

Predicting eukaryotic signal peptides using hidden Markov models

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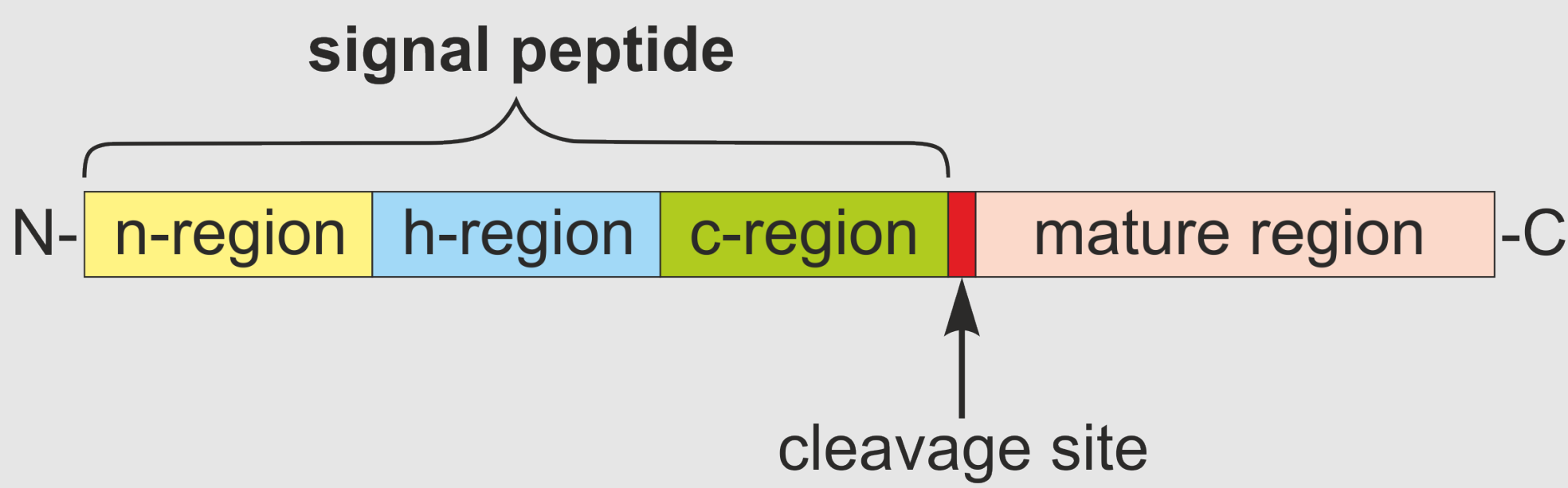
Goal of the project

Develop an accurate method of predicting signal peptide presence.

Introduction

- Secretory signal peptides:
- are short (20-30 residues) N-terminal amino acid sequences,
 - direct a protein to the endomembrane system and next to the extracellular localization,
 - possess three distinct domains with variable length and characteristic amino acid composition (Hegde and Bernstein, 2006).
 - are universal enough to direct properly proteins in different secretory systems - artificially introduced bacterial signal peptides can guide proteins in mammals (Nagano and Masuda, 2014) and plants (Moeller et al., 2009),
 - tag among others hormones, immune system proteins, structural proteins, and metabolic enzymes.

Organization of signal peptide



- n-region: mostly basic residues (Nielsen and Krogh, 1998),
- h-region: strongly hydrophobic residues (Nielsen and Krogh, 1998),
- c-region: a few polar, uncharged residues (Jain et al., 1994).

Hidden semi-Markov model (HSMM) of a signal peptide

- Assumptions of the model:
- the observable distribution of amino acids arises due to being in a certain region (state),
 - a duration of the state (the length of given region) is modeled by a probability distribution (other than geometric distribution as in typical hidden Markov models).

Training of the algorithm

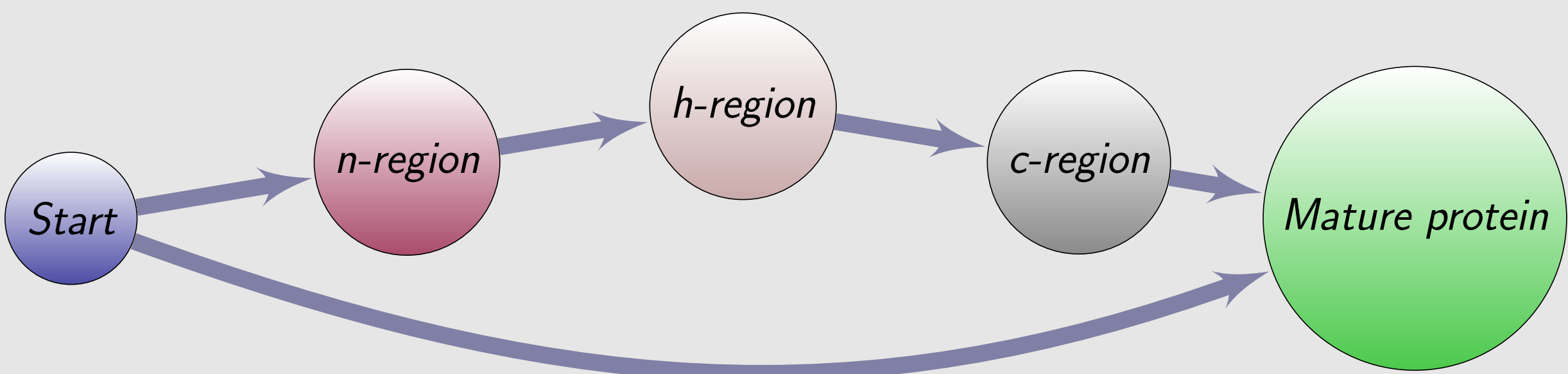
1. Removal of atypical (non-standard amino acids, more than one cleavage site) or poorly annotated records from data set of proteins with signal peptide from UniProt database,
2. determination of n-, h-, c-regions by the heuristic algorithm,
3. reduction of dimensionality by aggregating amino acids to several physico-chemical groups,
4. calculation of the amino acid group frequency in each region and the average length of the region,
5. training of two HSMM models for proteins with and without signal peptide.

Classification of amino acids used by signal.hsmm

	Group	Amino acids
Positively charged	1	K, R, H
Nonpolar and aliphatic	2	V, I, L, M, F, W, C
Polar and uncharged	3	S, T, N, Q
Negatively charged and nonpolar	4	D, E, A, P, Y, G

Signal peptide prediction

During the test phase, each protein is fitted to two HSMMs representing respectively proteins with and without signal peptides. The probabilities of both fits and predicted cleavage site constitute the software output.



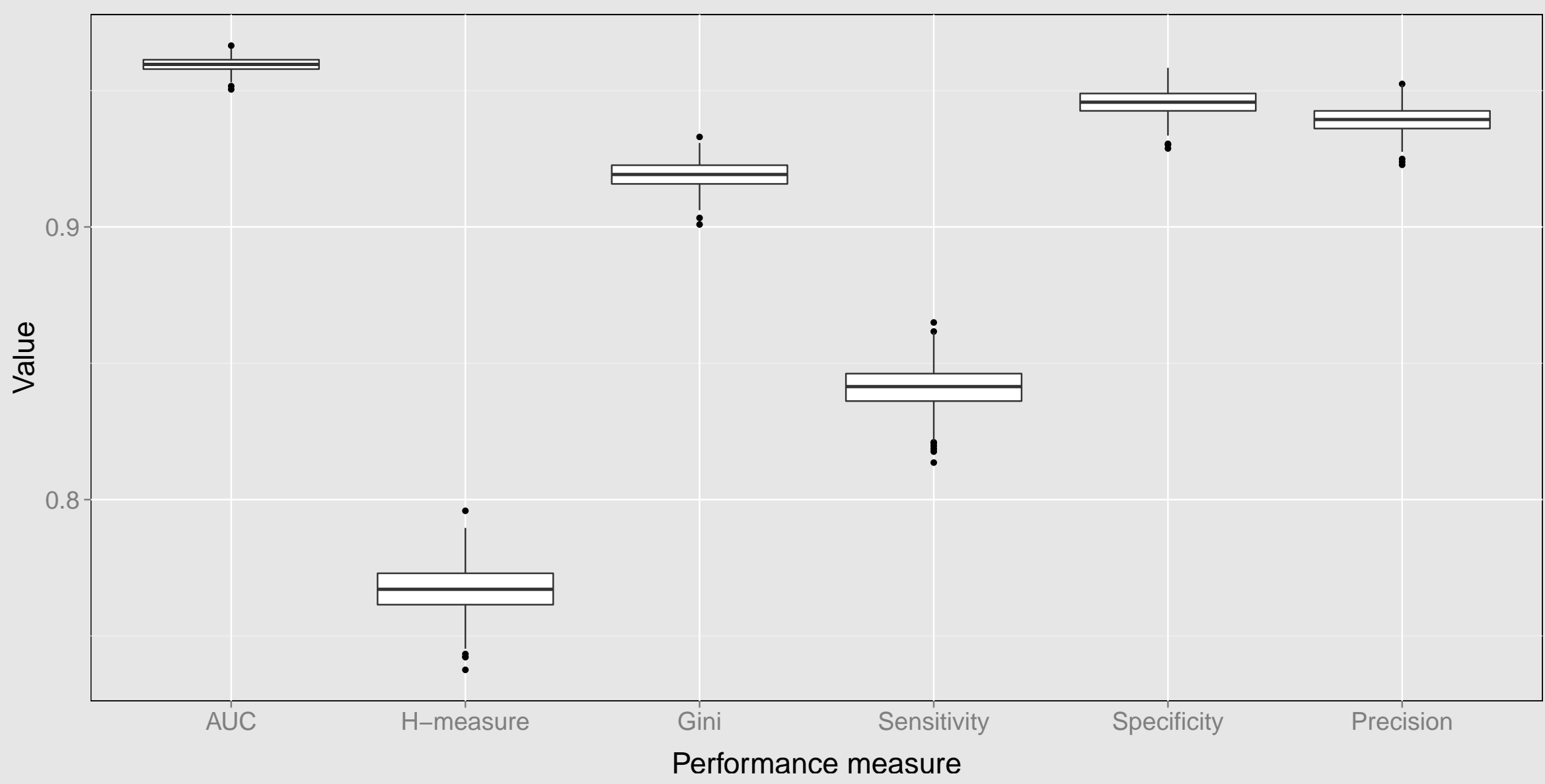
Data set

3816 eukaryotic proteins with experimentally confirmed signal peptides and 9795 eukaryotic proteins without signal peptides downloaded from UniProt database release 2014_07.

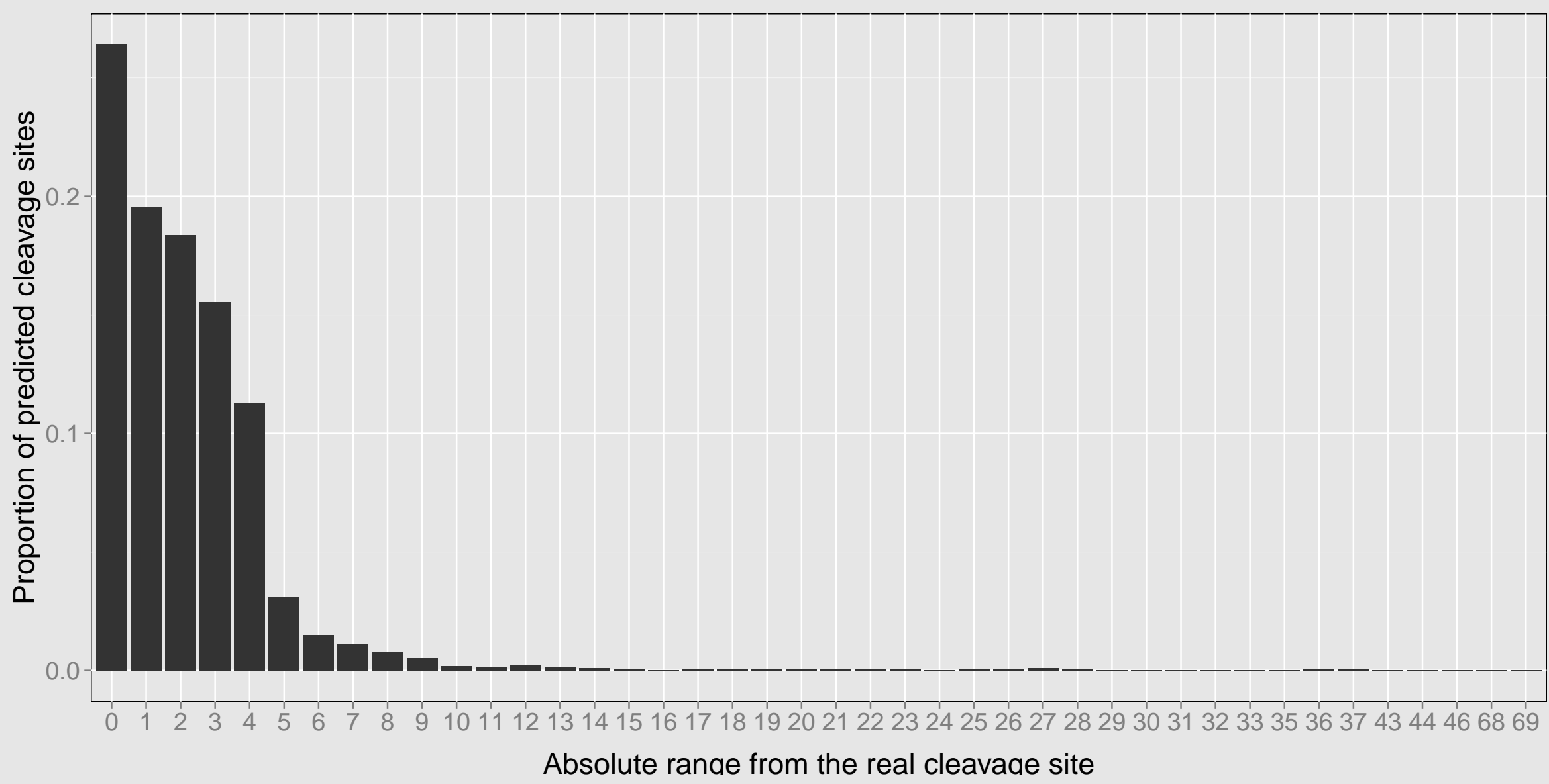
Validation procedure

1. Chose randomly (without replacement) 3816 proteins without signal peptides and train the algorithm (called signal.hsmm) and reshuffle 3816 proteins with signal peptides.
2. Perform 5-fold cross-validation.
3. Repeat step 1. and 2. 250 times.

Performance measures



Cleavage site prediction



Comparison with other signal peptide predictors

Benchmark data set: 140 eukaryotic proteins with signal peptide and 280 randomly chosen eukaryotic proteins without signal peptide added after 2010.

signal.hsmm1987: trained on data set of 496 eukaryotic proteins with signal peptides added before year 1987.

signal.hsmm2010: trained on data set of 3676 eukaryotic proteins with signal peptides added before year 2010.

Comparison of various software

STH

Summary

Hidden semi-Markov models can be used to accurately predict the presence of secretory signal peptides effectively extracting information from very small data sets.

Availability

signal.hsmm web server:

<http://michbur.shinyapps.io/signalhsmm/>



signal.hsmm R package:

<http://cran.r-project.org/web/packages/signal.hsmm/>

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