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. Identify a repeating period
2. Model a repeating segment
3. Extract the repeating structure

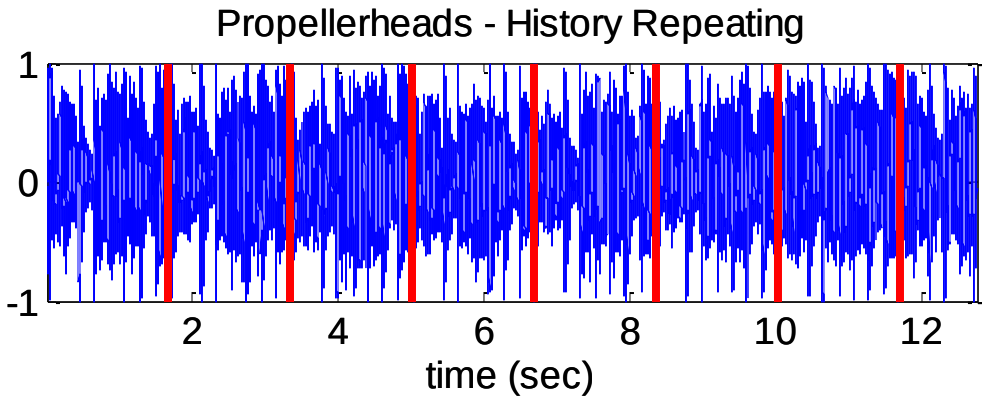
III. Music/Voice Separation

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

IV. Conclusion

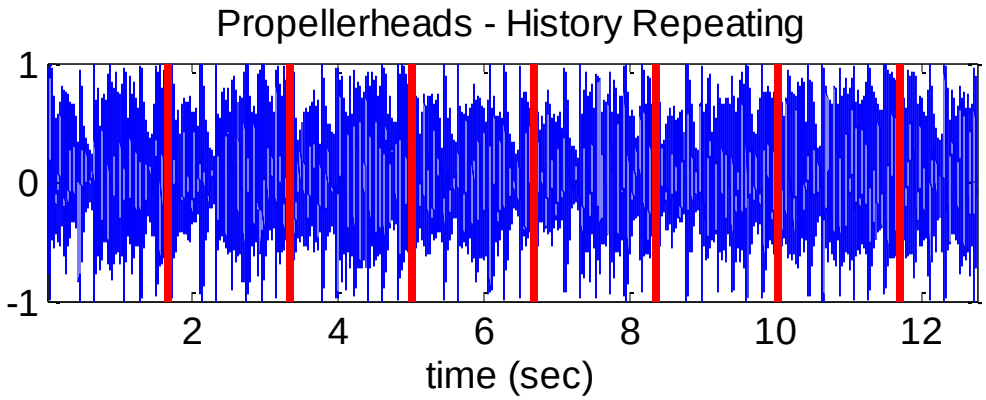
I. Introduction

- **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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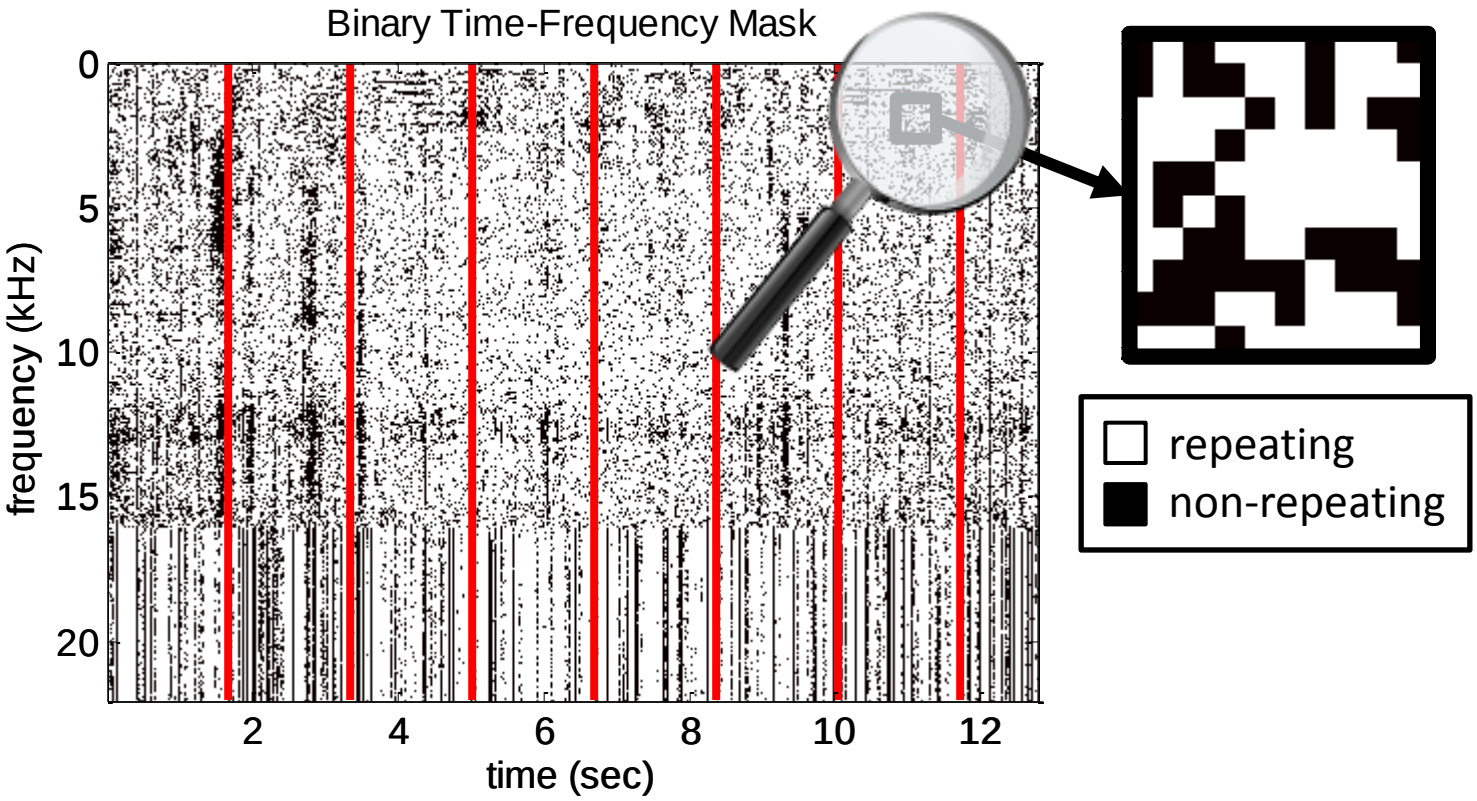


I. Introduction

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

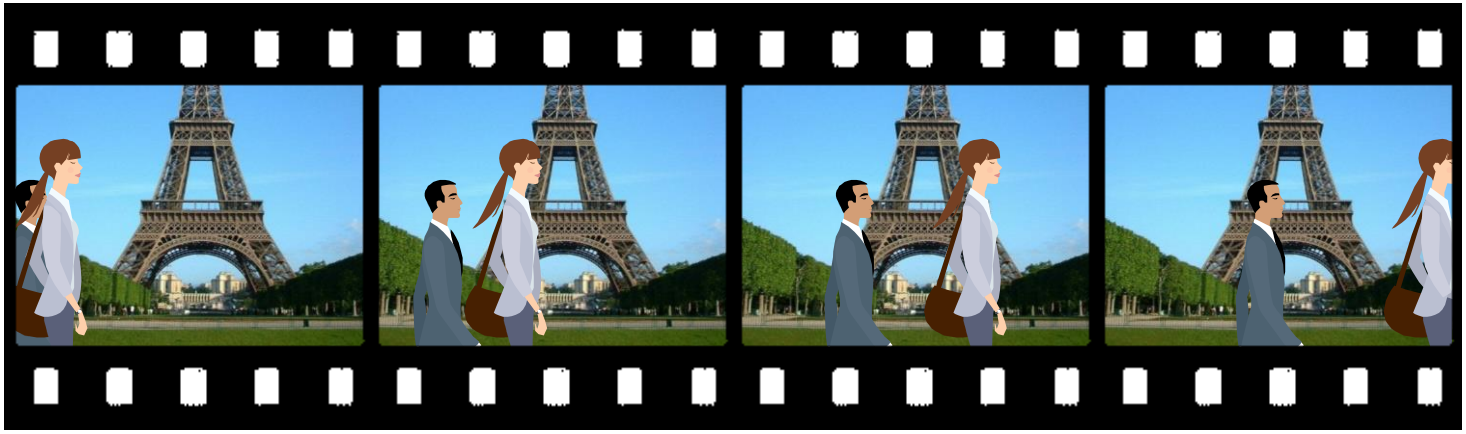
- **Method**: REpeating Patterns Extraction Technique (REPET)
  1. Identify a repeating period
  2. Model a repeating segment
  3. Extract the repeating structure

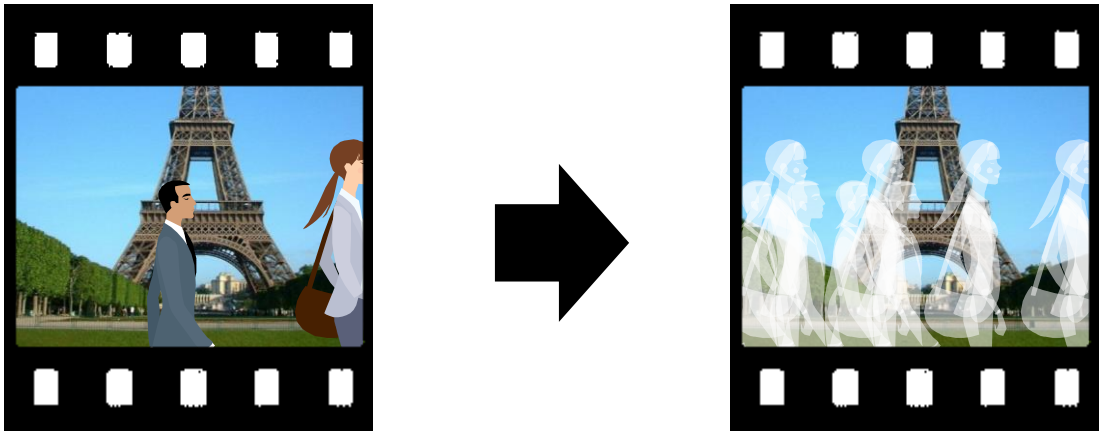
- **Result**: a simple music/voice separation system!
  - The underlying repeating structure ≈ *musical "background"*
  - The overlying non-repeating structure ≈ *vocal "foreground"*

I. Introduction

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

1. Compare frames to estimate a "background model"

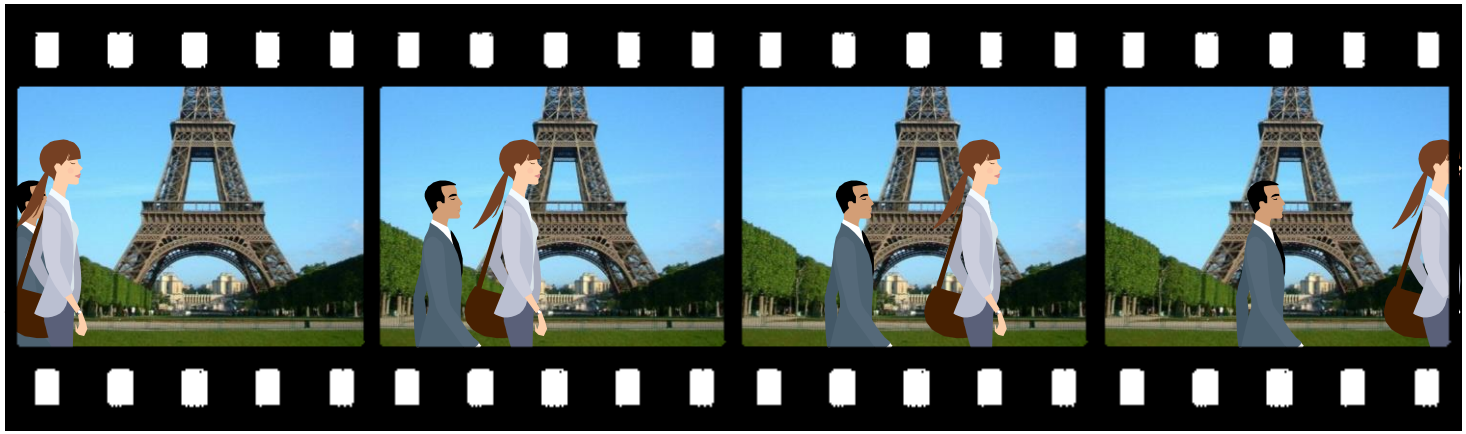




I. Introduction

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

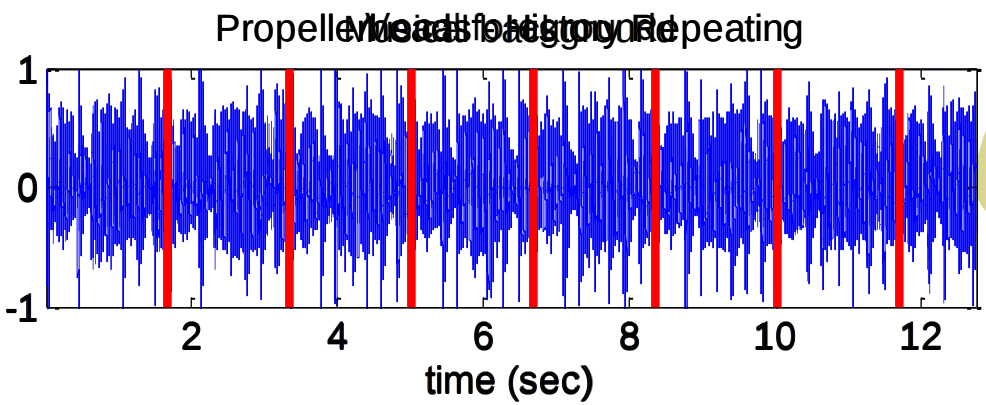
2. Extract the "background" from the "foreground"



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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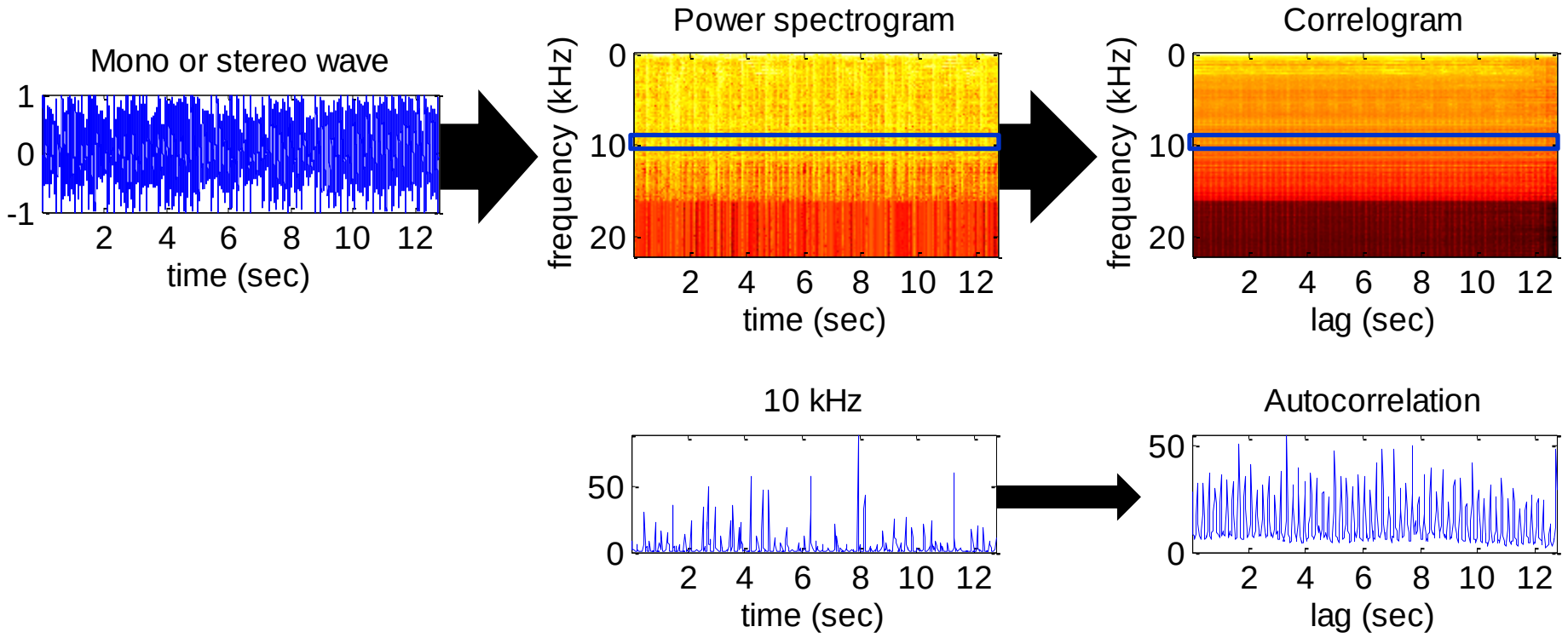
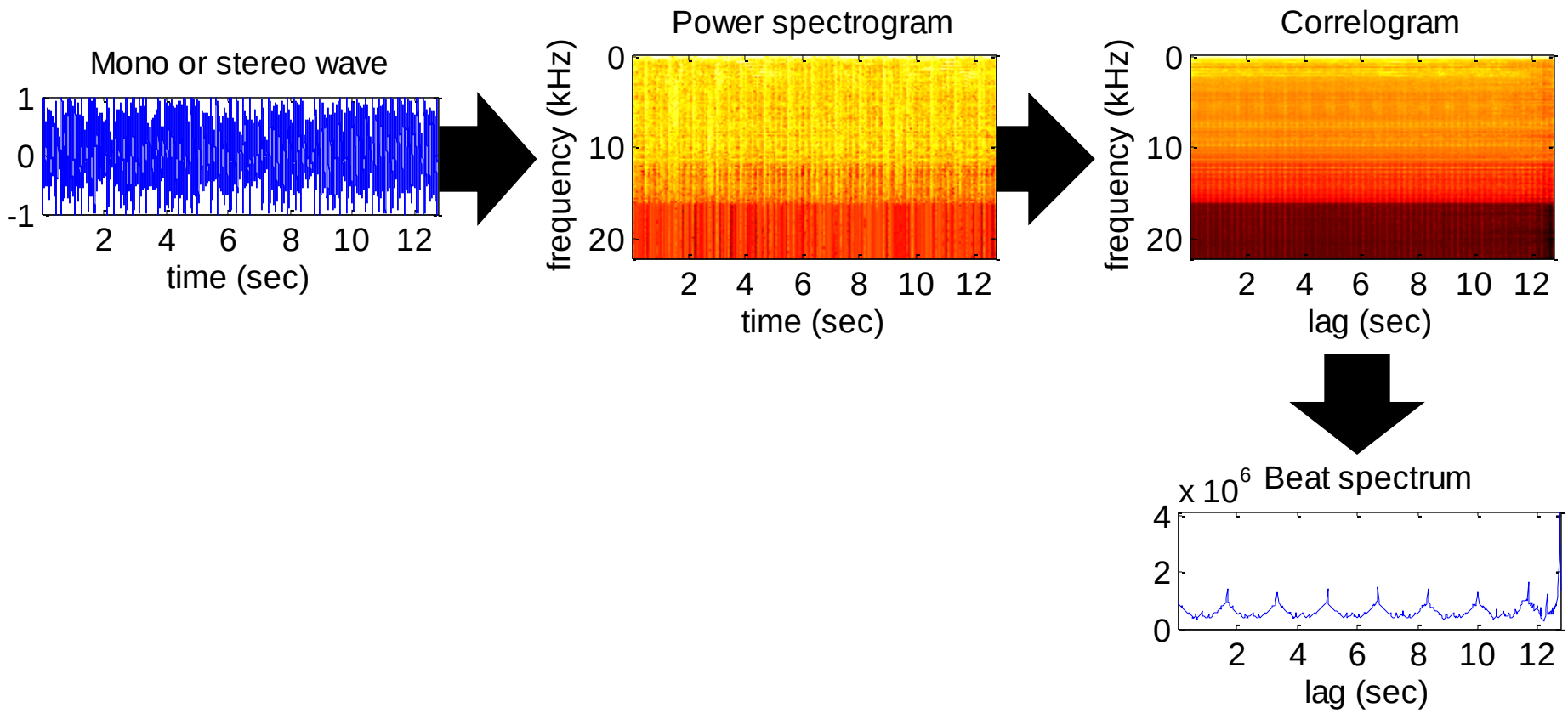
II. REPET – 1. Repeating Period

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



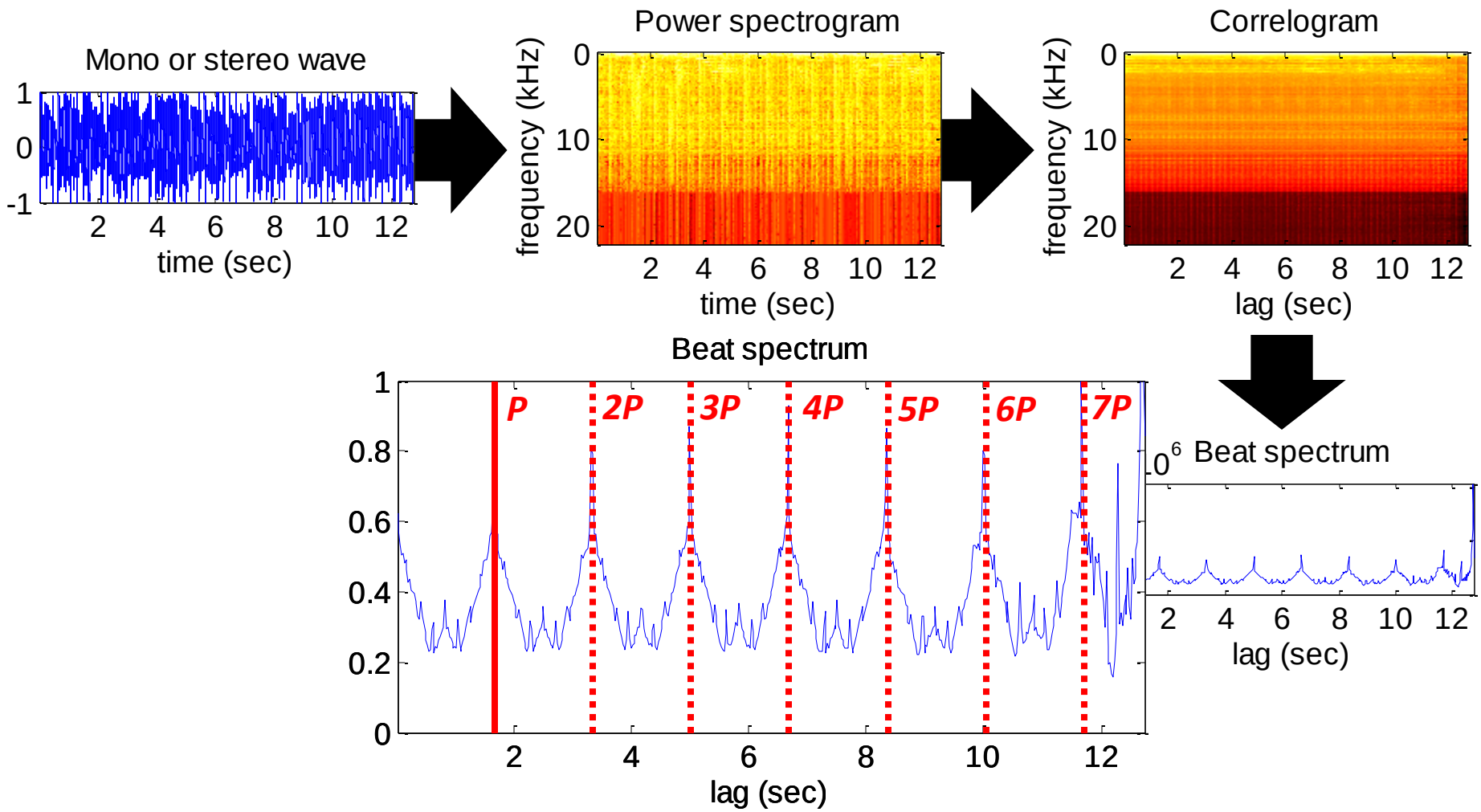
II. REPET – 1. Repeating Period

- 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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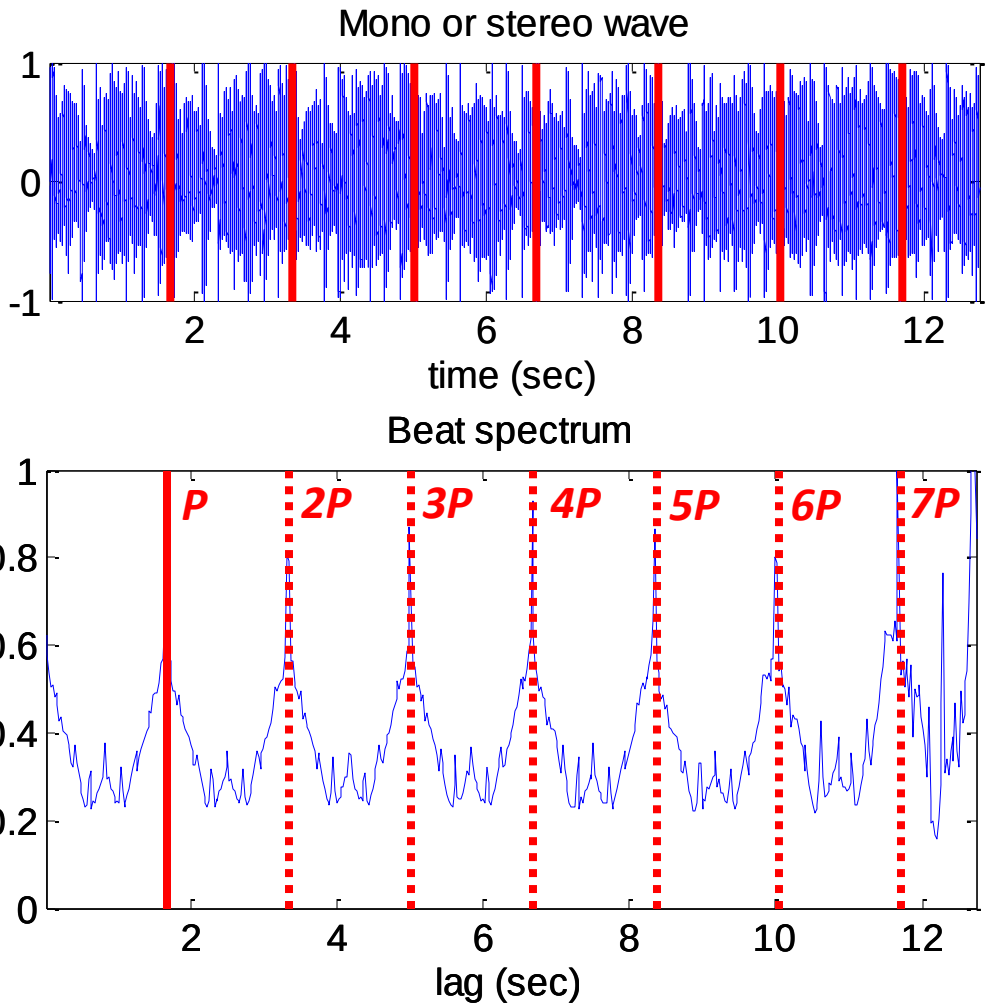

Plan

I. Introduction

II. **REPET Algorithm**

1. Repeating period
2. Repeating segment
3. Repeating structure

III. Music/Voice Separation

1. Evaluation
2. Examples
3. Future

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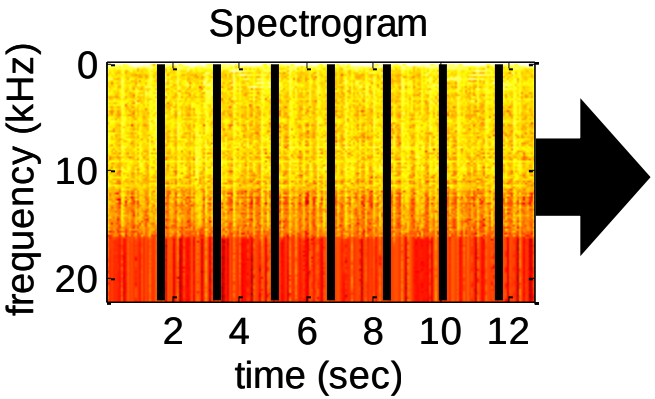
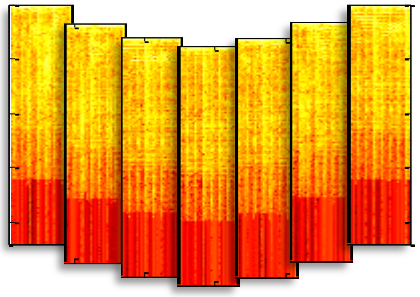
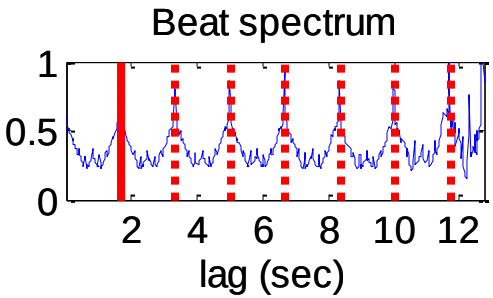
II. REPET – 2. Repeating Segment

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

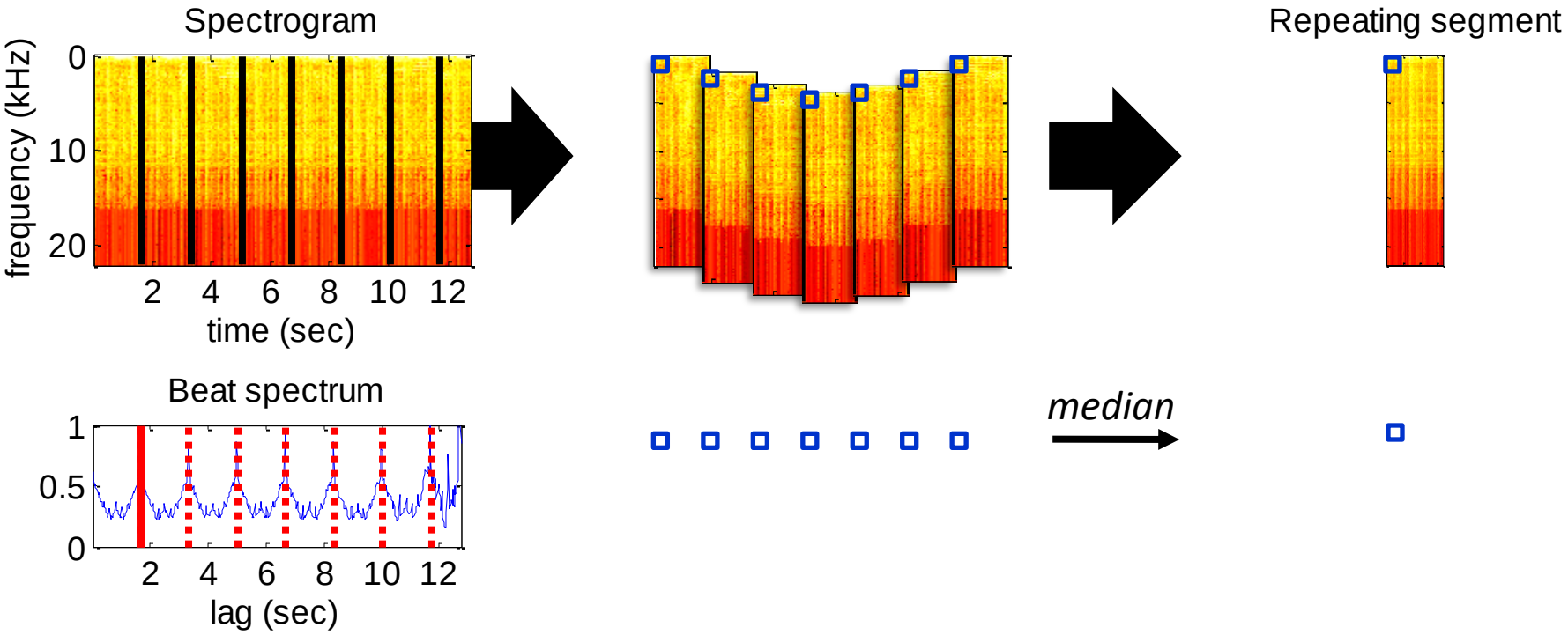






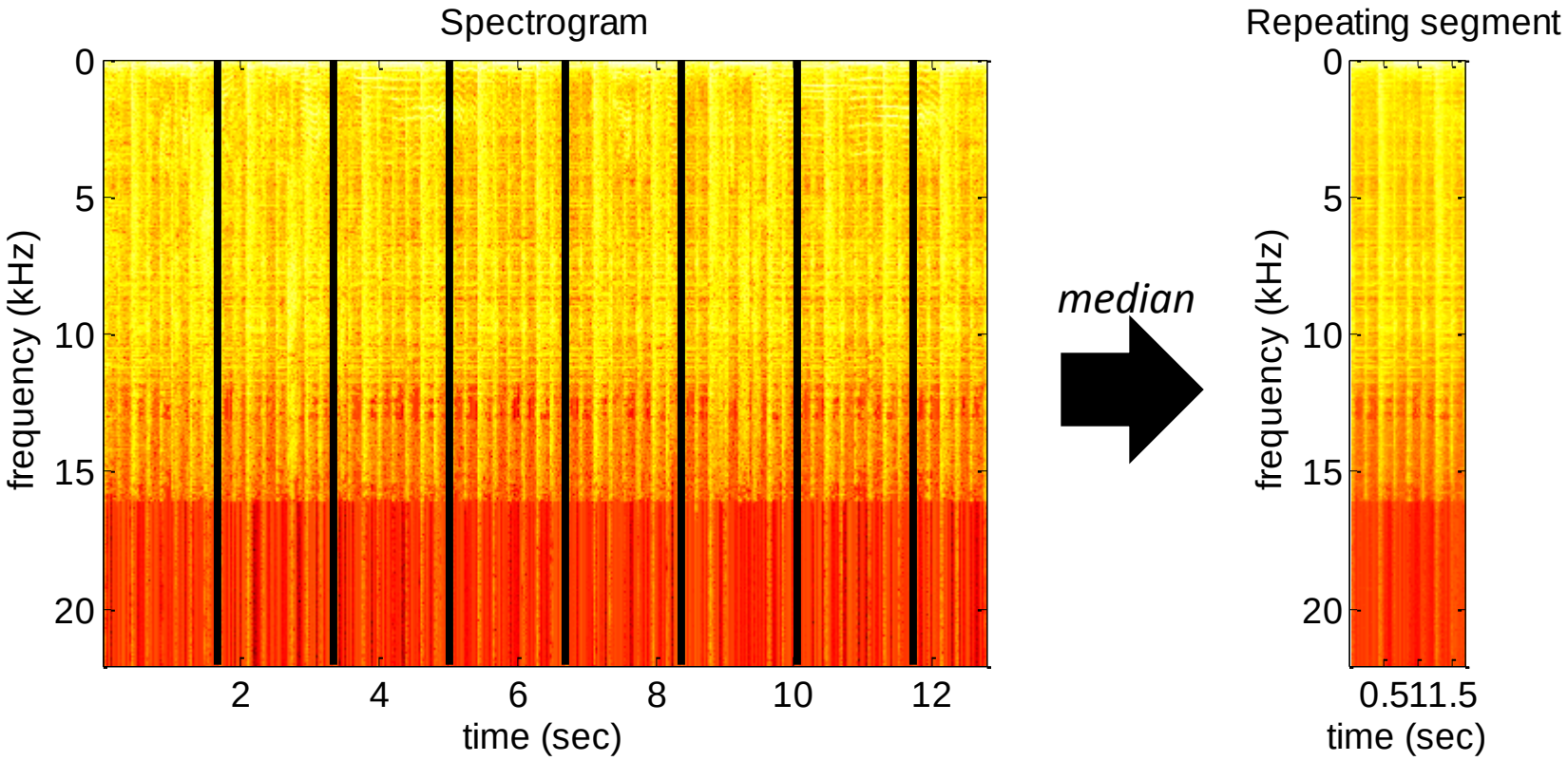
II. REPET – 2. Repeating Segment

- 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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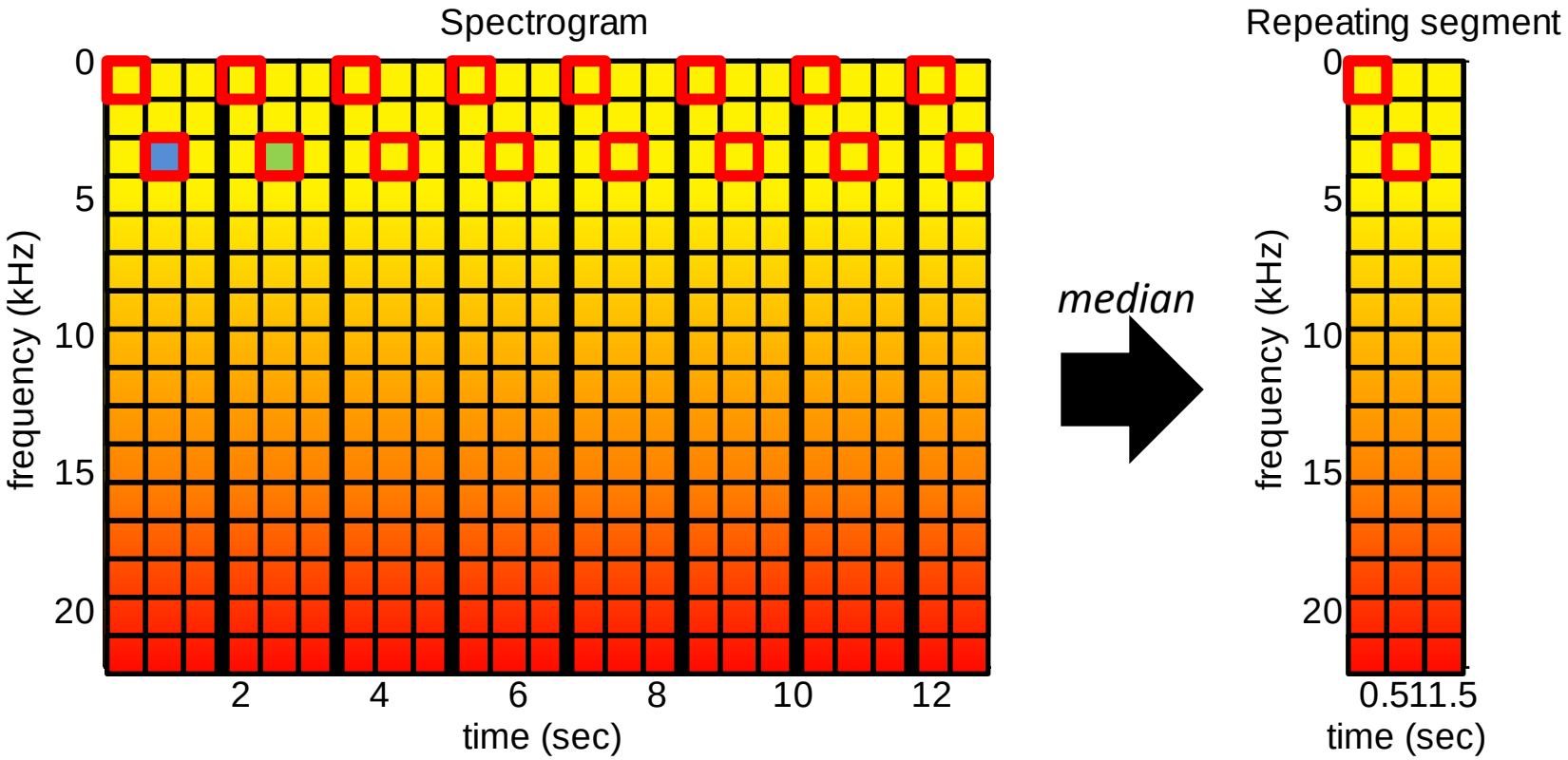

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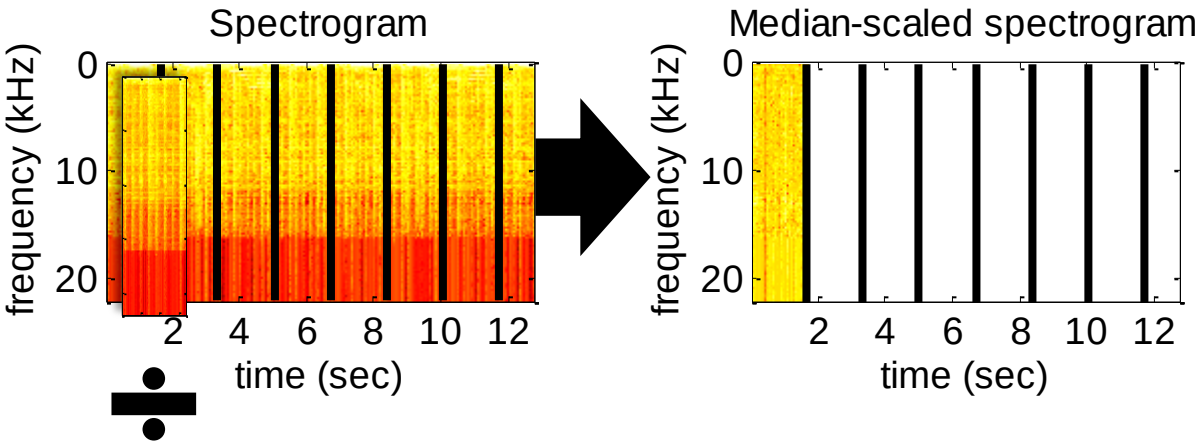
II. REPET – 3. Repeating Structure

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



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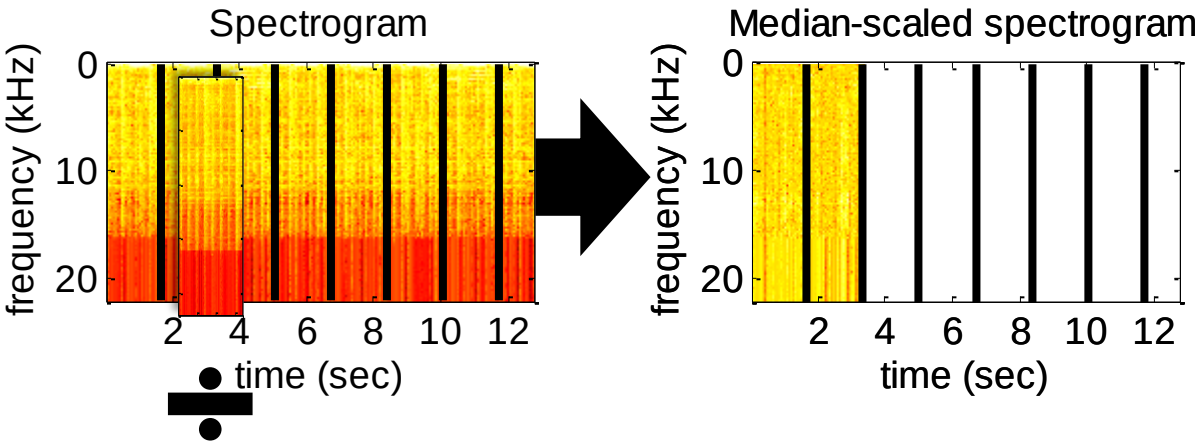

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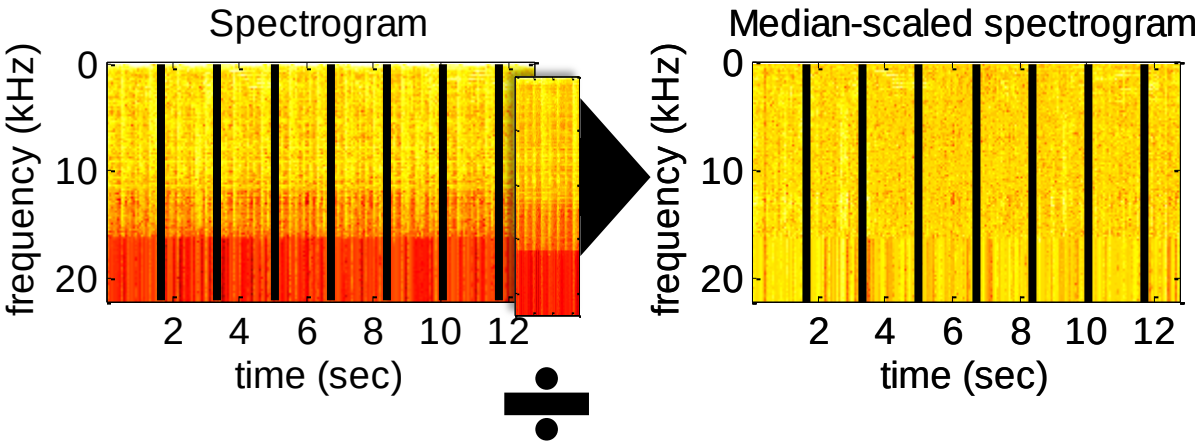
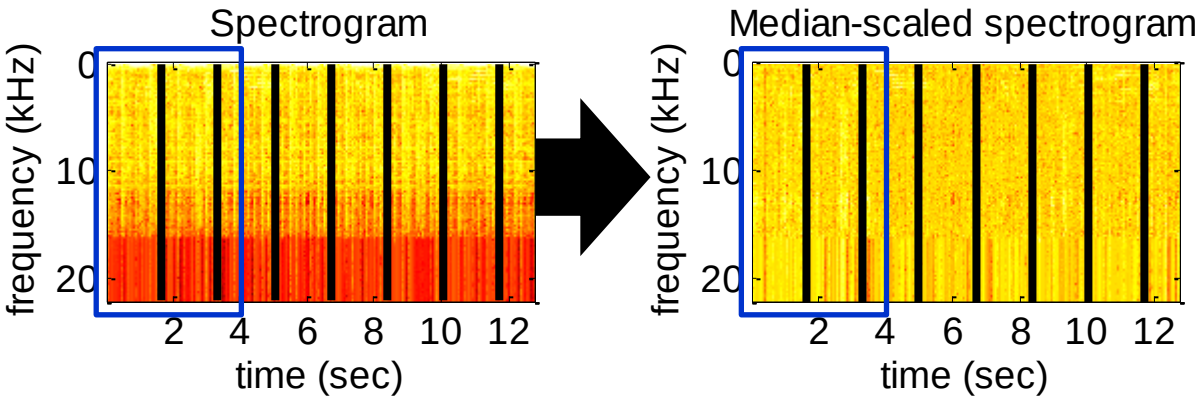


II. REPET – 3. Repeating Structure

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



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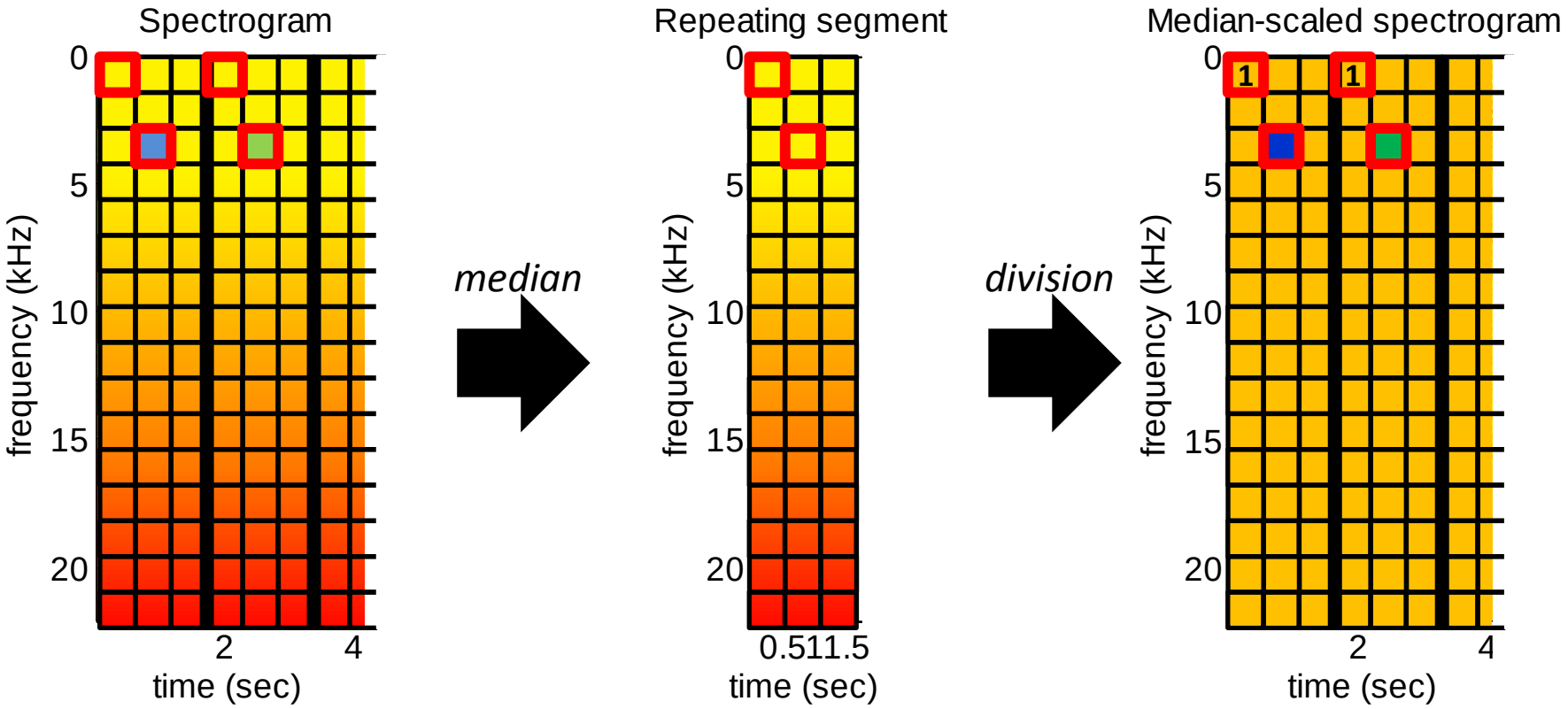
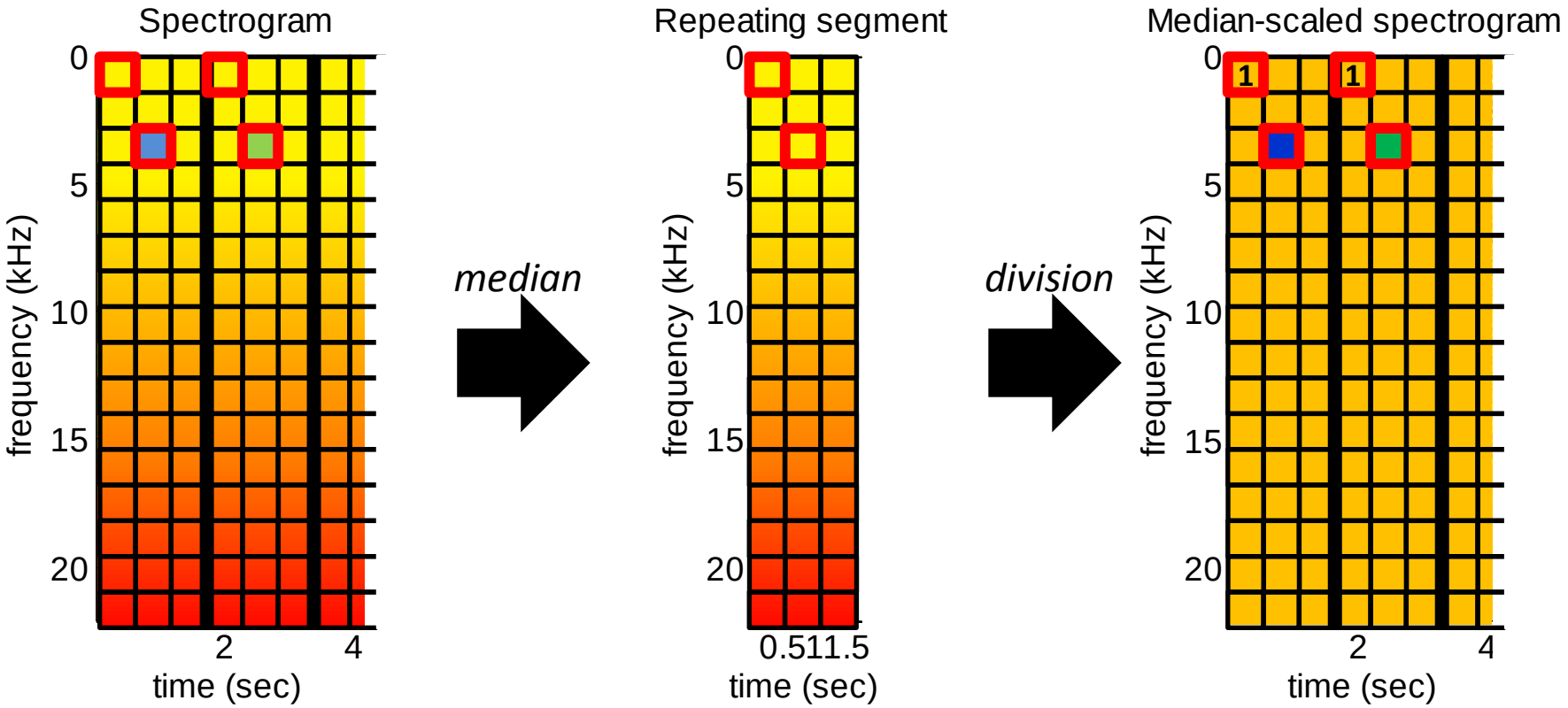


II. REPET – 3. Repeating Structure

- 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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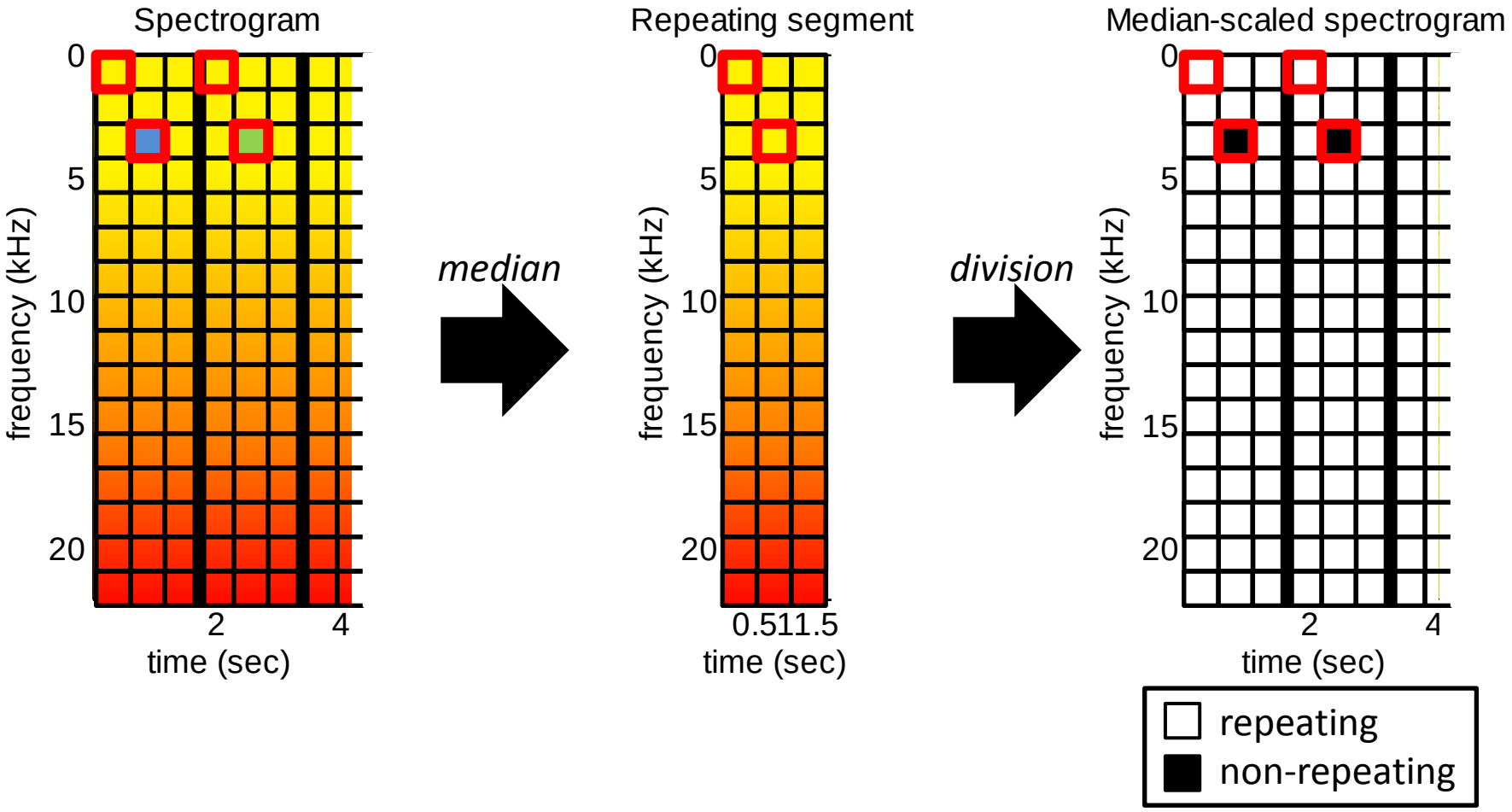

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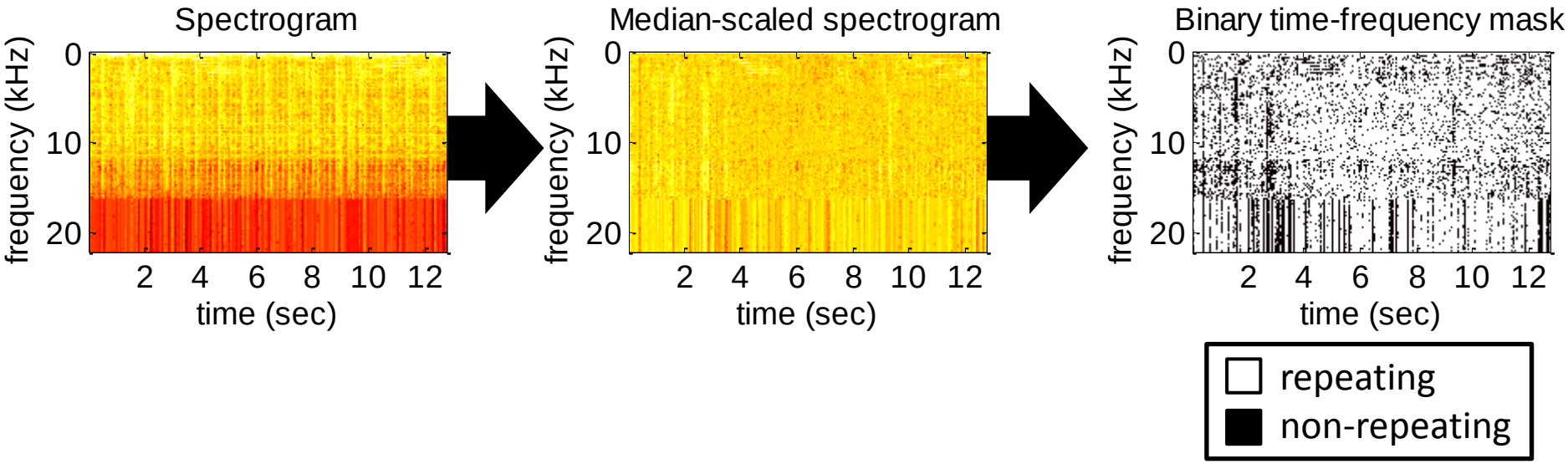
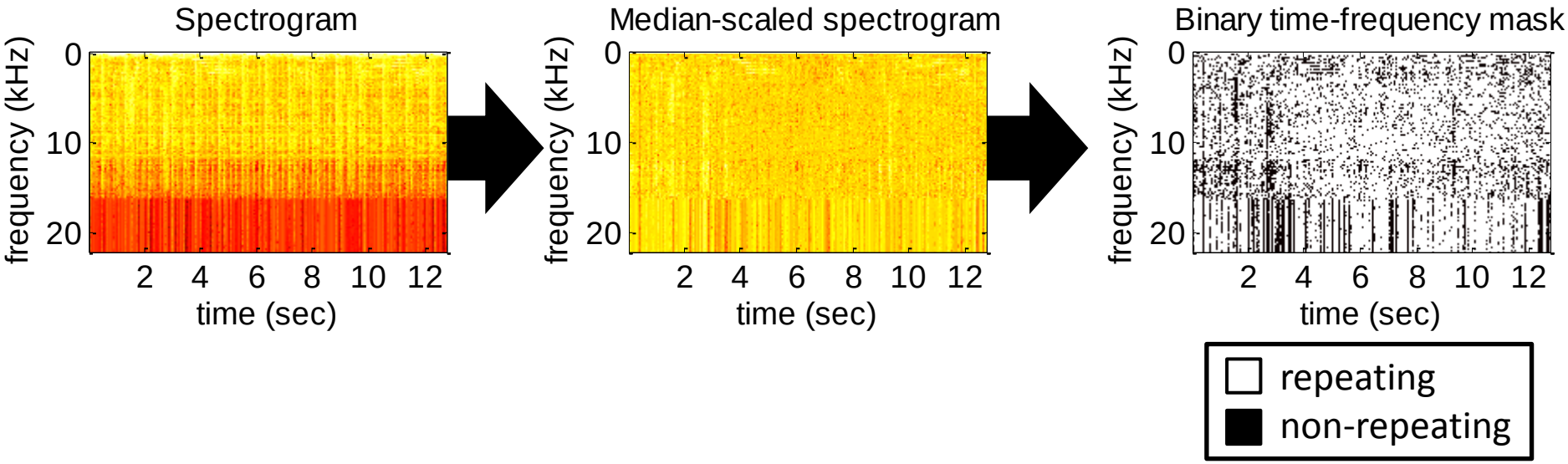


II. REPET – 3. Repeating Structure

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



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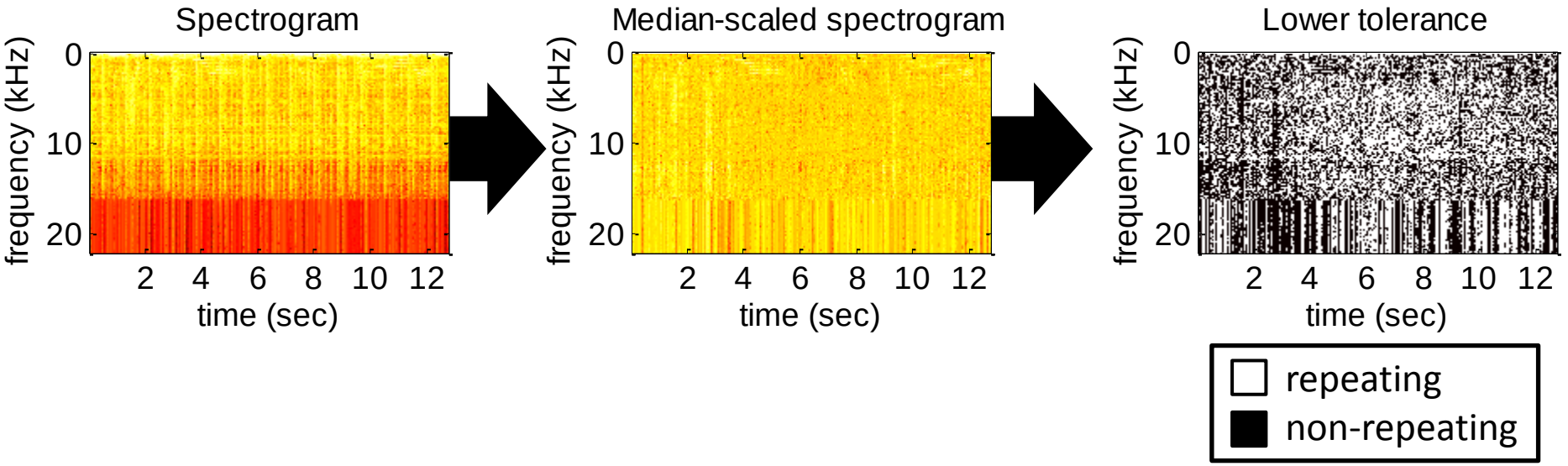

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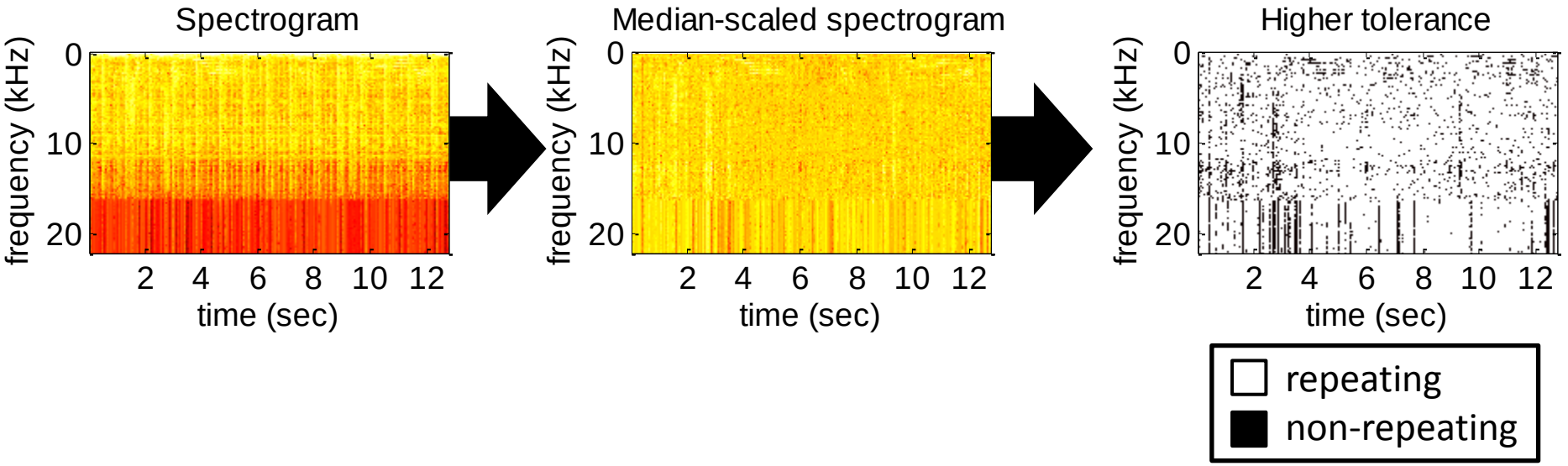
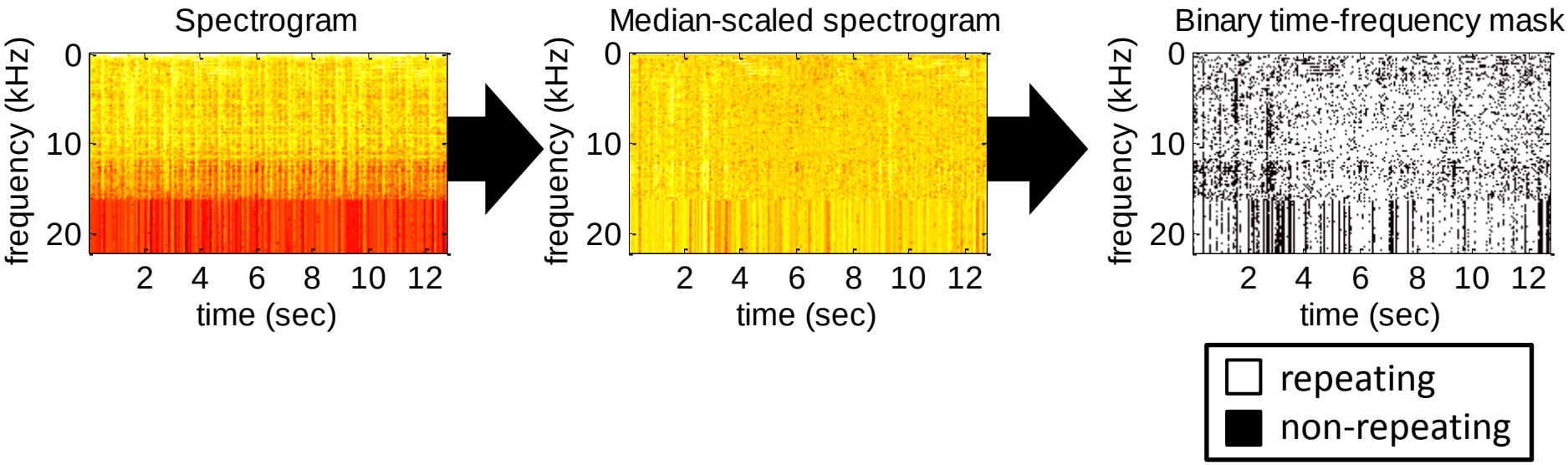


II. REPET – 3. Repeating Structure

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



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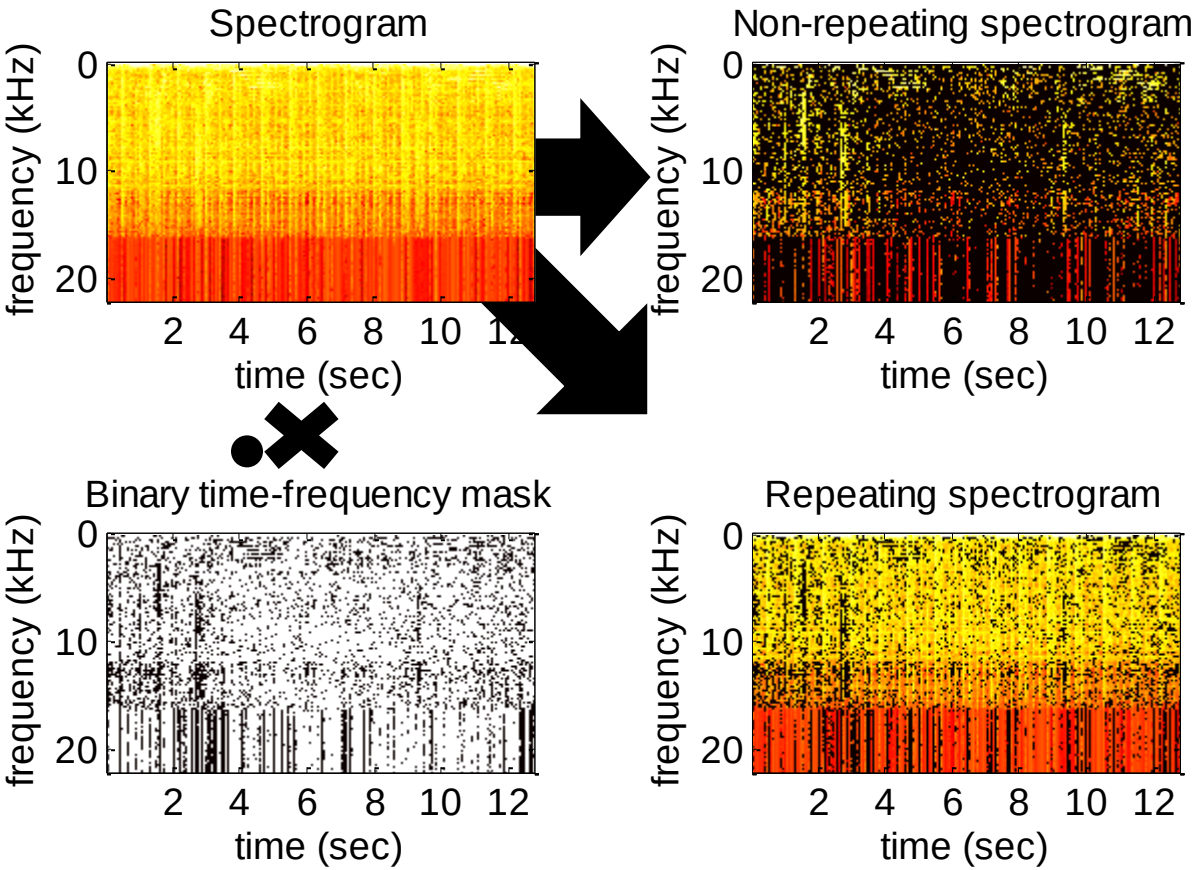
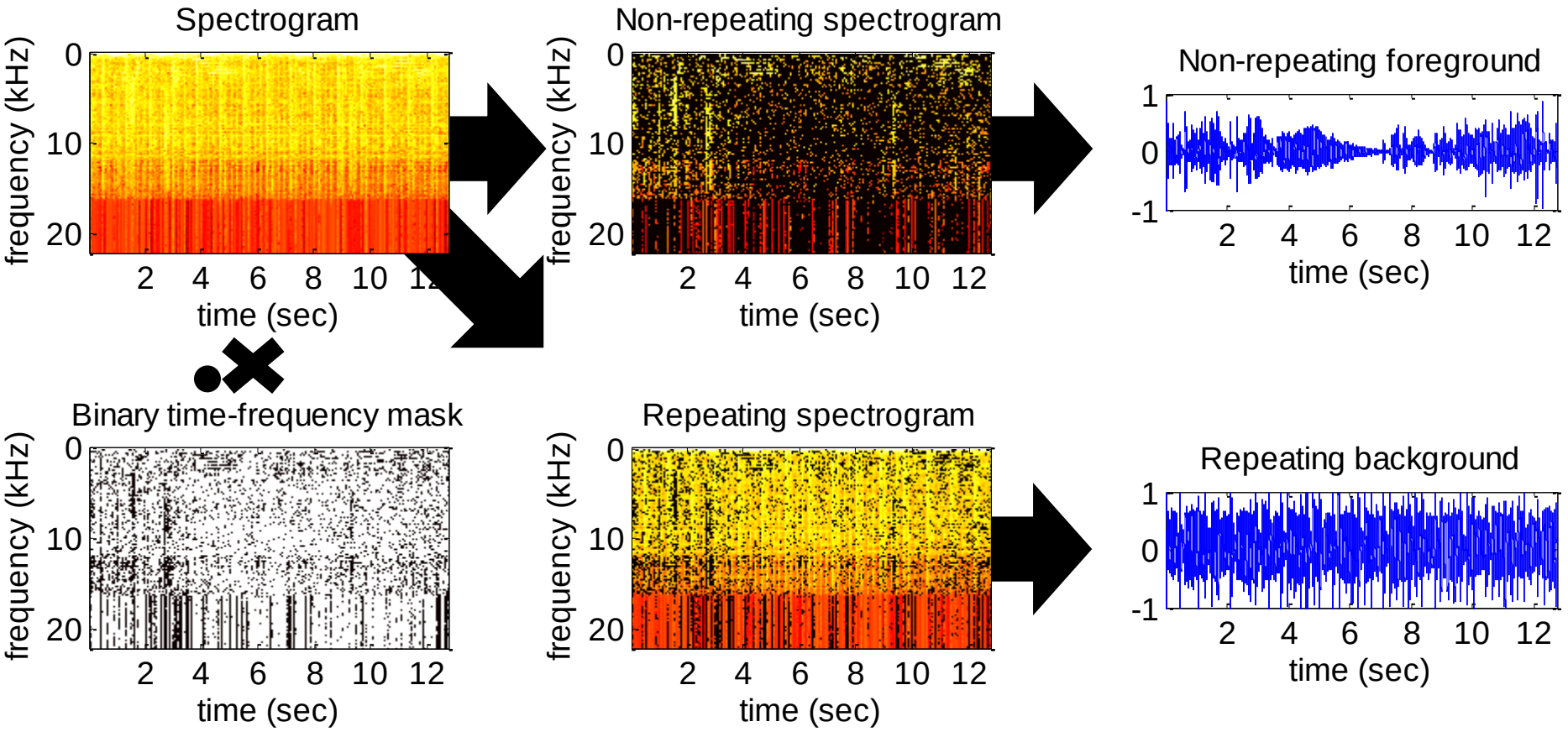


II. REPET – 3. Repeating Structure

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



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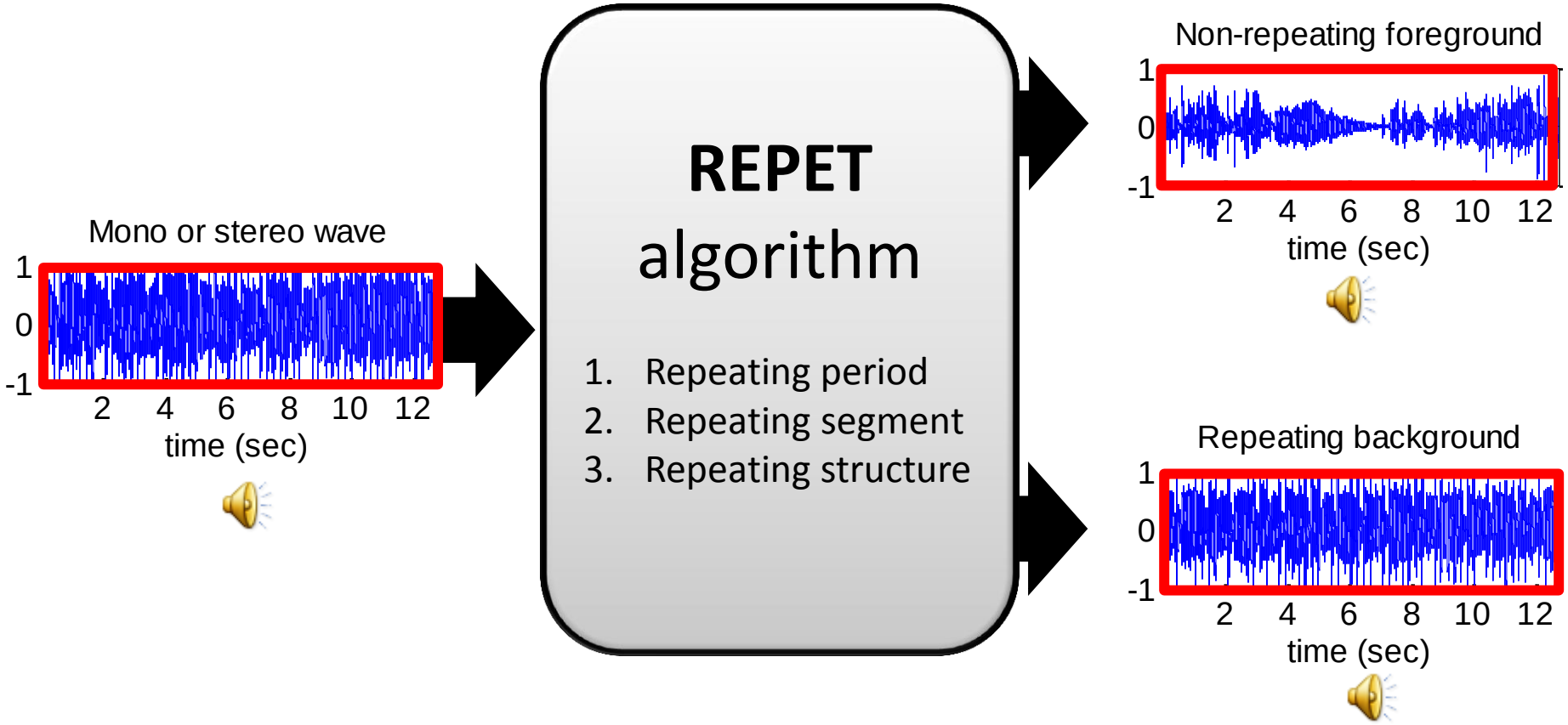
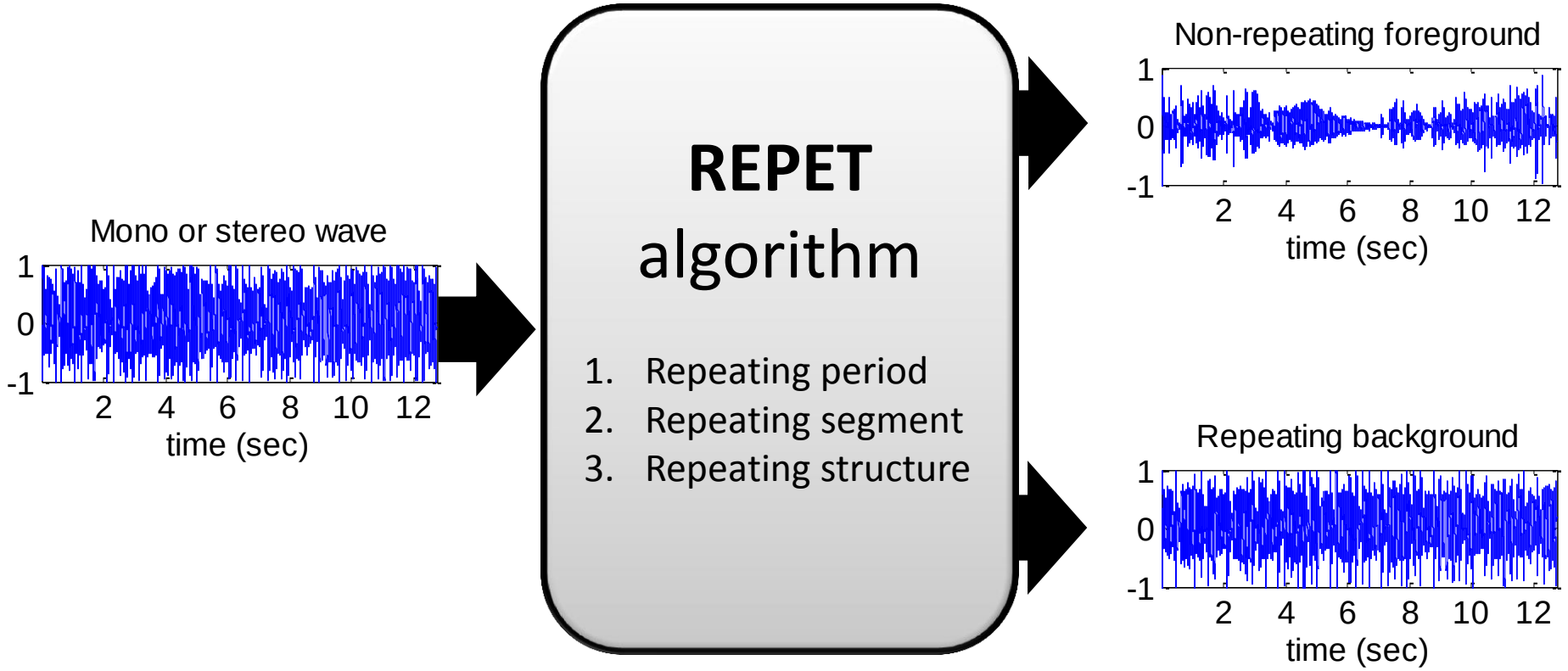


II. REPET – 3. Repeating Structure

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



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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

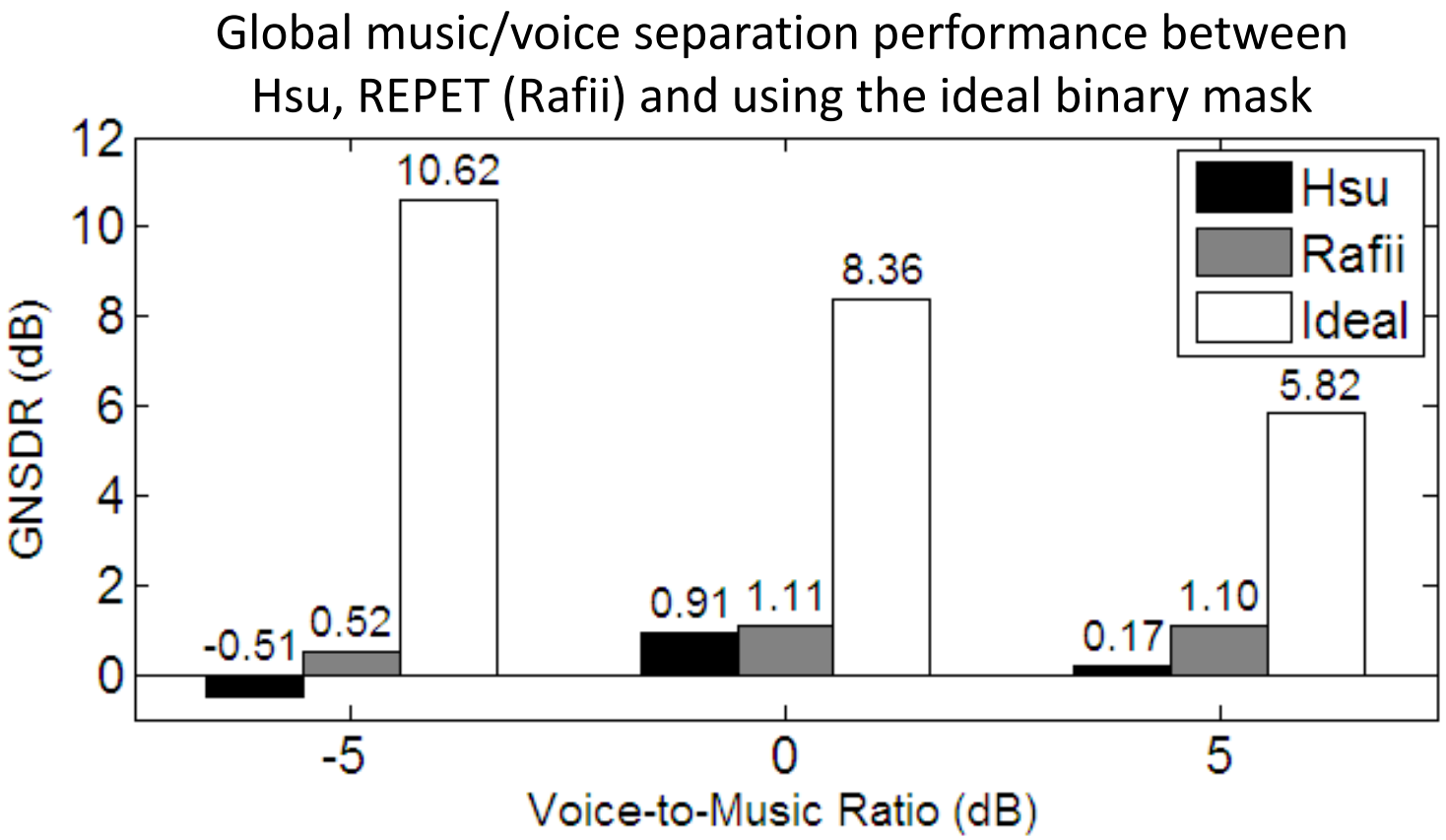
3. Pitch-based inference
   - Cannot extract unvoiced vocal frames
   - Harmonic structure of the instruments can interfere

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

III. M/V separation – 1. Experiment

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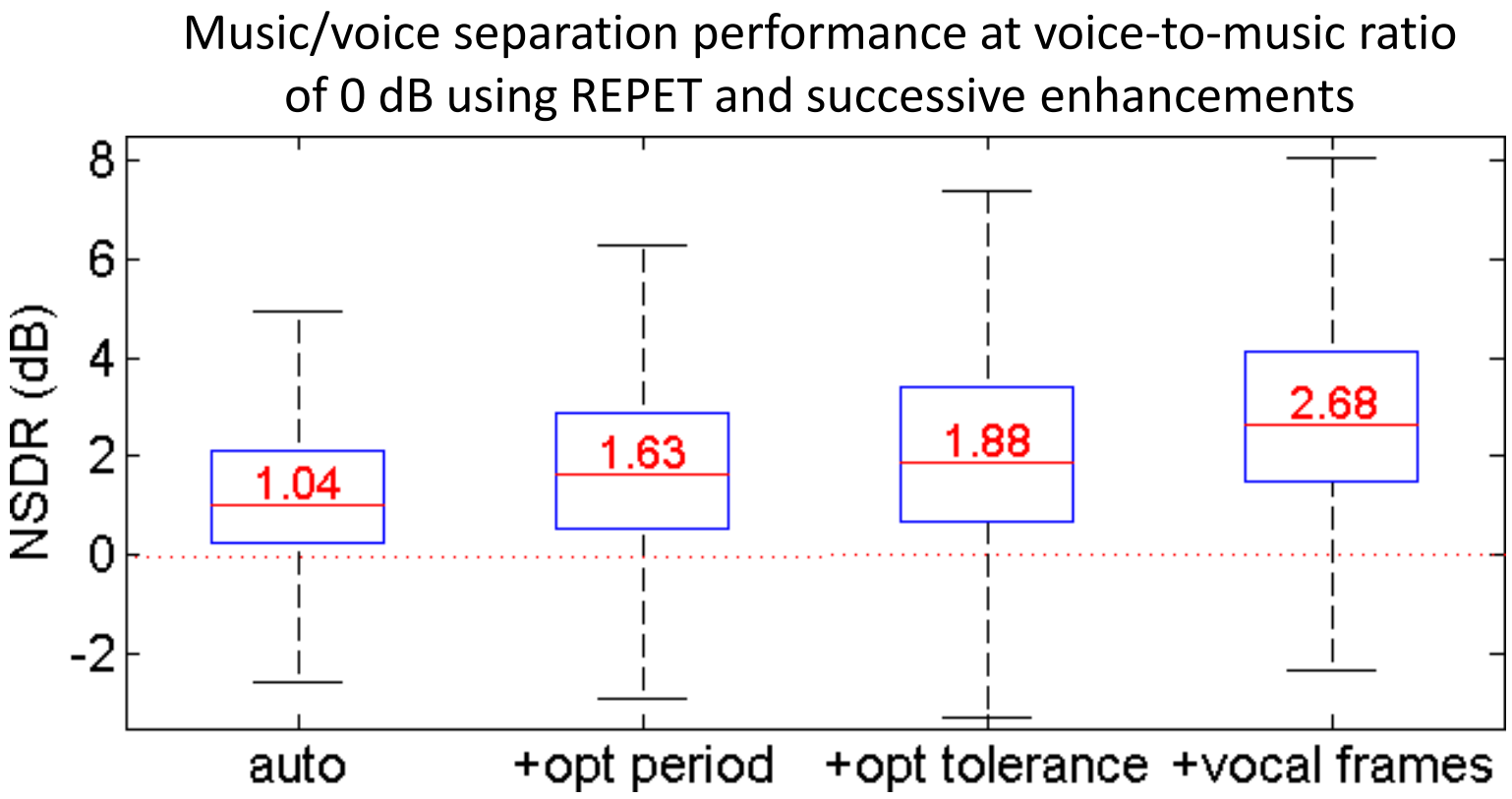

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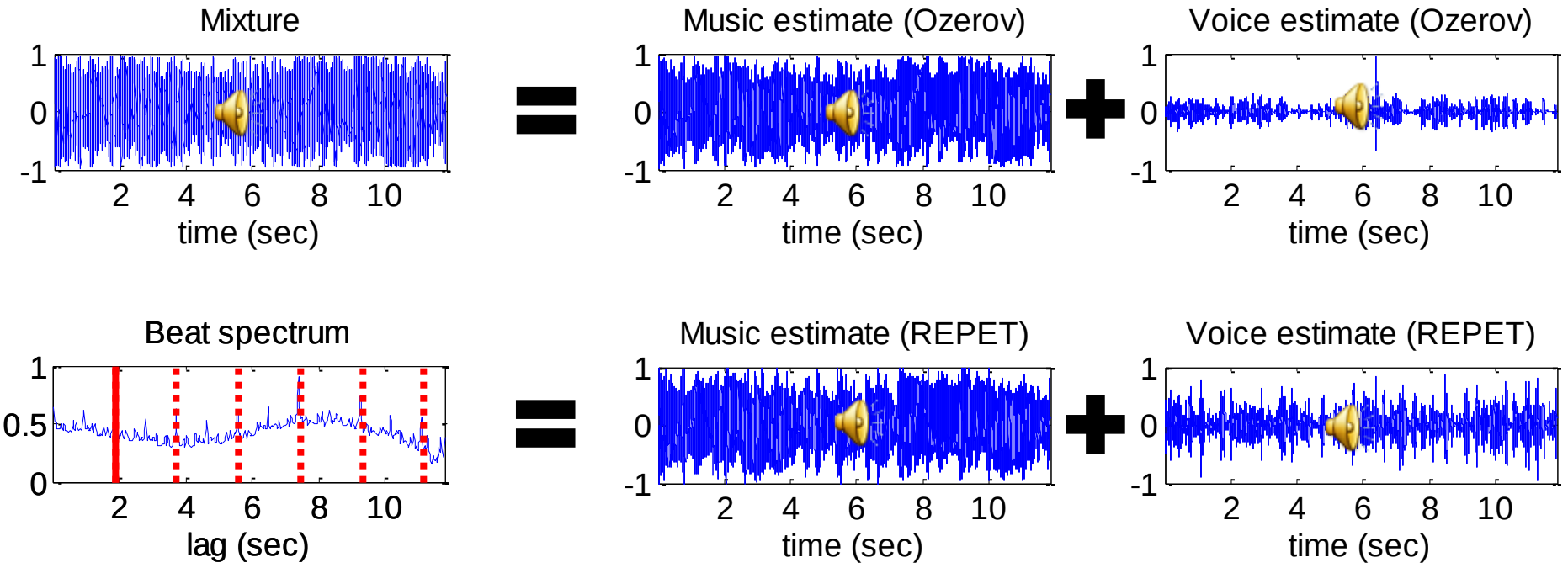
III. Music/Voice – 2. Examples

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

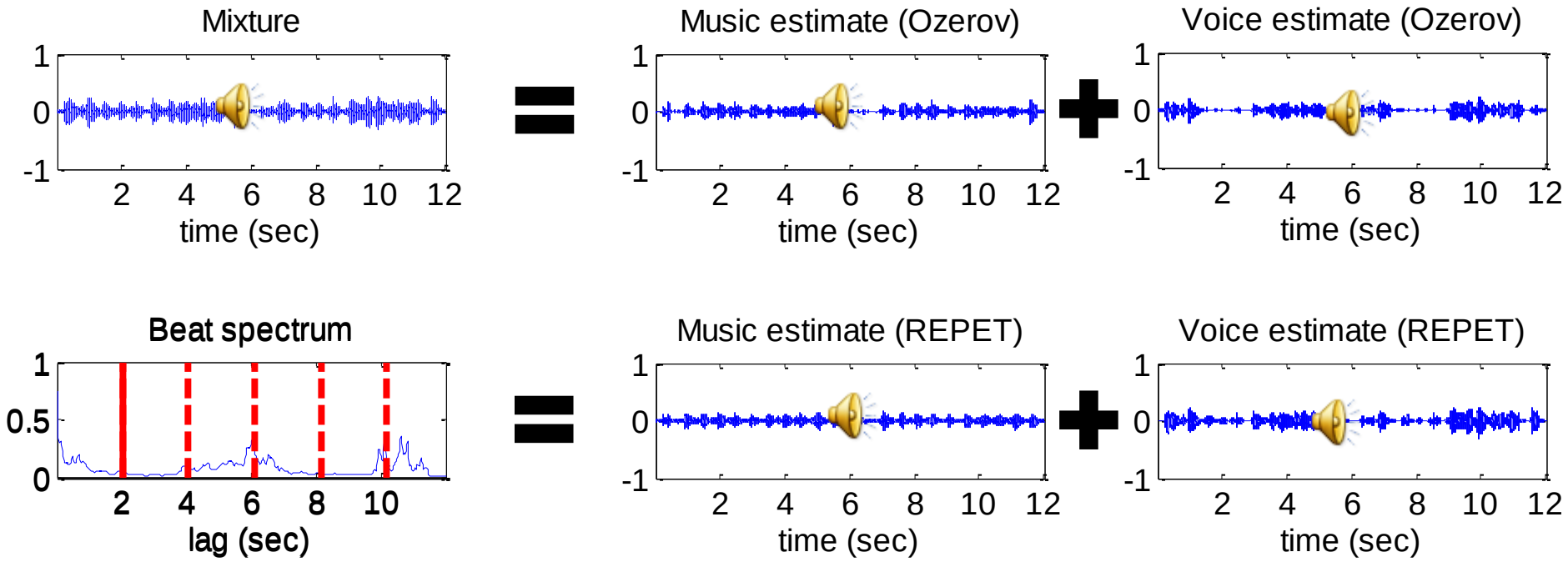
1. The Prodigy – Breathe



III. Music/Voice – 2. Examples

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

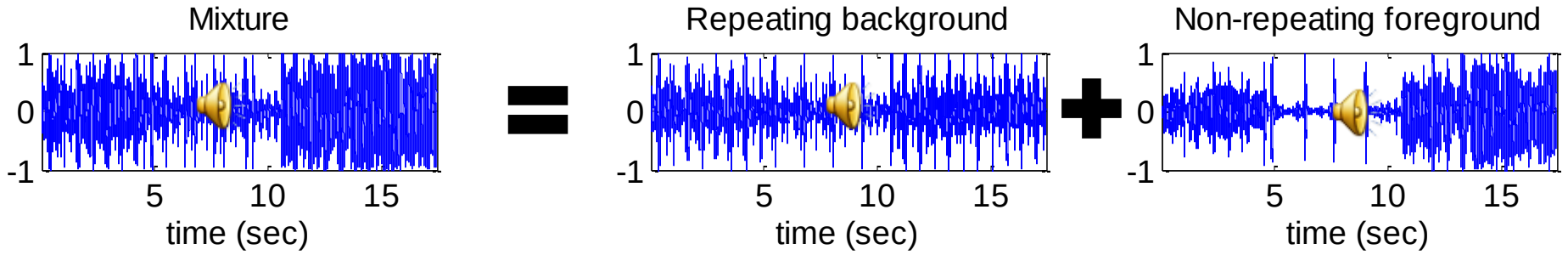
2. The Doors – People are strange



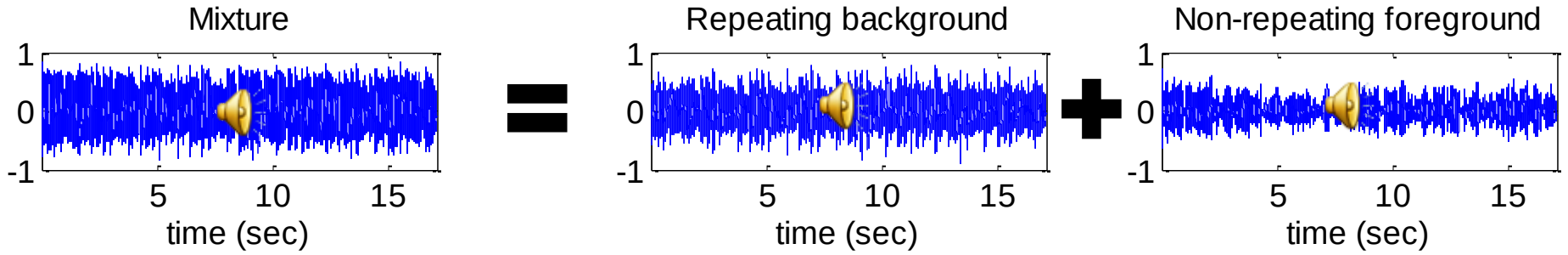
III. Music/Voice – 2. Examples

- More audio examples:

3. RJD2 – Ghostwriter (no vocals)



4. Rebecca Black – Friday (because tomorrow is Saturday…)



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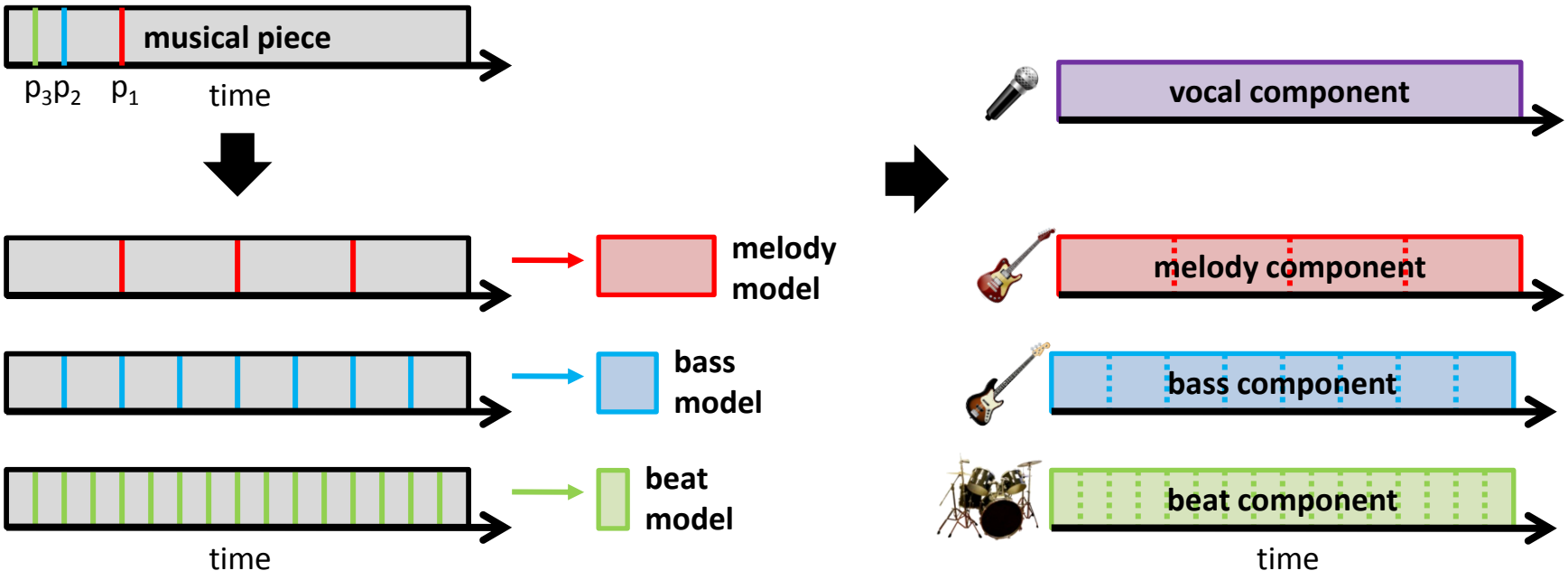
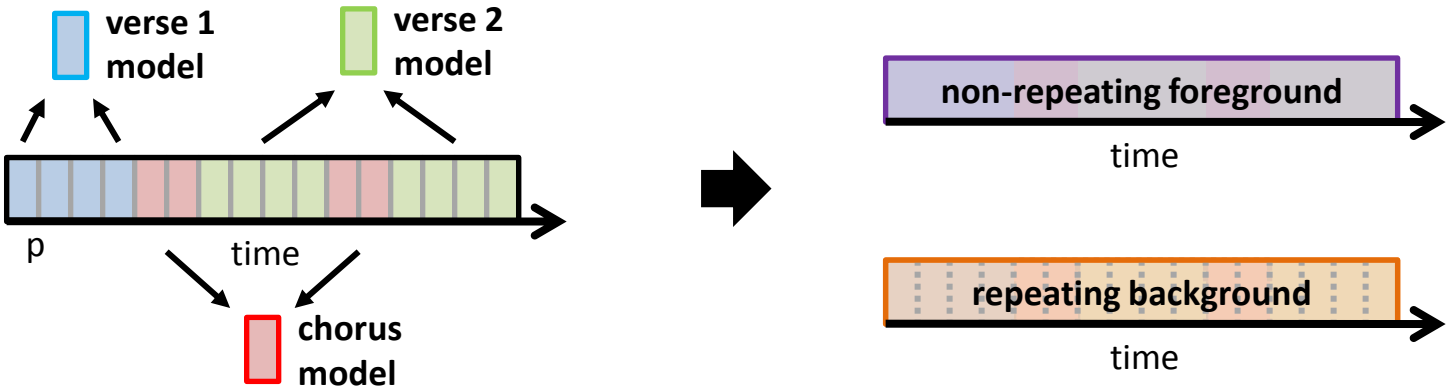
III. Music/Voice – 3. Future

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



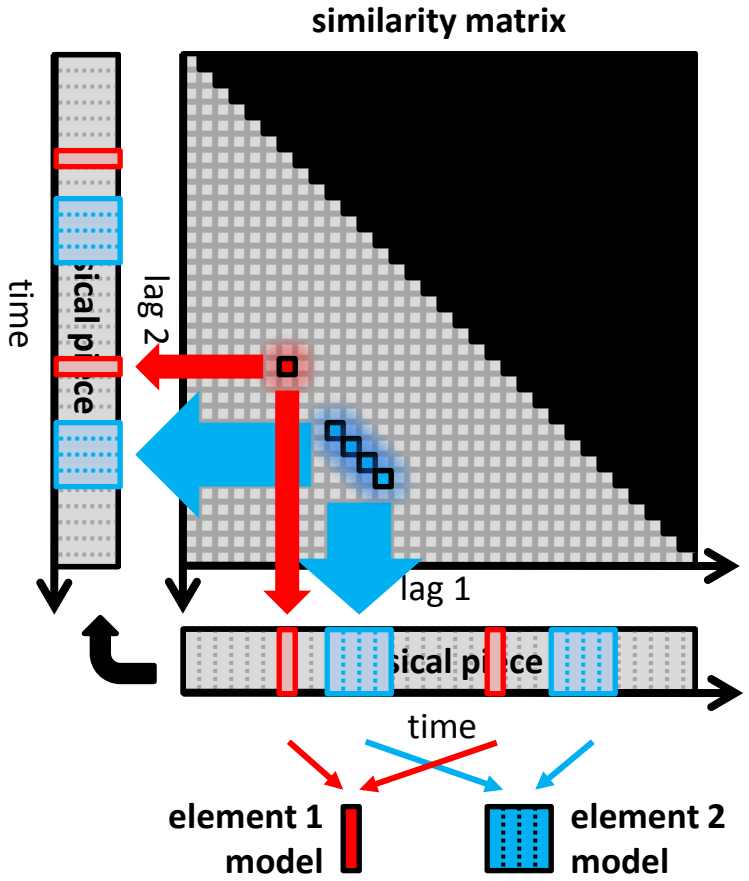
III. Music/Voice – 3. Future

- 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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- **REPET**: REpeating Pattern Extraction Technique

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

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

Questions ?