EUROPEAN COLLEGE OF SPORT SCIENCE

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Exercise Induced Hypoxemia Modeling

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What is Exercise Induced Hypoxemia

- EIH is a physiological phenomenon exhibited by some high-level endurance trained athletes (Dempsey et al., 1984)
- At least PaO_2 10mmHg and/or 4% of SpO_2 between rest and end of maximal exercise (Prefaut et al., 2000)
- Between 52 and 70% of endurance trained athletes (Powers et al., 1988; Constantini et al., 2017)
- Multi-factorial but principally due to inadequate hyperventilation and gas exchange limitations (Durand et al., 2000)

Severity depends of SpO_2 minimal value:

- 95-93% SpO_2 → mild EIH
- 93-88% SpO_2 → moderate EIH
- <88% SpO_2 → severe EIH

EIH consequences

Same VO_2max while SpO_2 fall is greater for EIH (Chapman et al., 1999; Gaston et al., 2016)

→ Specific adaptations (muscular and cerebral oxygenation) (Raberin et al., 2019)

- Drop of VO_2max greater for EIH than NEIH with a reduction in SpO_2max and max HR (Gaston et al., 2016; Raberin et al., 2019)
- Lower ventilatory response to hypercapnia (Granger et al., 2020)
- After 5 days of moderate altitude → lower resting and maximal SpO_2 and greater Qc in EIH than NEIH

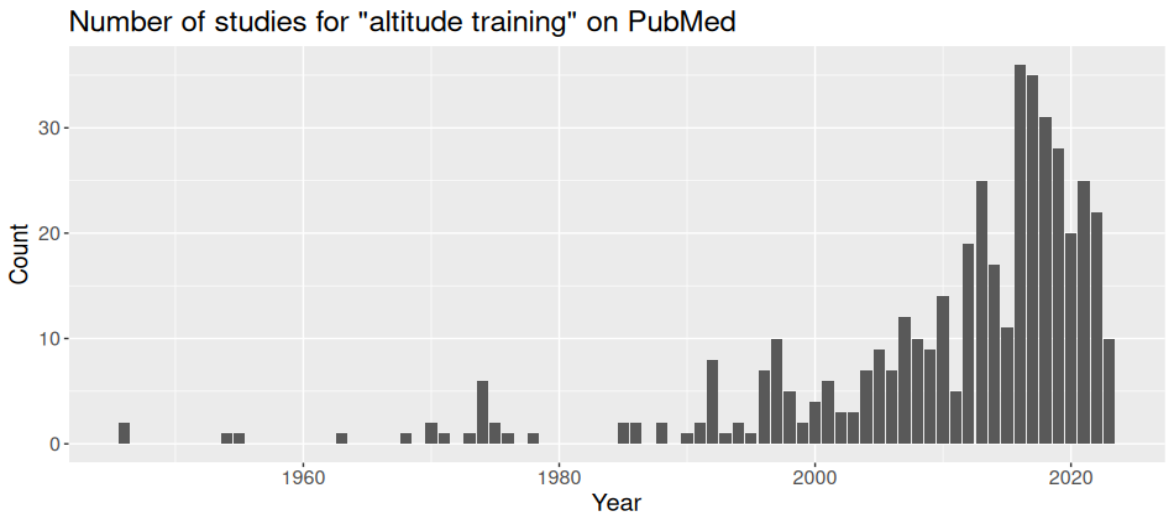
→ Specific cardiovascular adaptations that enabled the achievement of the same VO_2max in chronic hypoxia

→ Ventilatory and cardiovascular parameters are impacted on EIH athletes exposed to acute and/or chronic hypoxia

EIH and altitude/hypoxia

- More and more endurance trained athletes experienced altitude/hypoxia
  → Among them EIH athletes (due to prevalence of the phenomenon)

- Numerous studies about altitude/hypoxic training



- ➔ Various and contradictory results
- ➔ Role of EIH?
- ➔ Not measured!

Artificial intelligence in sport

- AI approaches can be used to predict or estimate features

  Davidson et al. (2023) estimate VO_2 using LSTM networks with speed, HR, cadence, etc.

- We observe an increased amount of studies using AI in sport sciences

- Such approach are useful to:

  - Analyze large amount of data

  - Detect slight changes and variations

Objective of the study

- EIH impact the responses to altitude/hypoxia at rest and during exercise
- EIH is easy to measure but isn't done in studies investigating altitude/hypoxia training
- However, these studies generate recommendations and guidelines for altitude/hypoxia training for athletes and coaches
- More and more AI is used in sport sciences and could be pertinent for this work

In order to re-analyze already acquired data

The purpose of this work was to classify athletes as EIH or NEIH without SpO_2 measurement using classic statistics and AI

Material & method

Population:

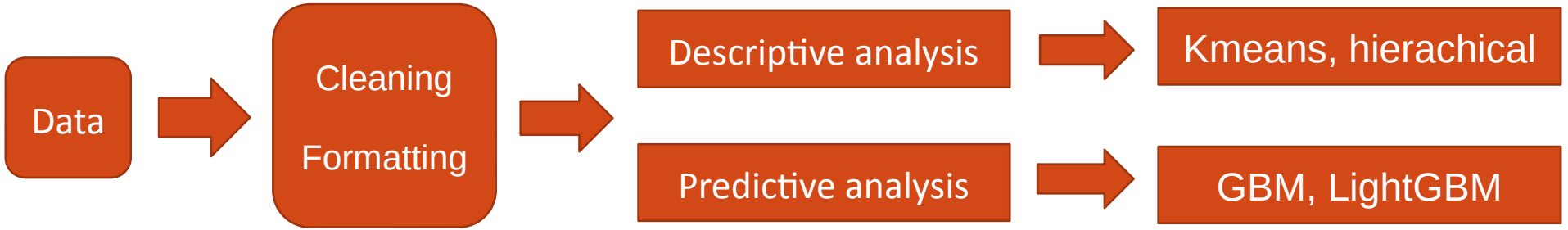
- From various works done by our team and others (retrospective study)
- 125 males, endurance trained athletes → EIH n = 64; NEIH n =61

	age	height	weight	train_volume	train_years
NEIH	31.8 ± 7.9	177.2 ± 6.5	70.5 ± 7.5	10.1 ± 5.5	11.5 ± 8.3
EIH	33.2 ± 8.1	179 ± 6.3	72.2 ± 8.2	11.9 ± 5.2	11.4 ± 7.6

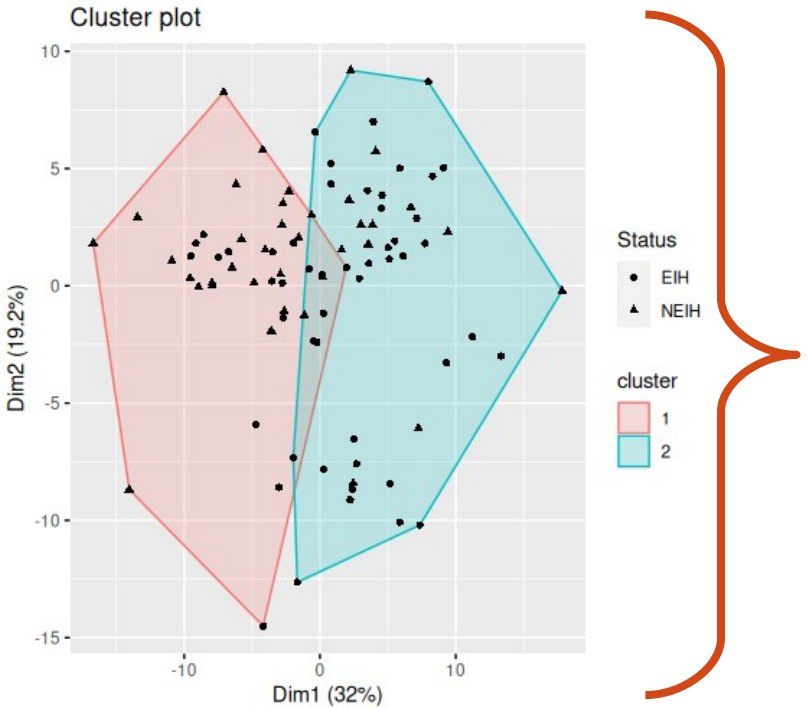
Material & method

Data and design:

- From maximal exercise with continuous gas exchange measurements:
  - HR, VE, BF, VO_2, VCO_2, VE/VO_2, VE/VCO_2, VO_2/VCO_2
  - Median, mean, sd, rms, max, min, relative
- SpO_2 measured with an ear oximeter (Nonin Palmsat) → at rest and maximum effort end



Results: EIH status



Data placed in a 2 dimensional place

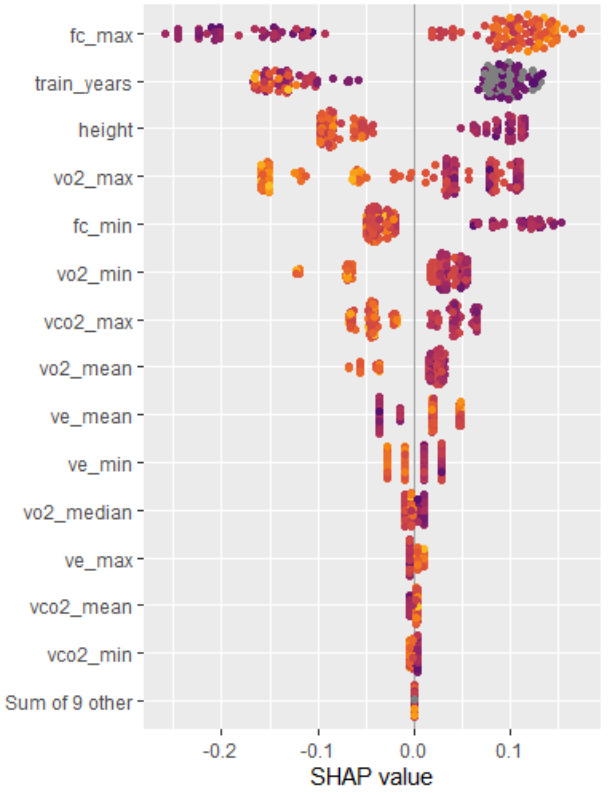
Cluster based on distances without using saturation

- Colors = cluster
- Forms = EIH status

EIH & NEIH are mixed in clusters

Clustering methods are not powerful enough to discriminate EIH & NEIH subjects

Results: EIH status



Classification without saturation data

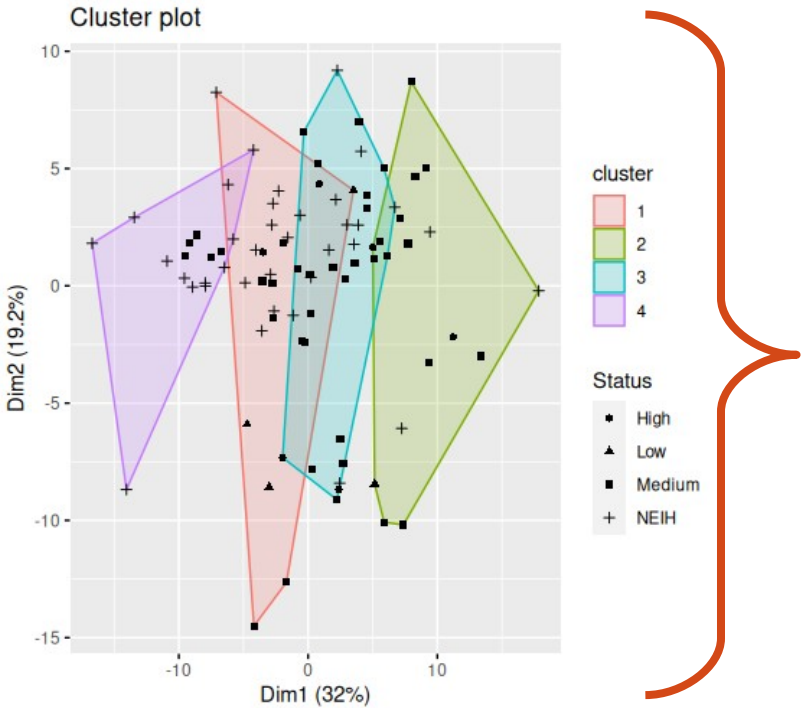
88% accuracy for EIH/NEIH status

Insights about the features used for this classification

Accuracy	Kappa	AccuracyLower	AccuracyUpper	AccuracyNull
0.720000000	0.437299035	0.575094643	0.837689399	0.520000000

AccuracyPValue	McnemarPValue
0.003151612	0.789268026

Results: EIH intensity



Data placed in a 2 dimensional place

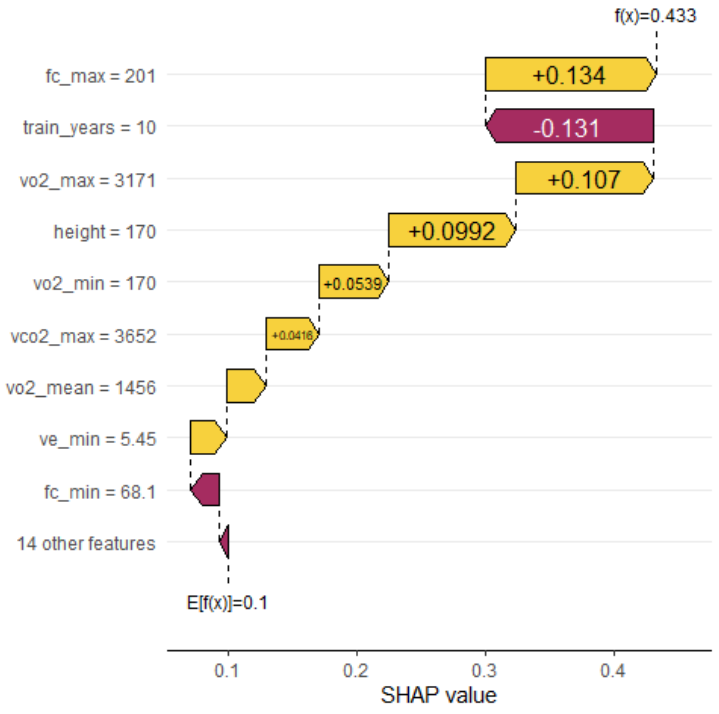
Cluster based on distances without using saturation

- Colors = cluster
- Forms = EIH intensity

Intensities are mixed in clusters

Clustering methods are not powerful enough to discriminate EIH intensities

Results: EIH intensity



Classification without saturation data

80% accuracy for EIH intensity

Insights about the features used for this classification

Accuracy	Kappa	AccuracyLower	AccuracyUpper	AccuracyNull
0.720000000	0.437299035	0.575094643	0.837689399	0.520000000

AccuracyPValue	McnemarPValue
0.003151612	0.789268026

Discussion

- Most effective method: LightGBM

  This approach is able to classify subjects using only gas exchange data

- Accuracy are correct and results are coherent:
  - 88% and 80% for status and intensity respectively
  - Most important factor for classification have a physiological interest: VO_2max, HR, age, etc. → physiological factors for EIH (Prefaut et al., 1994)

Conclusion

We are able to classify and detect EIH athletes using only gas exchange data

Those results can be used for research purpose

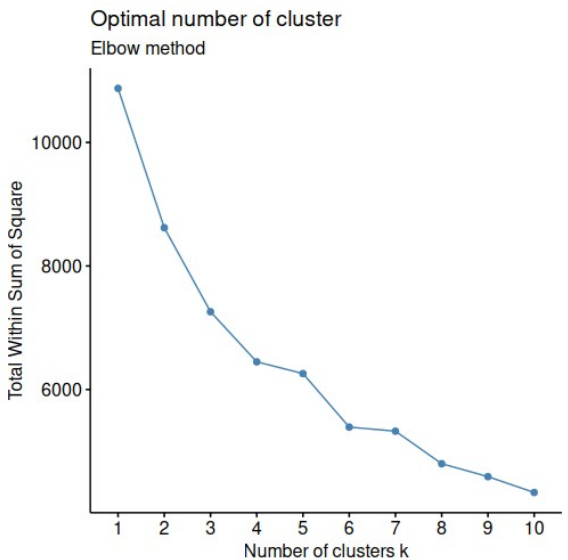
Future perspectives:

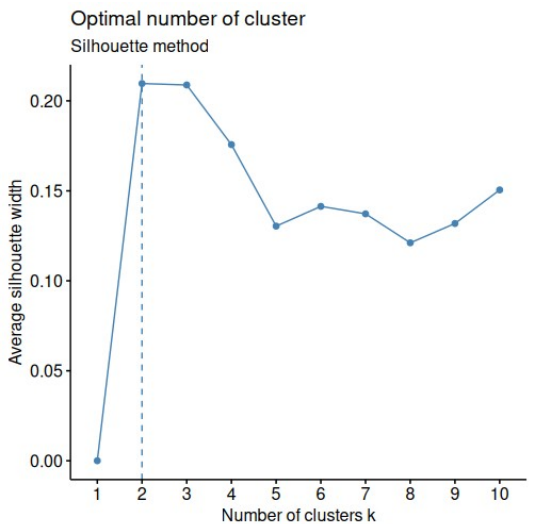
1. Increase data amount
2. Create other models (impact of altitude on EIH athletes performances)

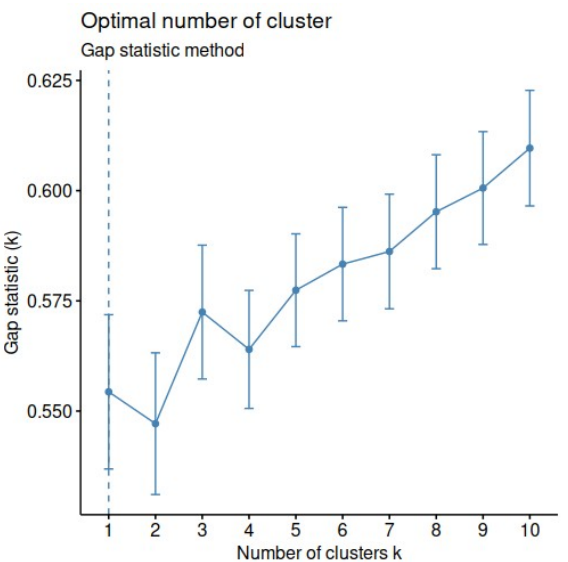
The end

Cluster number choice

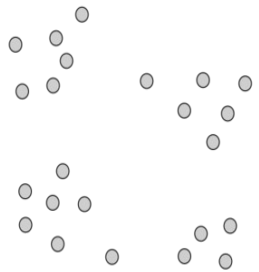
Levels: 2 & 4 → status and intensity



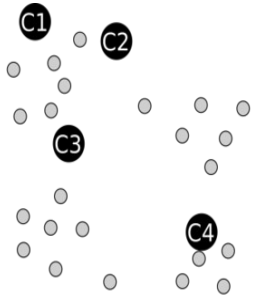




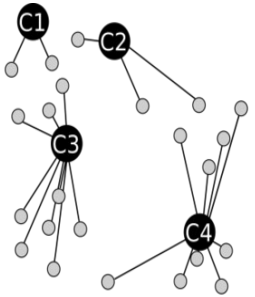
Clustering method



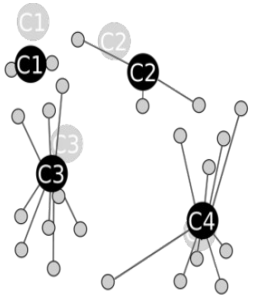
0a. Données d'entrée



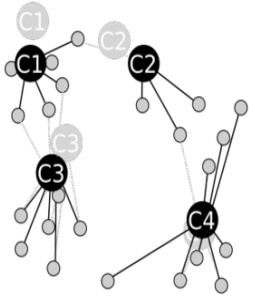
0b. intialisation



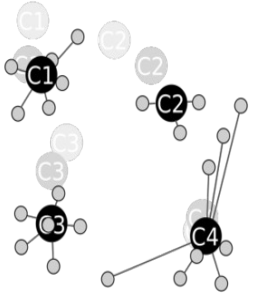
1a. assignation



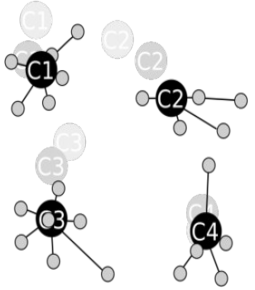
1b. calcul des points moyens



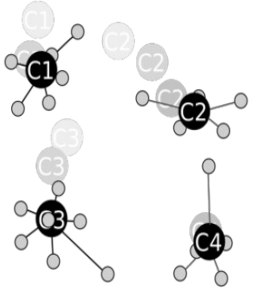
2a. assignation



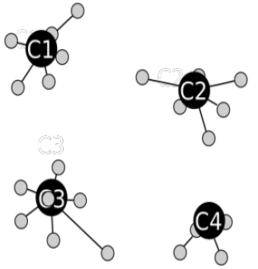
2b. calcul des points moyens



3a. assignation



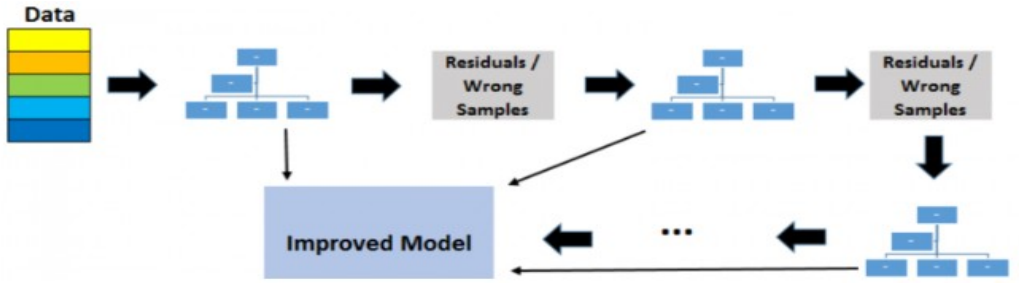
3b. calcul des points moyens

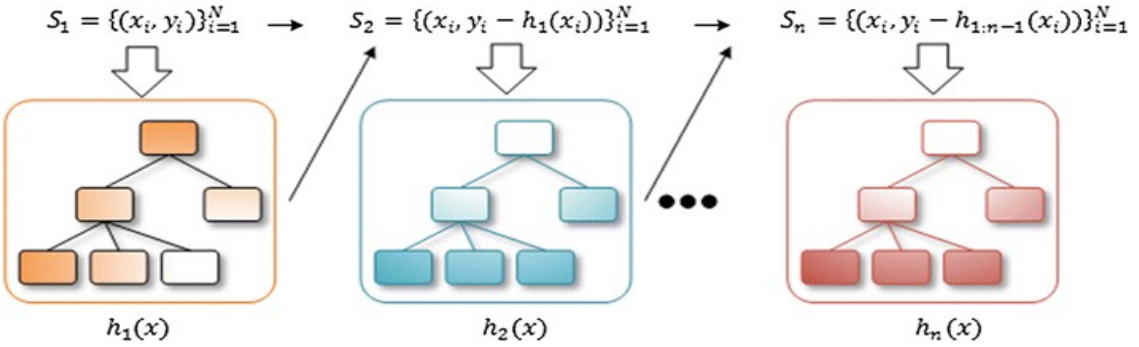


4a. assignation

clusters stables (fin)

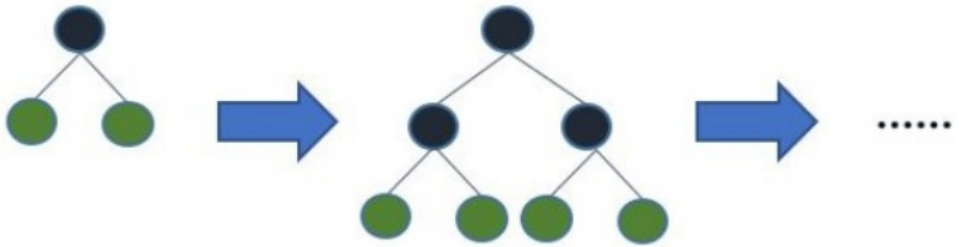
LighGBM


Data
Residuals / Wrong Samples
Residuals / Wrong Samples
Improved Model


$S_1 = \{(x_i, y_i)\}_{i=1}^N$
$S_2 = \{(x_i, y_i - h_1(x_i))\}_{i=1}^N$
$S_n = \{(x_i, y_i - h_{1:n-1}(x_i))\}_{i=1}^N$
$h_1(x)$
$h_2(x)$
$h_n(x)$

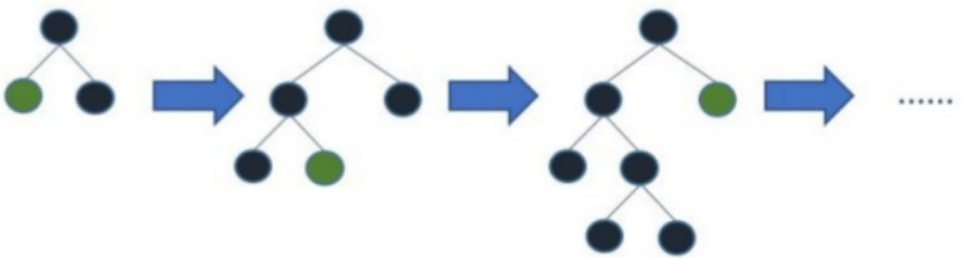
LightGBM: GOSS

XGBoost:



Level-wise tree growth

LightGBM:



Leaf-wise tree growth

LightGBM: EFB

feature1	feature2	feature_bundle
0	2	6
0	1	5
0	2	6
1	0	1
2	0	2
3	0	3
4	0	4

AI

AI is defined as the ability of a system to interpret and learn from exterior data correctly (Kaplan et al., 2019)