



# Low-complexity detection of atrial fibrillation in continuous long-term monitoring

Biomedical Signal Processing | 2024 - 2025

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## 1 Introduction

### ► Introduction

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### ► Results

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# Introduction

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- For long-term monitoring, non-invasive techniques are required;
- non-invasive methods → small devices must be used, but they have some limitations:
  - limited battery life;
  - limited computational power.
- The proposed algorithm aims to overcome these constraints.



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## 2 The algorithm

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# Introduction

## 2 The algorithm

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## 2 The algorithm

The algorithm:

- uses a few mathematical operators;
- ignores:
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  - bigeminy events;
- employs a short window for detection
  - no need to use a large buffer.



# Pipeline of the algorithm

## 2 The algorithm

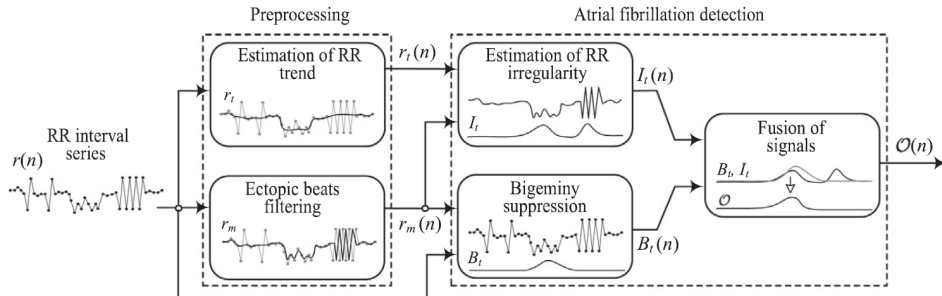


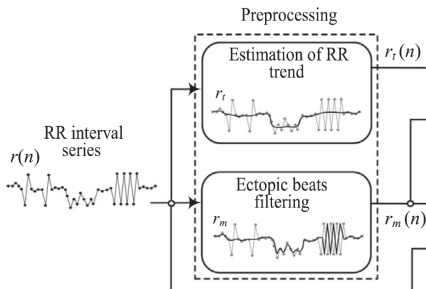
Figure: Block diagram of the algorithm [1]



# Preprocessing - Filters

## 2 The algorithm

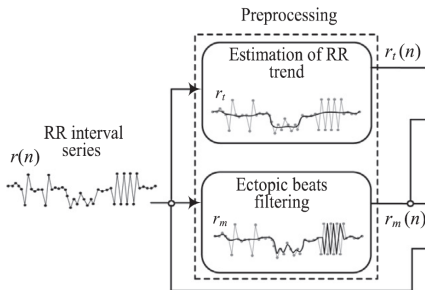
The series is filtered with:





# Preprocessing - Filters

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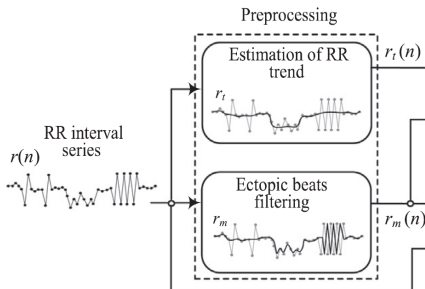
- 3-point Median Filter  $\rightarrow$  reduce the influence of ectopic beats and outlier intervals

$$r_m(n) = \text{median}\{r(n-1), r(n), r(n+1)\};$$



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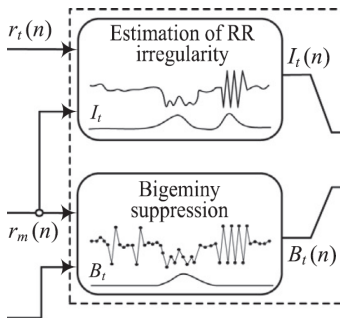
- Exponential Average  $\rightarrow$  estimate the RR trend

$$r_t(n) = r_t(n-1) + \alpha(r(n) - r_t(n-1)).$$



# Atrial Fibrillation detection - Estimation of RR irregularity and Bigeminy suppression

## 2 The algorithm



- Estimation of RR irregularity:

$$M(n) = \frac{2}{N(N-1)} \sum_{j=0}^{N-1} \sum_{k=j+1}^N H(|r(n-j) - r(n-k)| - \gamma)$$

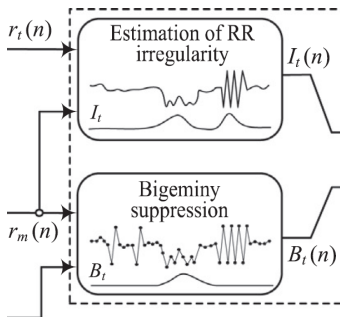
$M(n)$  filtered with exponential average and divided by  $r_t(n)$ ;





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- Suppression of bigeminy events

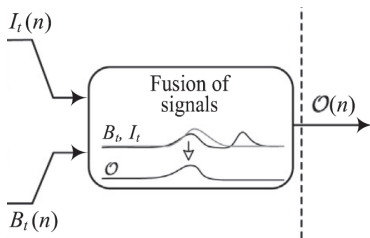
$$B(n) = \left( \frac{\sum_{j=0}^{N-1} r_m(n-j)}{\sum_{j=0}^{N-1} r(n-j)} - 1 \right)^2$$

then filtered with exponential average.



# Atrial Fibrillation detection - Merge and detection

## 2 The algorithm



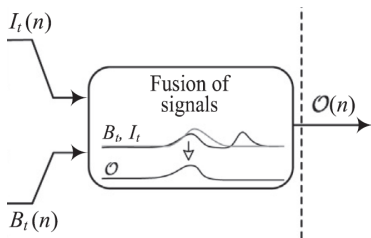
- Final series is obtained by merging:
  - the irregularity detection series;
  - the bigeminy-suppressed series;

$$\mathcal{O}(n) = \begin{cases} I_t(n), & B_t(n) \geq \delta \\ B_t(n), & B_t(n) < \delta. \end{cases}$$



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- Atrial Fibrillation is detected where signal exceeds a threshold  $\eta$ .



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## 3 Dataset and measurements

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## Dataset used

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Performance evaluation using the LTAF Database from PhysioNet, composed by 84 signals.



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- is a recording typically from 20-24 hours;



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- contains Atrial Fibrillation events of varying durations;





## Dataset used

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Performance evaluation using the LTAF Database from PhysioNet, composed by 84 signals. Each signal:

- is a recording typically from 20-24 hours;
- contains Atrial Fibrillation events of varying durations;
- includes rhythm classifications → AFIB label indicates Atrial Fibrillation.

| Record | N               | SVTA      | VT        | AFIB          | B           | T        | IVR | AB          | SBR            |
|--------|-----------------|-----------|-----------|---------------|-------------|----------|-----|-------------|----------------|
| 00     | 5 (18:31:31)    | -         | 40 (0:42) | 44 (2:14:54)  | -           | -        | -   | -           | -              |
| 01     | 457 (3:38:53)   | 25 (0:58) | -         | 53 (16:13:06) | 16 (1:46)   | 6 (0:53) | -   | 293 (27:36) | 83 (10:02)     |
| 03     | 1648 (14:56:49) | 11 (0:32) | 2 (0:03)  | 22 (1:20:03)  | 2 (0:13)    | 1 (0:14) | -   | 34 (4:53)   | 1587 (7:52:53) |
| 05     | 14 (24:17:02)   | 2 (0:05)  | -         | 3 (0:40)      | -           | -        | -   | 8 (0:29)    | -              |
| 06     | 48 (24:22:27)   | 16 (0:29) | -         | 19 (45:04)    | -           | -        | -   | 11 (0:44)   | 1 (0:01)       |
| 07     | 499 (21:25:26)  | 28 (1:21) | -         | 8 (3:24:47)   | 416 (33:44) | 1 (0:07) | -   | 51 (4:27)   | -              |
| 08     | 20 (25:42:48)   | 13 (0:17) | -         | 4 (1:38)      | 1 (0:04)    | -        | -   | 1 (0:04)    | -              |
| 10     | 148 (8:23:01)   | 68 (3:35) | -         | 80 (17:07:44) | -           | -        | -   | 1 (0:05)    | -              |

Figure: Table of rhythms [2]



# Measurements

## 3 Dataset and measurements

- Algorithm executed with values suggested by the reference paper ( $\alpha = 0.02, \gamma = 0.03, N = 8, \delta = 2e^{-4}, \eta = 0.725$ );



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  1. generation of an array for AF predictions;



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  3. computation of performance metrics.



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  1. generation of an array for AF predictions;
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for each signal.





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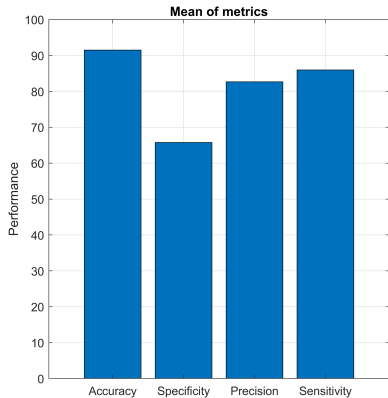
## 4 Results

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# Overall results

4 Results

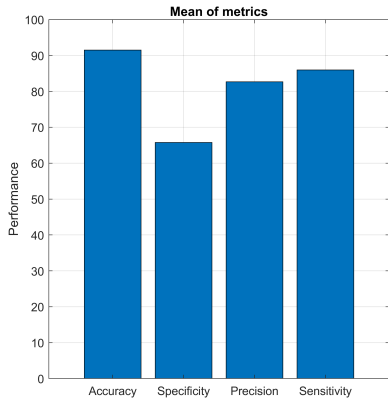


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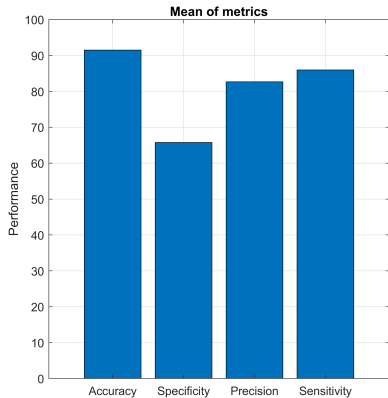
Overall:

- Mean of accuracy  $\approx 92\%$



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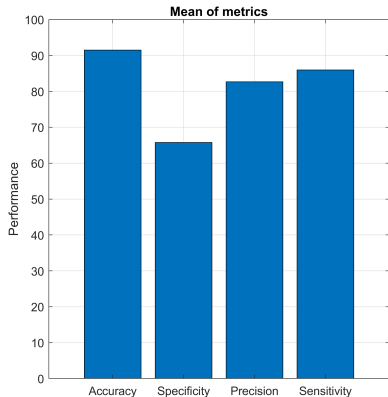
Overall:

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  - 56 signals result with accuracy  $> 96\%$ ;



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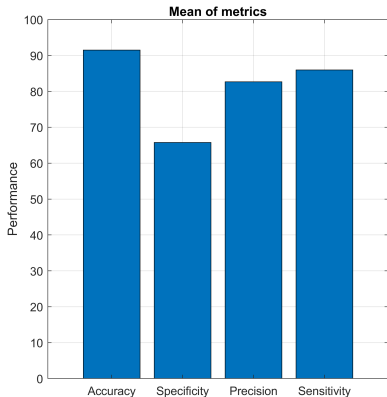
Overall:

- Mean of accuracy  $\approx 92\%$ 
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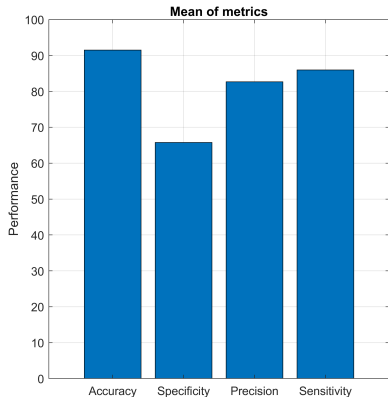
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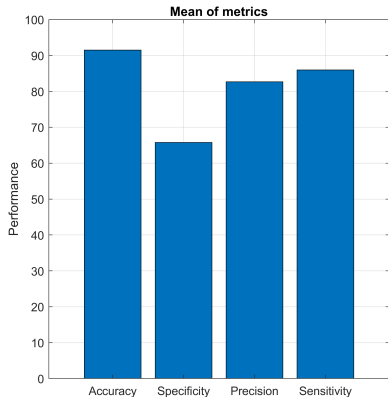
Overall:

- Mean of accuracy  $\approx 92\%$ 
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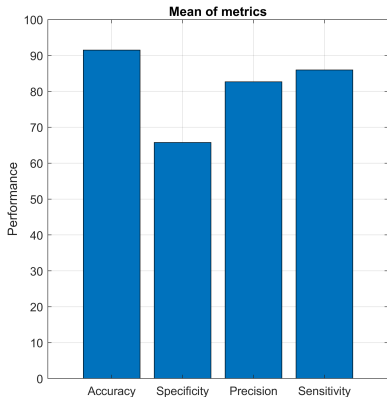
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- Mean of accuracy  $\approx 92\%$ 
  - 56 signals result with accuracy  $> 96\%$ ;
- Mean of precision  $\approx 83\%$ 
  - influenced by misclassifications;
- Mean of sensibility  $\approx 86\%$
- Mean of specificity  $\approx 66\%$ 
  - strongly lowered by false positives in long AF events.



# Lacks of precision and sensibility

## 4 Results

Lacks of precision and sensibility are caused by:



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    - (algorithm removes only ectopic beats and bigeminy events);





# Lacks of precision and sensibility

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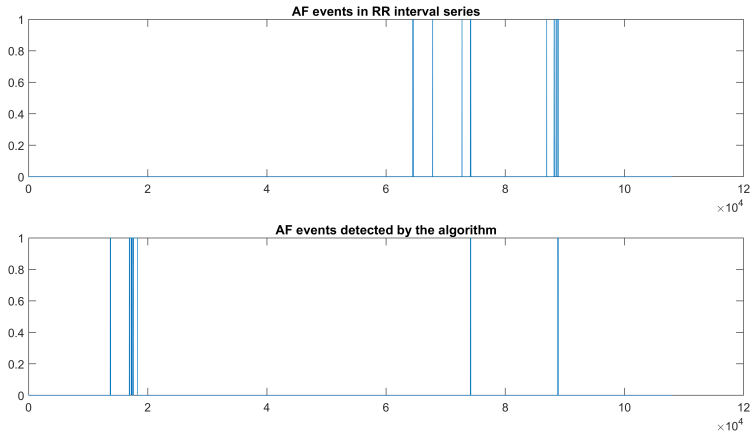
Lacks of precision and sensibility are caused by:

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- changes in the heart's rhythm:
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    - (algorithm removes only ectopic beats and bigeminy events);
  - they could be wrongly classified as AF.



$\alpha = 0.02$  of signal 19

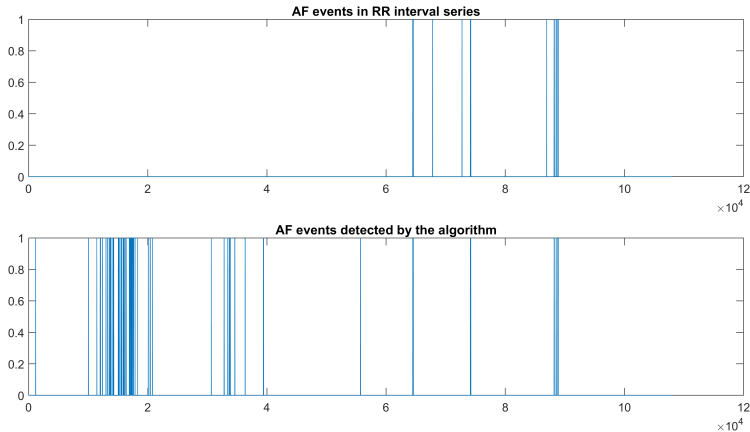
4 Results





# $\alpha = 0.06$ on signal 19

4 Results





## Low mean of specificity

### 4 Results

- Low values detected most in long AF events



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  - specificity values were close to zero;



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- other metrics remain with high values;



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- Low values detected most in long AF events
  - specificity values were close to zero;
  - algorithm does not detect short pauses of no-AF;
- other metrics remain with high values;
- without them, specificity  $\approx 86\%$ .





# Low mean of specificity

## 4 Results

| Signal | Accuracy | Precision | Sensibility | Specificity | Percentual_of_AF_in_the_signal |
|--------|----------|-----------|-------------|-------------|--------------------------------|
| 11     | 99,92    | 100       | 99,93       | 0           | 99,31                          |
| 20     | 99,84    | 100       | 99,84       | 0           | 99,94                          |
| 25     | 98,5     | 98,5      | 100         | 0           | 98,35                          |
| 33     | 98,78    | 98,91     | 99,87       | 0           | 98,96                          |
| 34     | 99,89    | 99,98     | 99,91       | 0           | 99,92                          |
| 43     | 99,94    | 99,99     | 99,95       | 0           | 99,97                          |
| 44     | 99,95    | 99,99     | 99,95       | 0           | 99,96                          |
| 48     | 99,97    | 99,97     | 100         | 0           | 99,96                          |
| 60     | 99,96    | 100       | 99,96       | 0           | 98,95                          |
| 62     | 99,87    | 99,87     | 100         | 0           | 99,83                          |
| 65     | 93,85    | 100       | 93,86       | 0           | 99,59                          |
| 68     | 99,92    | 99,99     | 99,94       | 0           | 99,69                          |
| 103    | 59,66    | 59,68     | 99,96       | 0           | 51,87                          |
| 203    | 98,23    | 99,97     | 98,26       | 0           | 99,91                          |
| 204    | 98,58    | 98,63     | 99,94       | 0           | 98,33                          |
| 206    | 99,98    | 99,98     | 100         | 0           | 99,15                          |
| 207    | 99,86    | 99,91     | 99,95       | 0           | 99,26                          |

Figure: Signals where specificity = 0

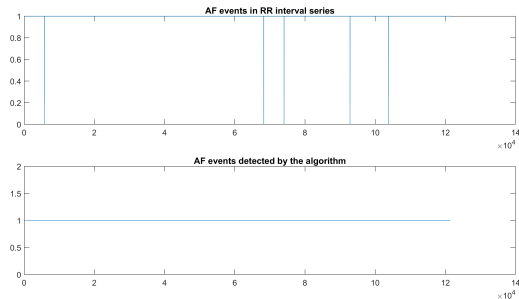


Figure: Ground truth and prediction of signal 206



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# Conclusions

## 5 Conclusions

The proposed algorithm:



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- ✗ suffers from misclassifications during changes in rhythm;



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The proposed algorithm:

- ✗ performs worse in the presence of short AF events;
- ✗ suffers from misclassifications during changes in rhythm;
- ✓ efficiently detects long AF events with high performances.



## References

### 6 Conclusions

- [1] Andrius Petrėnas, Vaidotas Marozas, and Leif Sörnmo. “Low-complexity detection of atrial fibrillation in continuous long-term monitoring”. In: *Computers in Biology and Medicine*, 65 (2015), pp. 184–191.
- [2] PhysioNet. *Tables of beats and rhythms*. URL: <https://physionet.org/files/ltafdb/1.0.0/tables.shtml>.