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Questions

Classification of fractionated electrograms in epicardial mappings using a recurrent neural network

Rob Romijnders

Eindhoven, University of Technology RomijndersRob@gmail.com

October 27, 2016

Abstract

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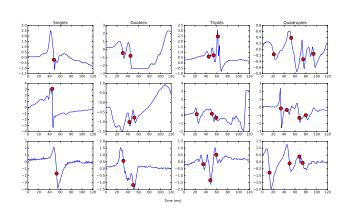
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Overview

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Pipeline

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Figure: Data pipeline

Data

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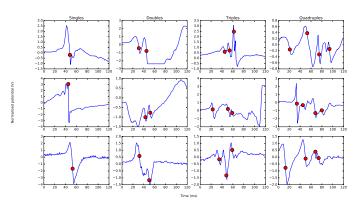


Figure: Examples of simple electrograms

Notation

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$$\{(x^{(i)}, y^{(i)})\}_{i=0}^{N-1} \tag{1}$$

- $x^{(i)} \in R^{120}$
 - t indexes time with t = 0, 1, ..., T 1
- $y^{(i)} \in \{l_1, l_2, ..., l_{K^i}\}.$
 - \blacksquare I_k denotes the location of the k-th annotation
 - lacksquare K denotes the total number of annotations at sample i
 - For example, $y^i = \{35, 75, 95\}$ is a triple with deflections at 35 ms, 75 ms and 95 ms.

CI and FI

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Complexity Index

$$CI(x^{(i)}) = \frac{1}{T} \sum_{t=1}^{T-1} \mathbb{1}(\mathbb{1}(x_{t-1}^{(i)} \ge 0)) = \mathbb{1}(x_t^{(i)} < 0))$$
 (2)

Fractionation Index

$$FI(x^{(i)}) = \frac{1}{T} \sum_{t=2}^{T-1} \mathbb{1}(\mathbb{1}(x_{t-1}^{(i)} \ge x_{t-2}^{(i)}) = \mathbb{1}(x_t^{(i)} < x_{t-1}^{(i)})))$$
(3)

with $\mathbb{1}()$ denoting the indicator function

■ Sample entropy (Cirugeda-Roldan, 2015)

Design choices

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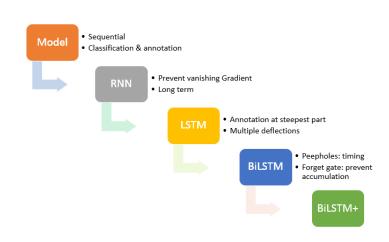


Figure: Flow graph for design choices

Model

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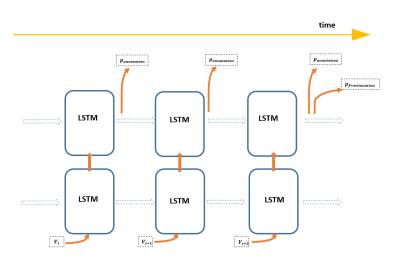


Figure: Network architecture

Long Short-term memory

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$$i_t = \sigma(W_{xi}x_t + W_{hi}h_{t-1} + W_{ci}c_{t-1} + b_i)$$
 (4)

$$f_t = \sigma(W_{xf}x_t + W_{hf}h_{t-1} + W_{cf}c_{t-1} + b_f)$$
 (5)

$$o_t = \sigma(W_{xo}x_t + W_{ho}h_{t-1} + W_{co}c_{t-1} + b_o)$$
 (6)

$$c_t = f_t c_{t-1} + \tanh(W_{xc} x_t + W_{hc} h_{t-1} + b_c) \tag{7}$$

$$h_t = o_t \, \tanh(c_t) \tag{8}$$

Classification and annotation

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$$m_t = W_{hm}h_t + b_m$$
 $p(C_k|h_t) = \frac{e^{m_{t,k}}}{\sum_{\kappa=1}^4 e^{m_{t,\kappa}}}$ (9)

$$K = \operatorname*{argmax}_{k} C_{k} \tag{10}$$

$$p_t(annotation) = \sigma(W_{ha}h_t + b_a)$$
 (11)

Next, $I_k = t$ joins y if

$$p_t(annotation) > threshold$$
 (12)

Binary classification

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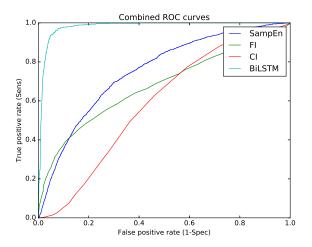


Figure: CI: 0.58 - FI: 0.68 - SampEn: 0.75 - BiLSTM: 0.98 (in AUC)

Refined classification

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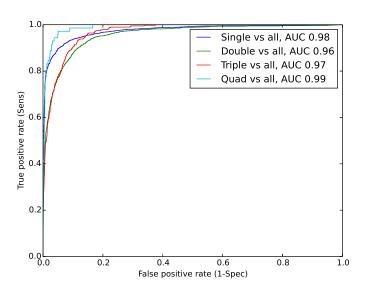
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Misclassifications

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		Model			
		Single	Double	Triple	Quad
Expert	Single	3565	821	134	36
	Double	76	1292	123	20
	Triple	2	58	262	68
	Quad	1	4	9	57

Table: **Confusion matrix** row, i, column, j, indicates how many complexes the expert classifies i and the model classifies j

Annotation

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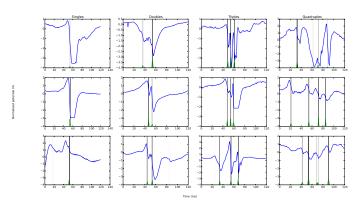


Figure: Probability for annotation per time

Annotation accuracy

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 \blacksquare The model annotates 91% of the annotations within 3 ms of the expert annotation

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- Misclassifications
 - Unbalanced confusion matrix
- Limitations
 - Pipeline
 - Modelling of annotations
 - Early stopping
- Future perspectives
 - Output capability metric

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Anomaly detection

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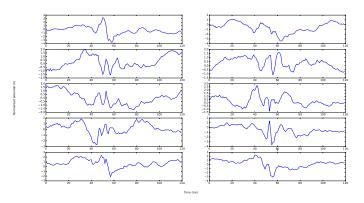


Figure: Noise sampled from 120D Gaussian fit to the data

Accuracy of annotations

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		Range				
		3	4	5		
Th	0.3	0.912 (0.892)	0.917 (0.901)	0.919 (0.906)		
	0.5	0.767 (0.796)	0.772 (0.801)	0.778 (0.805)		

Table: **Accuracy of annotations** Range is the maximum allowed distance between annotations by model and expert. Threshold (th) binarizes the probability of an annotation

Pipeline

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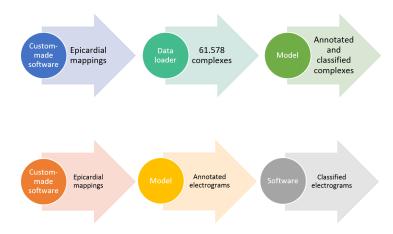


Figure: Data pipeline with improved pipeline

Resampling

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Set	Non-frac	tionated	Fractionated		
Set	Singles	Doubles	Triples	Quad.	
Train.	36414	12263	3235	516	
	(12263)	(12263)	(12263)	(12263)	
Val.	4589	1493	411	61	
	(1493)	(1493)	(1493)	(1493)	
Test	4618	1485	376	75	
	(1485)	(1485)	(1485)	(1485)	

Table: Sizes of training, validation and test set The first line denotes size before resampling and the second line (in parentheses) denotes size after resampling

LSTM block

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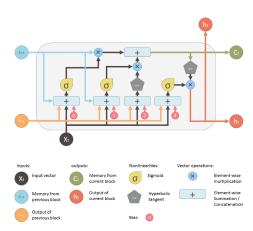


Figure: Diagram depicting LSTM block

Author: Shi Yan. Source: medium.com/@shiyan/

Low confidence samples

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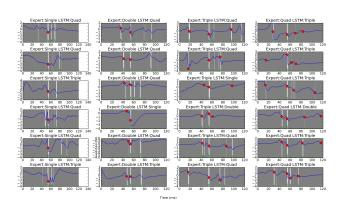


Figure: Samples of low confidence. Ordered per column