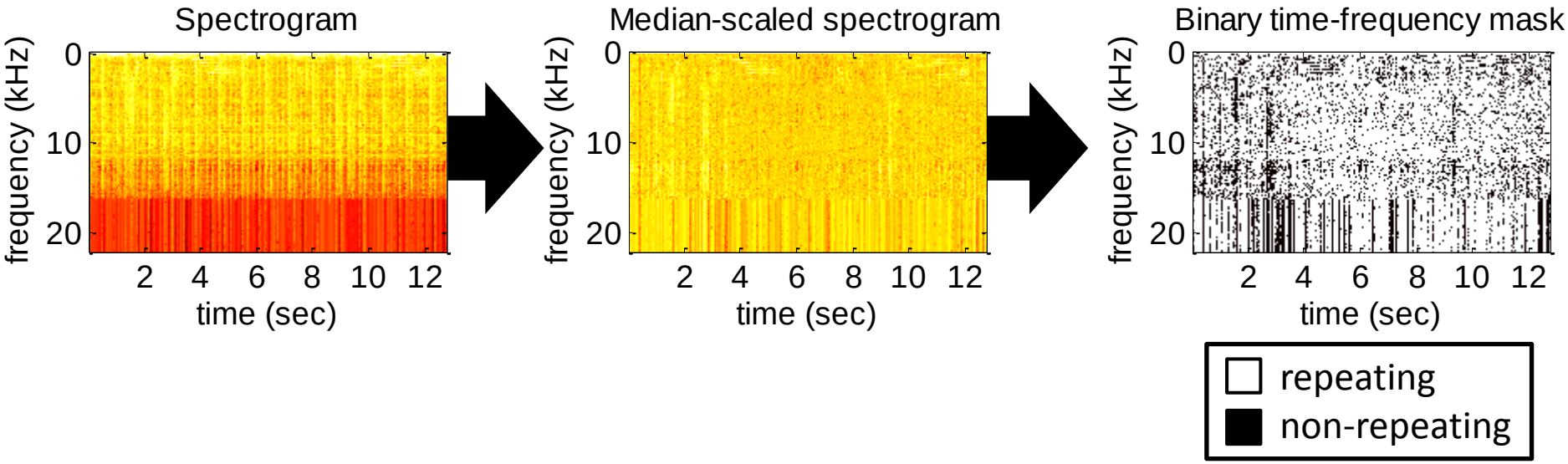


II. REPET – 3. Repeating Structure

- In practice, bins can overlap and repetitions can involve variations, therefore we introduced a **tolerance factor *T***



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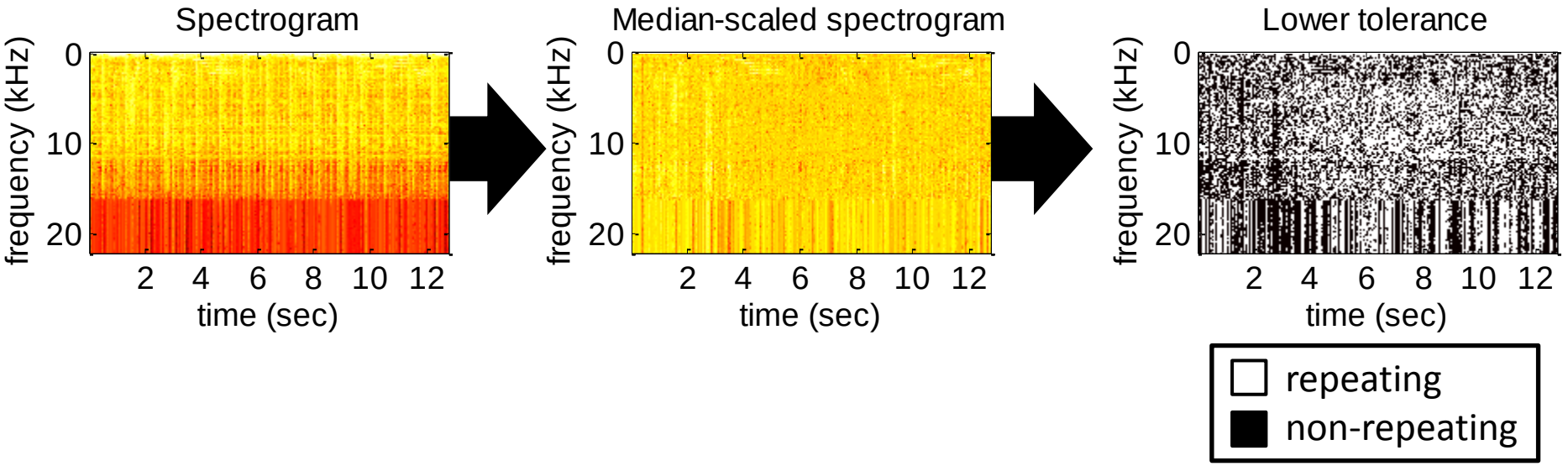

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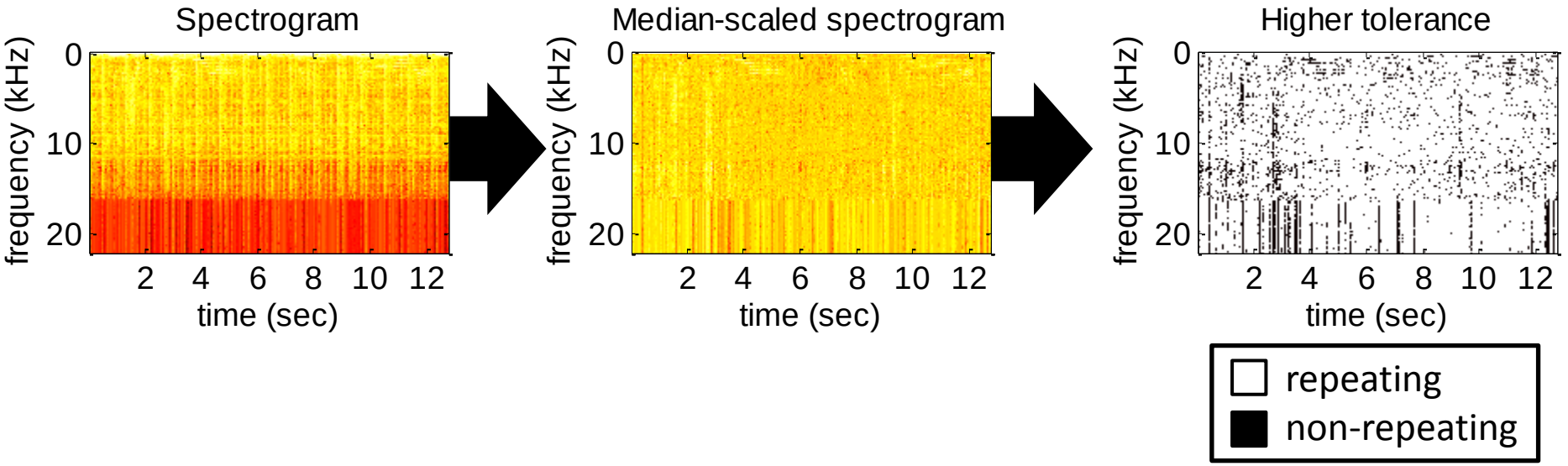
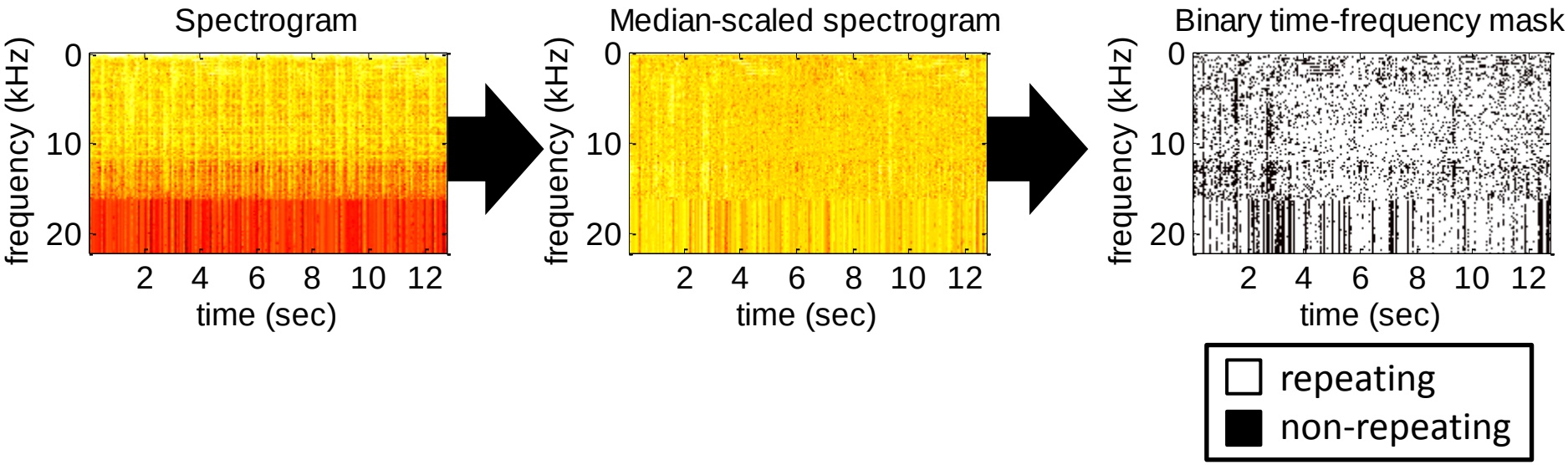


II. REPET – 3. Repeating Structure

- The **binary t-f mask** is used to extract the spectrogram of the underlying repeating structure



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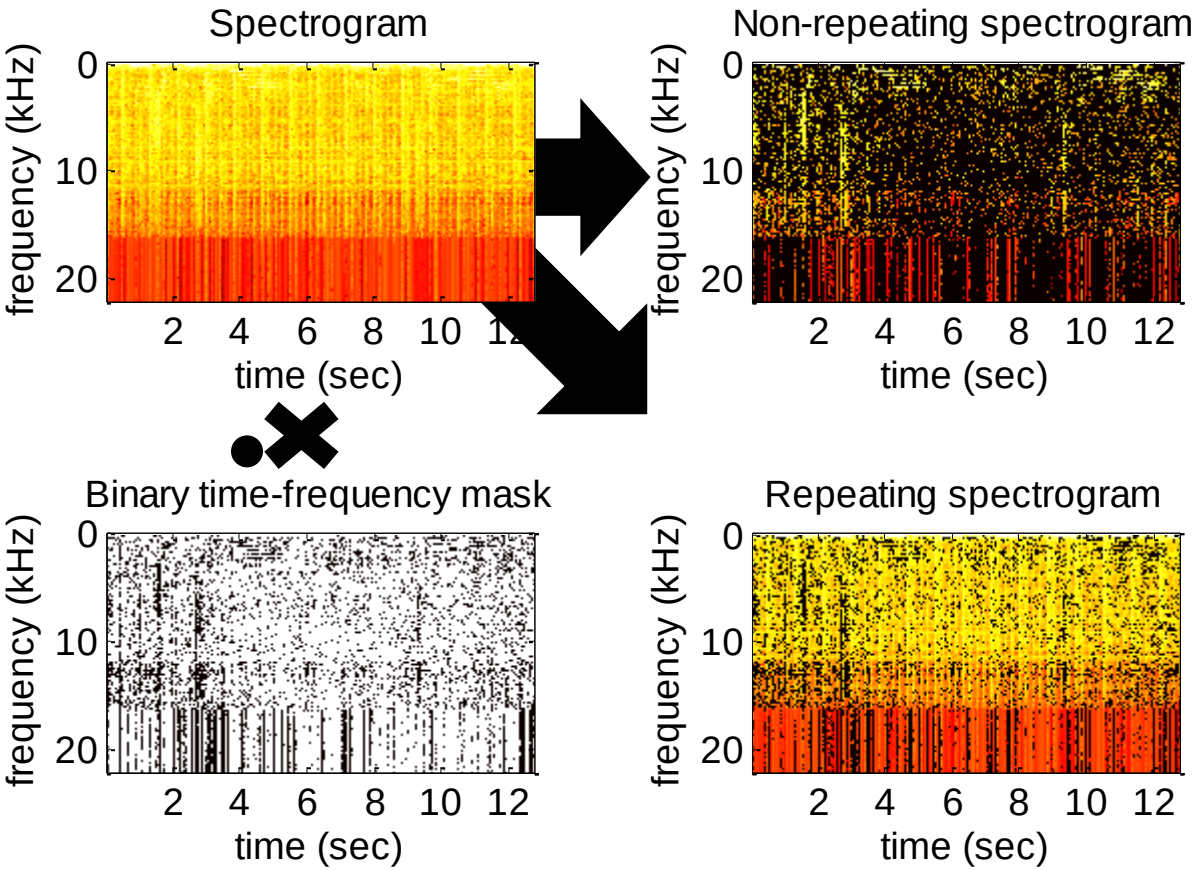
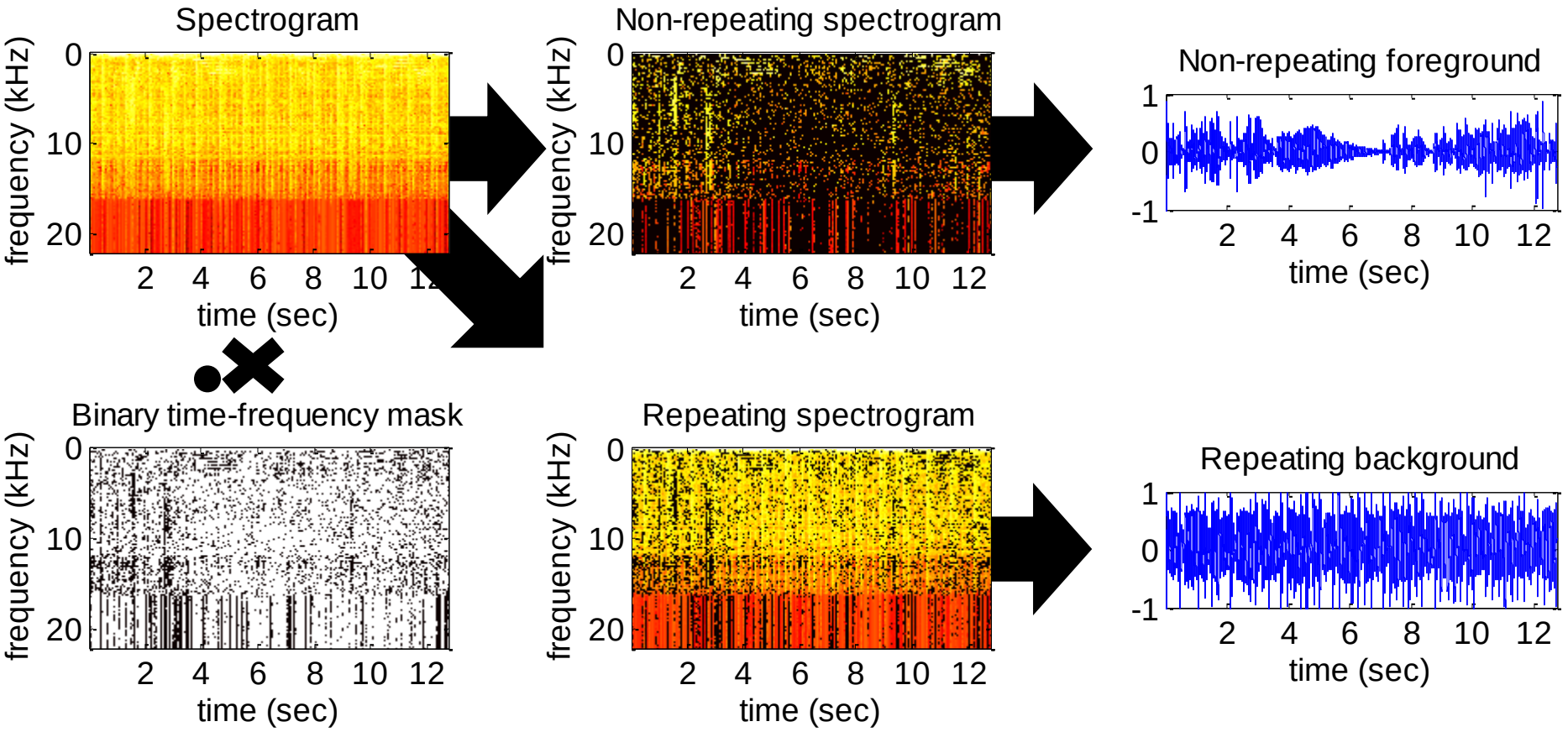


II. REPET – 3. Repeating Structure

- Finally, the audio signals can be reconstructed from their respective spectrograms



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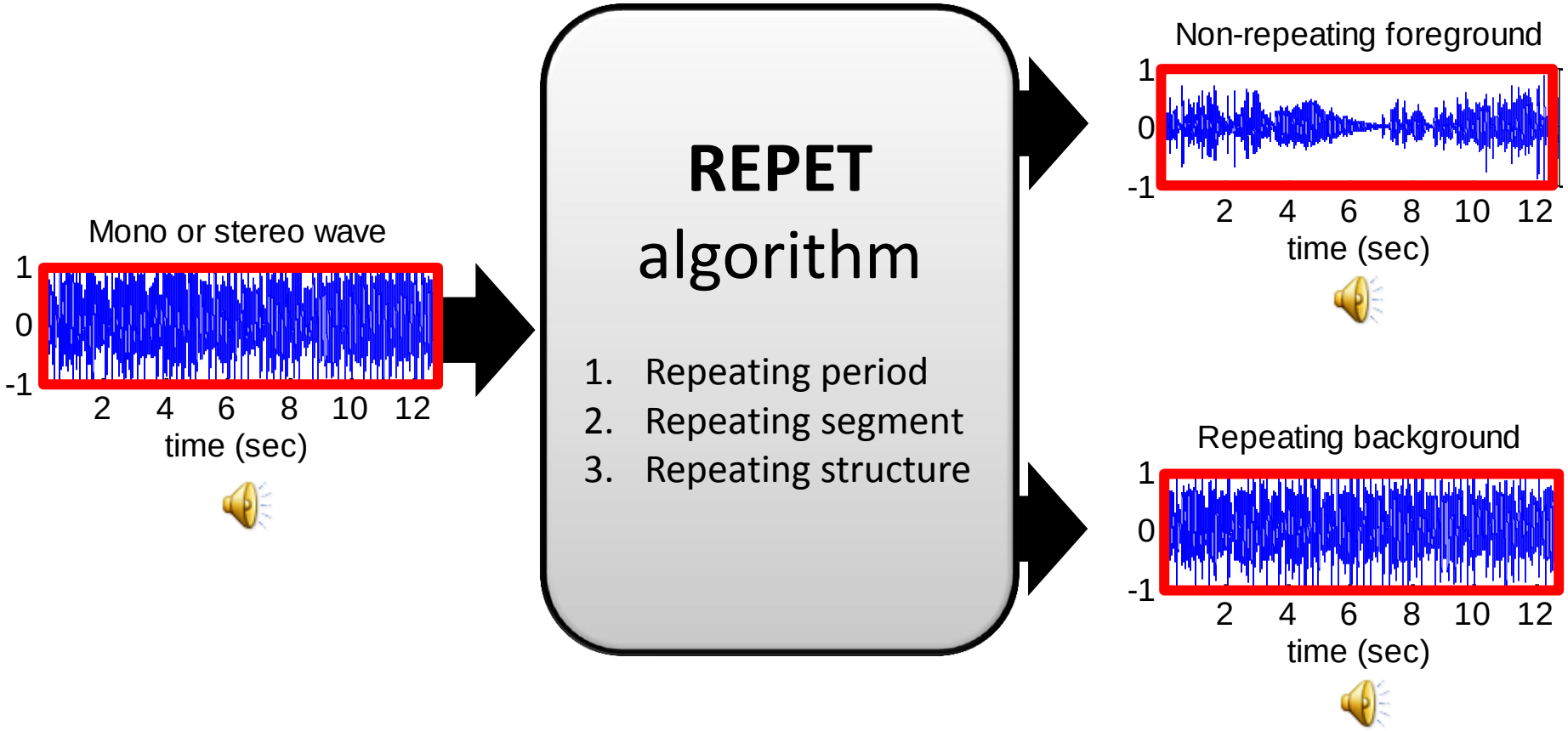
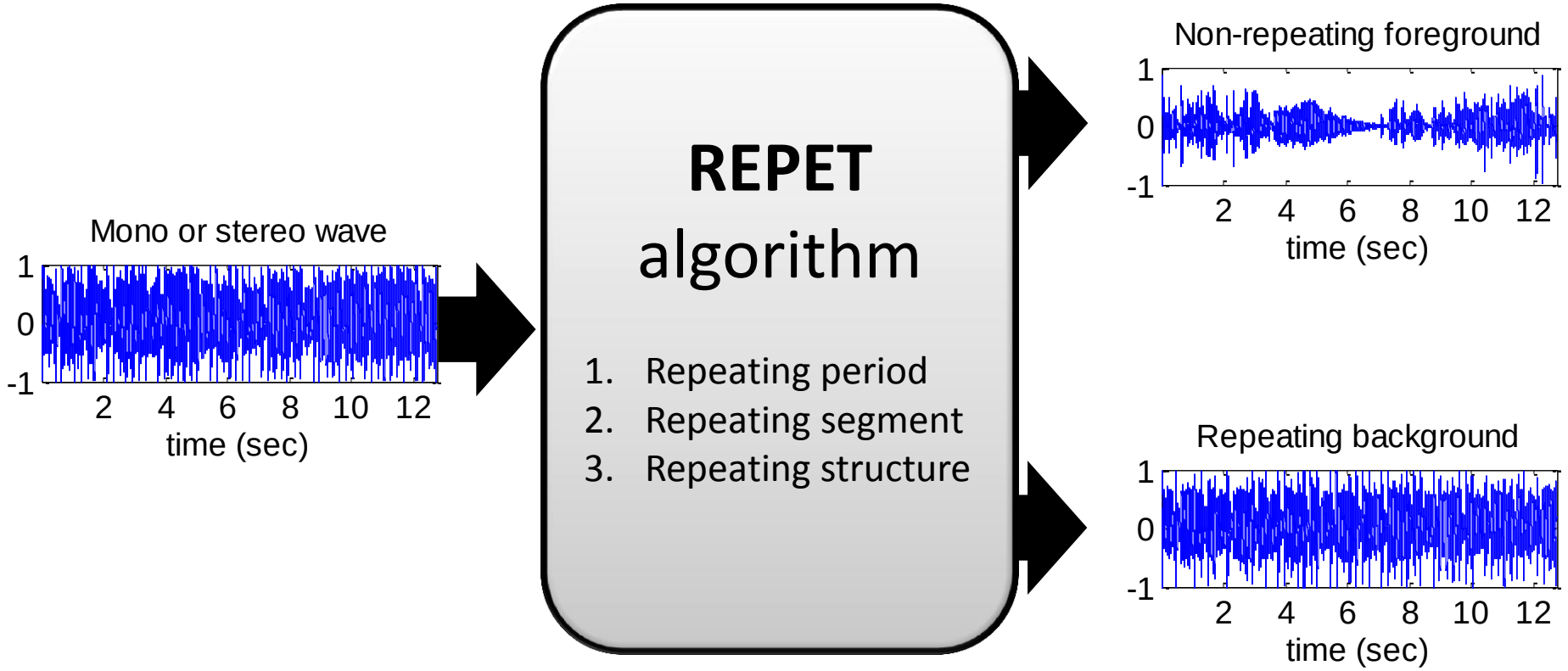


II. REPET – 3. Repeating Structure

- Overlying non-repeating structure ≈ **vocal foreground**
- Underlying repeating structure ≈ **musical background**



Plan

III. M/V separation – 1. Experiment

- There are only few papers dealing with m/v separation; the different approaches can be summarized as follows:

1. Non-negative Matrix Factorization (NMF)
   - Need to know the number of components
   - Need a proper initialization

2. Train spectra for accompaniment from non-vocal segments
   - Need vocal/non-vocal segmentation
   - Need sufficient amount of non-vocal frames

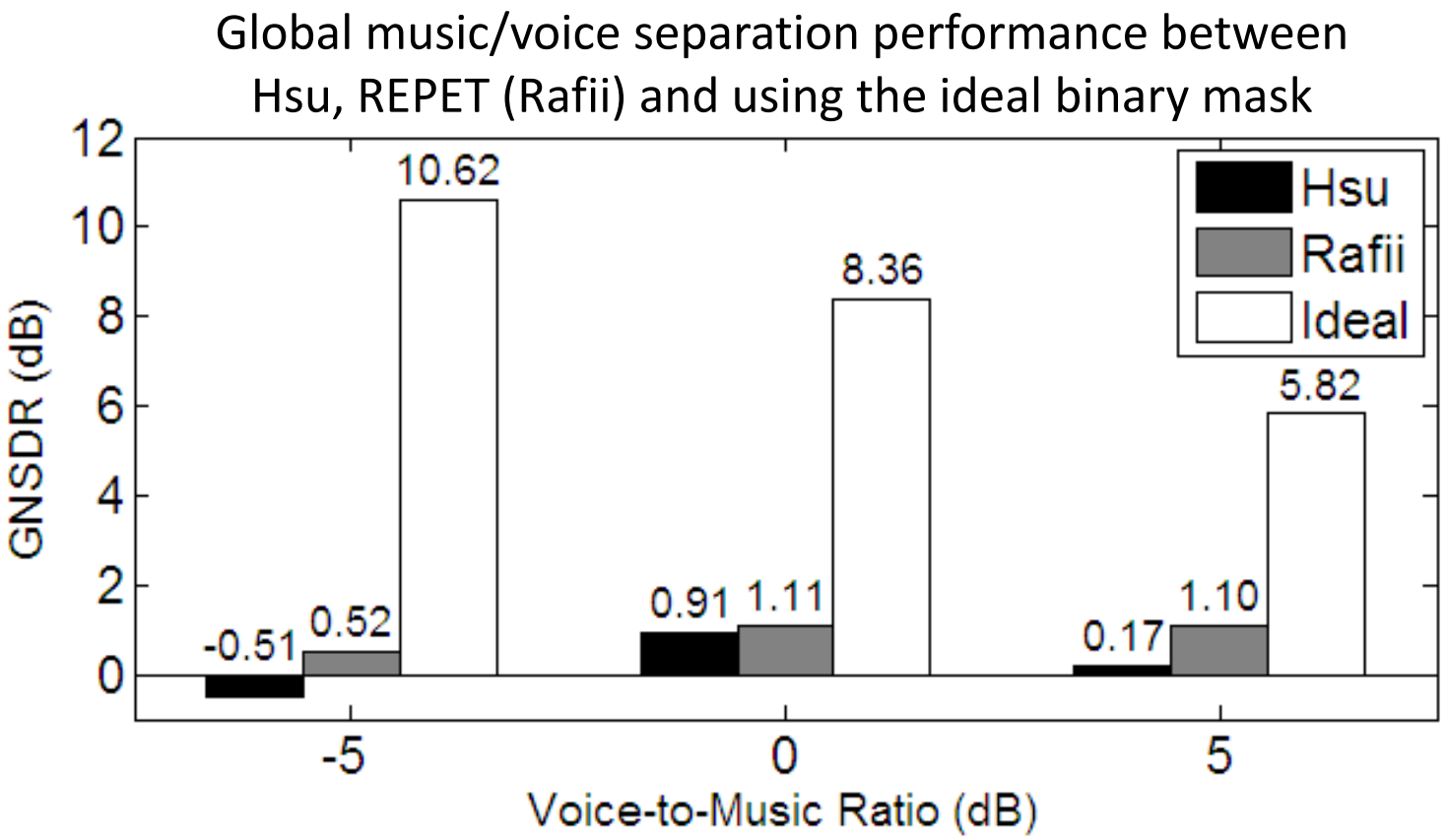
3. Pitch-based inference
   - Cannot extract unvoiced vocal frames
   - Harmonic structure of the instruments can interfere

III. M/V separation – 1. Experiment

- REPET vs. Hsu *et al.* [2010]:
  - Last state-of-the art m/v separation approach:
    - Vocals separation using pitch-based inference
    - Identification of unvoiced vocal frames
    - Spectral subtraction to eliminate interferences
  - Best automatic version of Hsu *et al.*:
    - Estimated pitch (not human-labeled)
    - Computer-detected unvoiced vocal frames (not human-labeled)
    - Voiced vocal enhancement (spectral subtraction)
  - Dataset:
    - 1,000 Chinese pop song clips
    - 3 sets of mixtures for 3 different "voice-to-music ratio" (-5, 0, 5 dB)

III. M/V separation – 1. Experiment

- REPET vs. Hsu *et al.* [2010]:



Rafii & Pardo, ICASSP 2011

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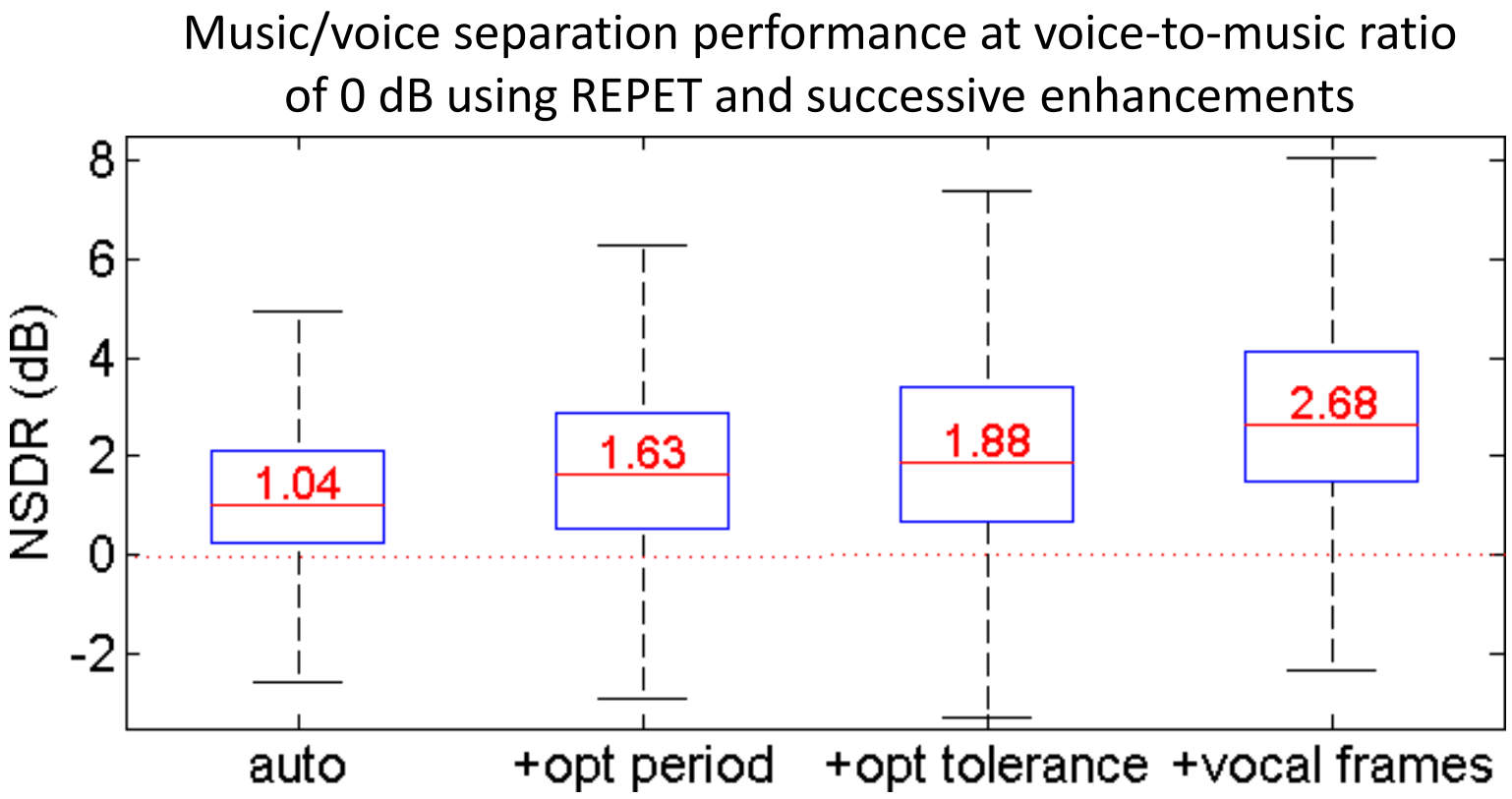

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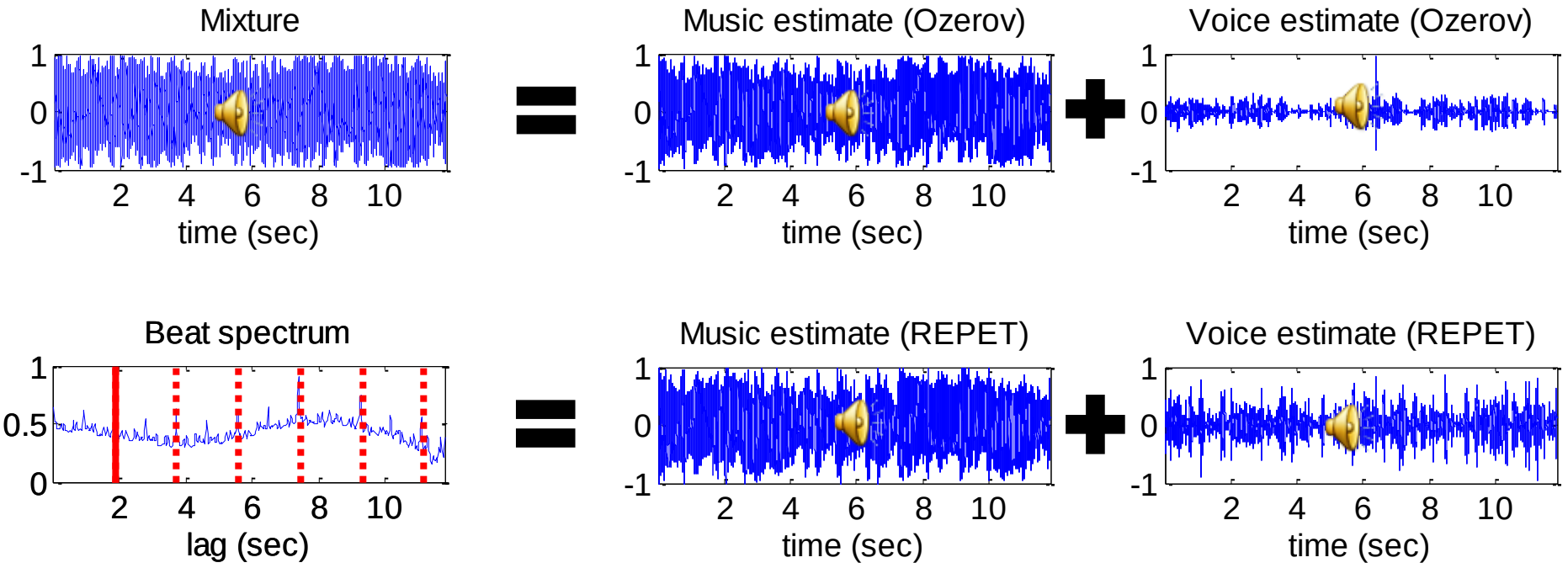
III. Music/Voice – 2. Examples

- REPET vs. Ozerov *et al.* [2008]:
  - Adapt accompaniment model from non-vocal frames

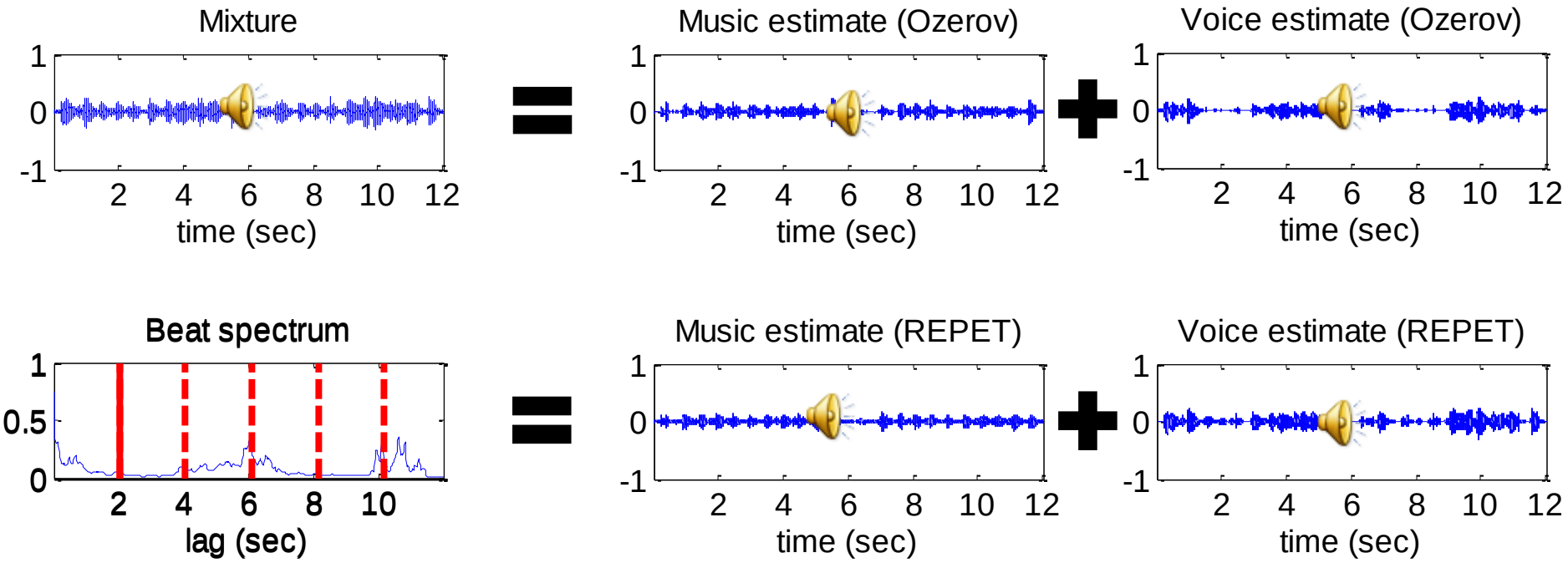
1. The Prodigy – Breathe



III. Music/Voice – 2. Examples

- REPET vs. Ozerov *et al.* [2008]:
  - Adapt accompaniment model from non-vocal frames

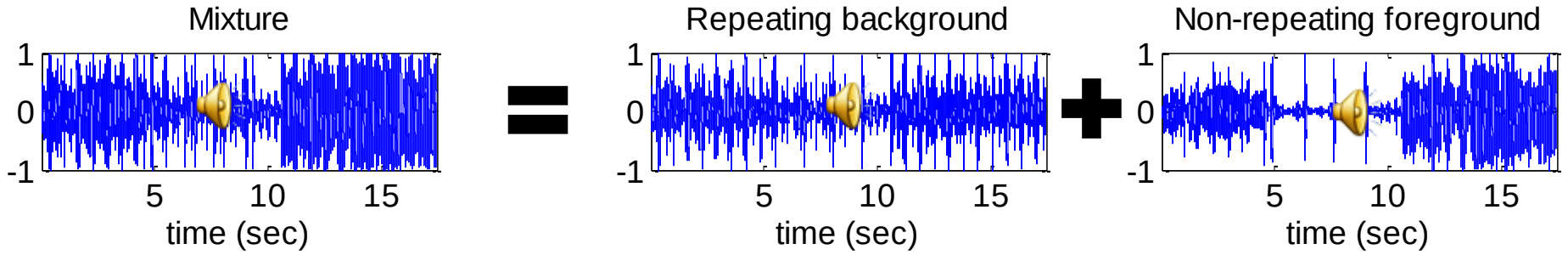
2. The Doors – People are strange



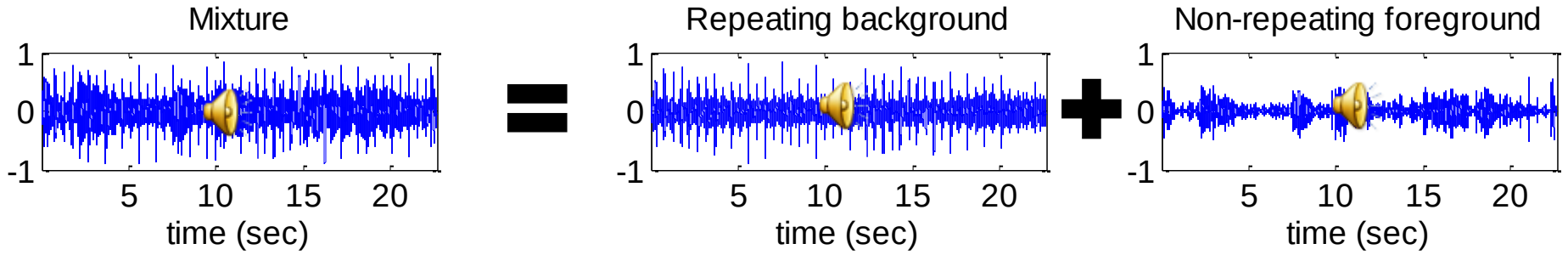
III. Music/Voice – 2. Examples

- More audio examples:

3. RJD2 – Ghostwriter (no vocals)



4. The Blues Brothers – Sweet Home Chicago ☺



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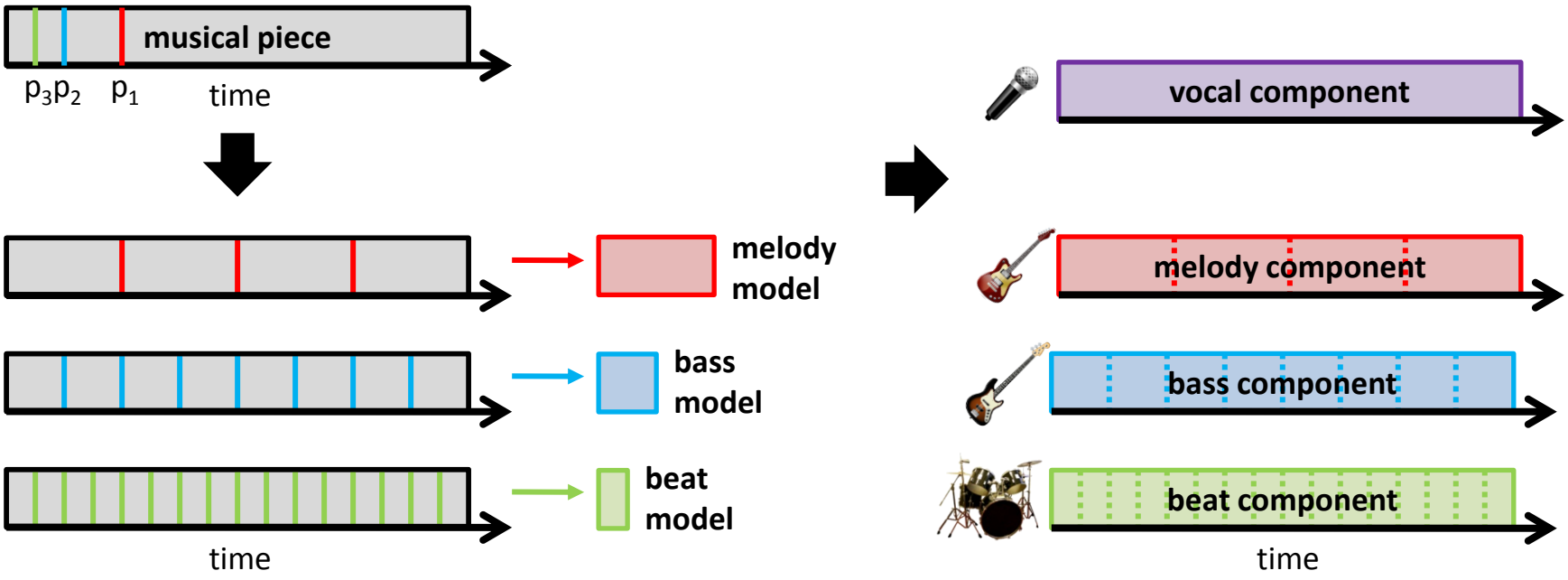
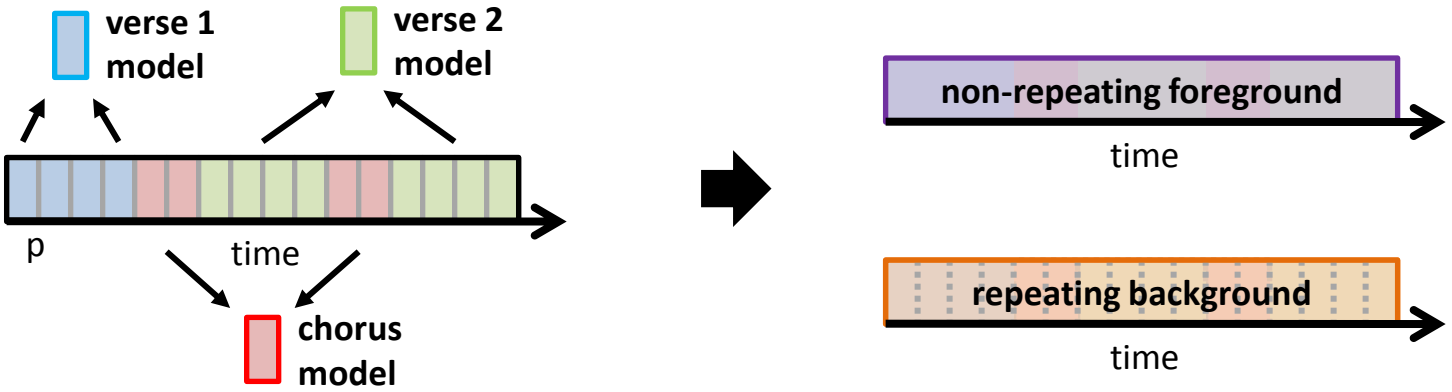
III. Music/Voice – 3. Future

- Extraction of a hierarchical repeating structure:
  - Extract multiple repeating layers at different period rates



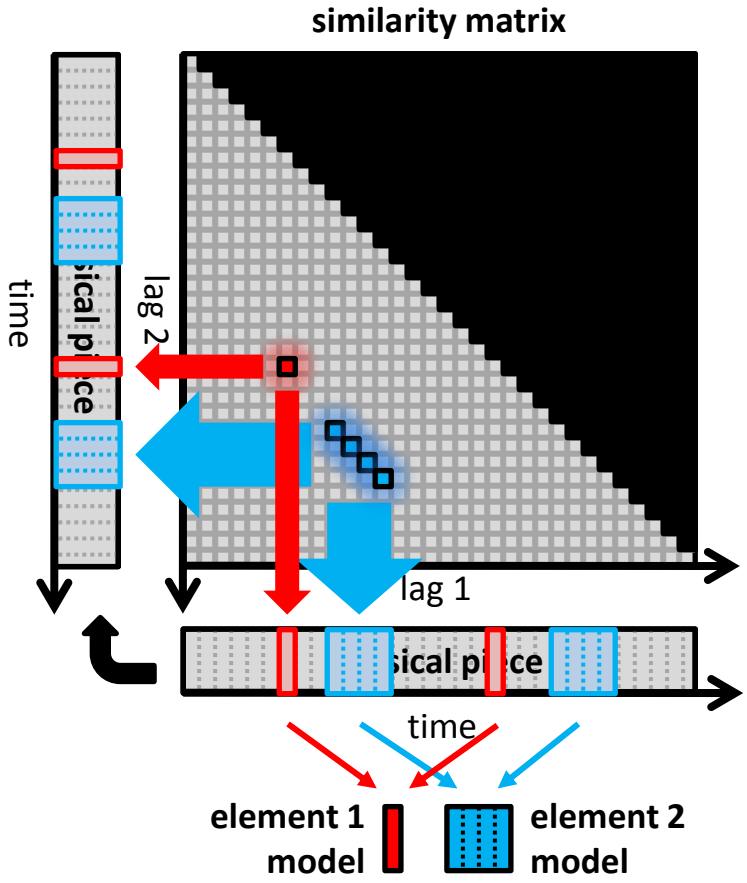
III. Music/Voice – 3. Future

- Use of a smart segmentation:
  - Model different repeating segments from/for different regions



III. Music/Voice – 3. Future

- Use of a similarity matrix:
  - Identify and extract individual repeating elements



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IV. Conclusion

- **REPET**: REpeating Pattern Extraction Technique

- **Music/voice separation** by extraction of the underlying repeating musical structure

- Strengths:
  - Simple
  - Fast
  - Blind
  - Automatable
  - Promising…

Questions ?