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# Automated Musical Rhythm Transcription of ECG RR Interval Time Series as a Tool for Representing Rhythm Variations and Annotation Anomalies in Arrhythmia Heartbeat Classifications

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## Introduction

**What we present:** We introduce a linear time algorithm for transcribing RR intervals into musical rhythms [1, 2] using approximate common divisors (ACDs) [6].

**What we obtain:** We transcribe long term ECGs records to have a rhythmic representation of them.

**What is this for:** The transcription of ECG signals may be useful for improving labelling of heartbeats in ECG signals.

## Approximate Common divisors

Let  $T = (t_0, t_1, \dots, t_n)$  be a series of onset times. Every  $a$  is associated with an error measure,

$$\epsilon_T(a) = \max_n \min_{m \in \mathbb{Z}} |t_n - am|. \quad (1)$$

We say that  $a > 0$  is an *approximate common divisor* (ACD) of  $T$  with threshold  $\tau > 0$  if

1.  $\epsilon_T(a) \leq \tau$
2.  $\epsilon_T$  has a local minimum at  $a$

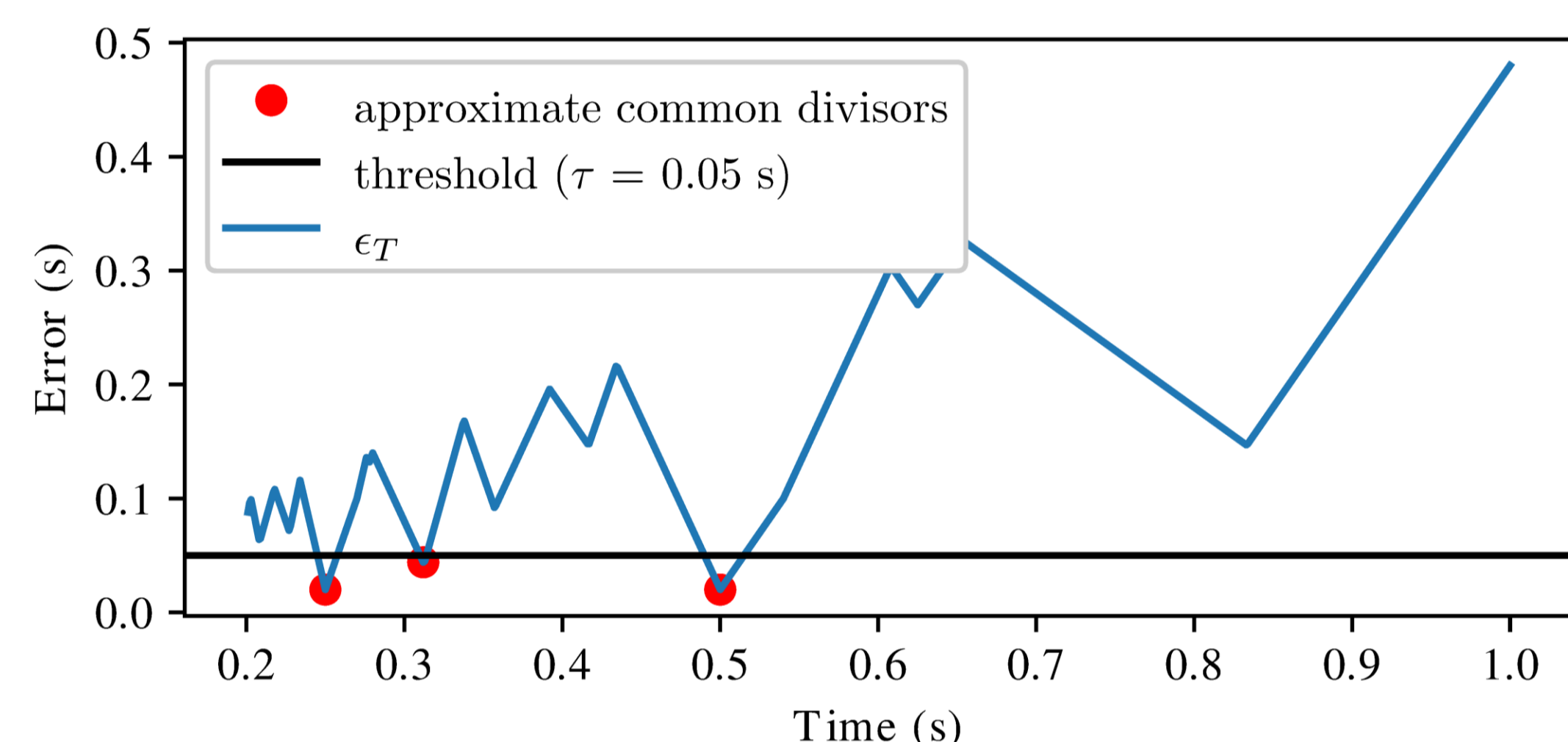
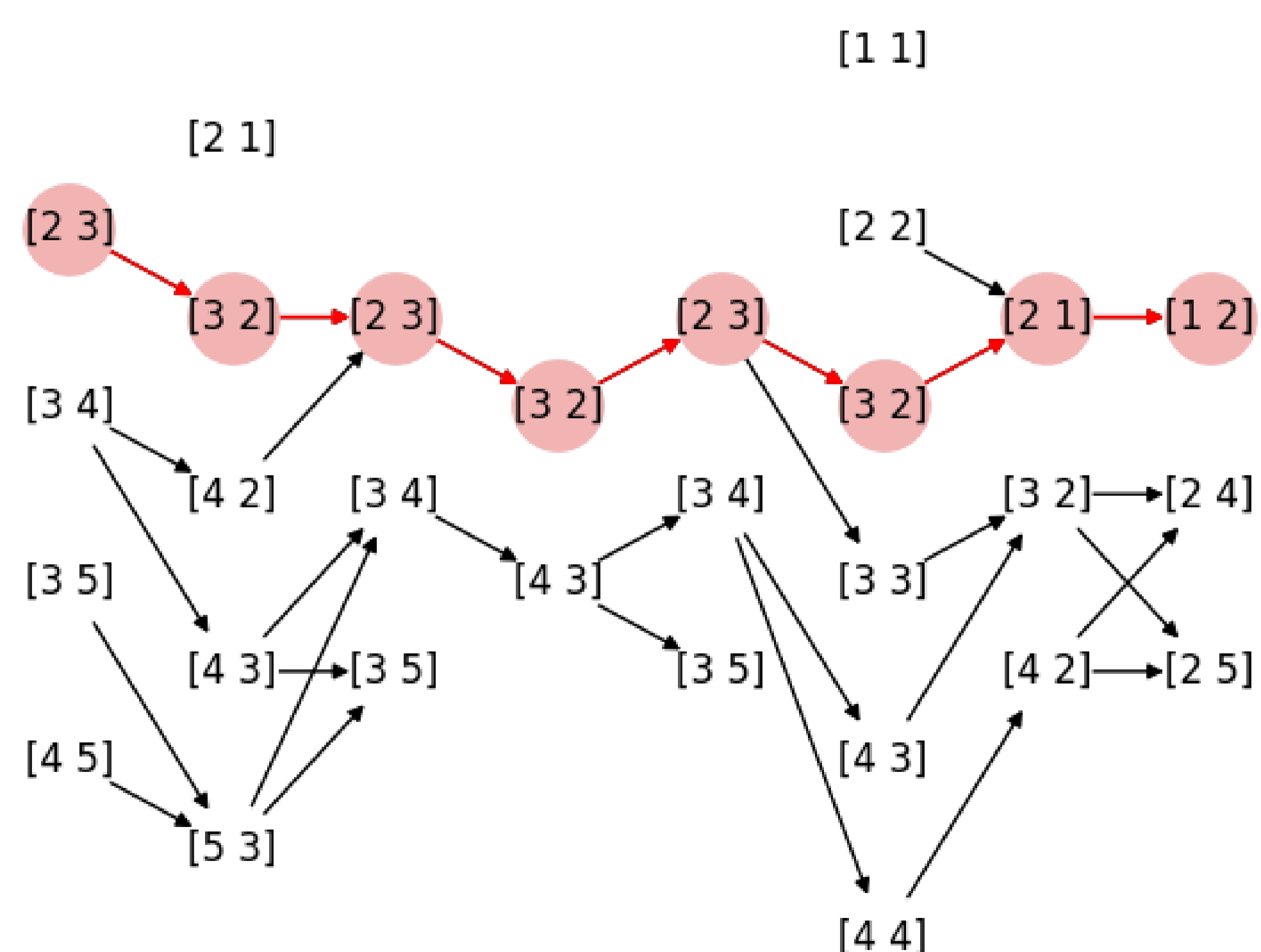


Figure 1: The  $\epsilon_T$  function of  $T = (0, 0.98, 1.52)$  for the range  $a \in [0.2, 1]$ . The ACDs are 0.5, 0.312 and 0.25.

## ACD graph

- Step 1:** We split the sequence in frames of length  $n$
- Step 2:** For each frame we compute the possible ACDs
- Step 3:** We create a graph where each ACD is a node
- Step 4:** We link ACDs of consecutive frames if they share a common duration



In the graph, a path is a way of transcribing the full sequence

→ : (2, 3, 2, 3, 2, 3, 2, 1, 2) ⇔ ♩ ♩ ♩ ♩ ♩ ♩ ♩ ♩ (♩ = 1)

## Rhythm & label patterns

We compare the rhythms with labels of the Long-Term AF Database [4, 5].

For example, N-A-N is most often transcribed rhythmically as 2-4-3.

Labels	Nb. of 2-4-3	Percentage	Total count
A-A-N	87	3.93 %	309
N-A-N	2104	95.03 %	3869
N-N-N	21	0.95 %	91839
N-V-N	2	0.09 %	3

Table 1: Beat category labels for the rhythm pattern 2-4-3 in LTAFFDB Record 06.

## Visualising transcriptions of triplets

We visualise the rhythm transcriptions of three-interval rhythms using the 2-dimensional *rhythm simplex* [3]

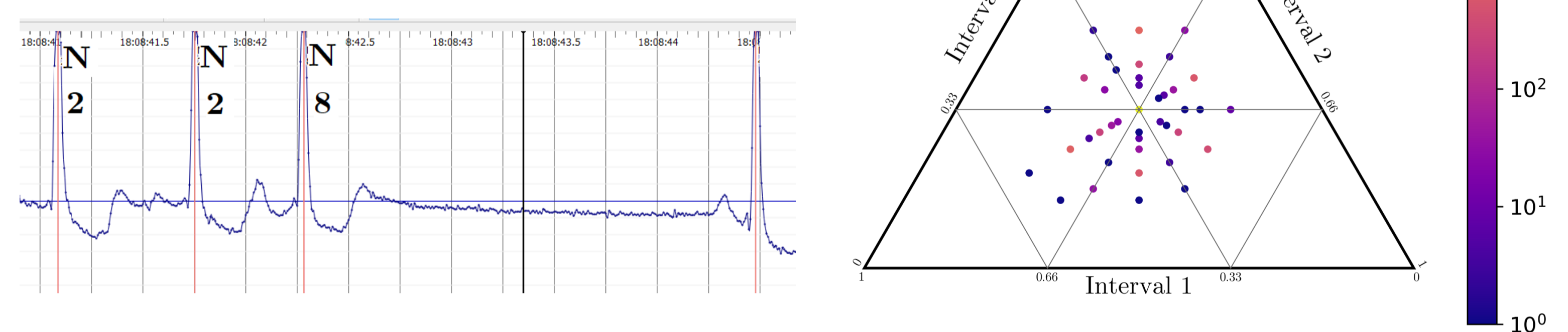
For any point  $(x, y, z)$  in the rhythm simplex, where  $x + y + z = 1$ , the *arrhythmic norm* is

$$\|(x, y, z)\|_R = \|(x, y, z) - (\frac{1}{3}, \frac{1}{3}, \frac{1}{3})\|_2, \quad (2)$$

which measures the irregularity of the RR intervals. Sinus rhythm will result in norm values at or close to zero; e.g. the rhythm  $(\frac{1}{3}, \frac{1}{3}, \frac{1}{3})$  has a norm of 0.

Rhythms with big norms are likely to stem from highly contrastive durations.

**Example:** the rhythm (2, 2, 8) corresponds to  $(\frac{1}{6}, \frac{1}{6}, \frac{2}{3})$  and has a norm of 0.41



## References & Acknowledgements

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