Politecnico di Torino

Università degli Studi di Napoli Federico II

Hierarchical Time Series Analysis

Predictive Analytics of Climate Stress Impact on the Italian Mediterranean Buffalo

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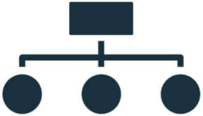
Prediction

Classification



Clustering

Prediction

- The hierarchy is a mathematical constraint.
- The numbers must add up.

Example

How many tourists are going to visit Italy?

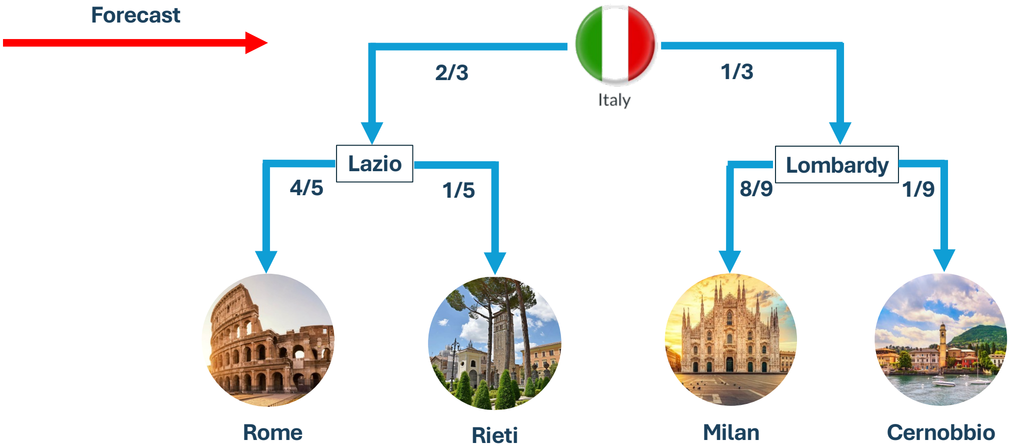
How about Piemonte?

How about Torino?

Italy has 20 Regions

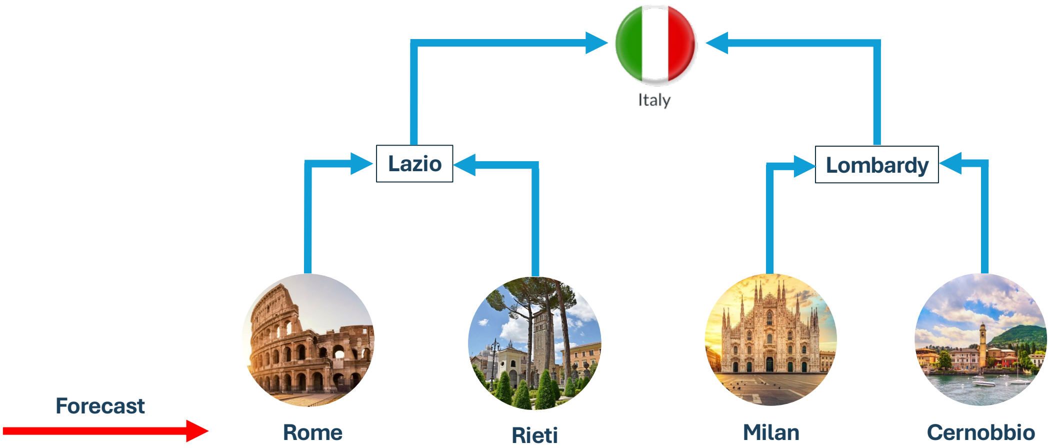
We need forecasts for the whole of Italy, for each region and for each city.

Approach 1 : Top Down


Forecast
Italy
2/3
1/3
Lazio
Lombardy
4/5
1/5
8/9
1/9
Rome
Rieti
Milan
Cernobbio

Problem : it is not accurate on the bottom levels

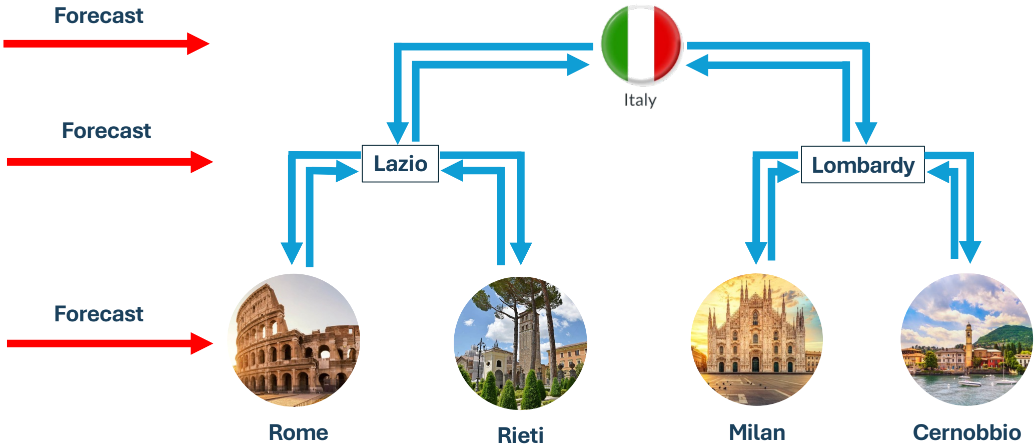
Approach 2 : Bottom UP


Italy
Lazio
Lombardy
Forecast
Rome
Rieti
Milan
Cernobbio

Problem : add up problem, sum of child forecasting is not equal to their parent

What is optimal solution?

Hierarchical Reconciliation


Forecast
Forecast
Forecast
Italy
Lazio
Lombardy
Rome
Rieti
Milan
Cernobbio

Hierarchical Reconciliation

- A model will be trained on the data[XGBoost, ...].
- Forecast on the data using current model.
- Reconcile the predicted values using statistical approaches.

Hierarchical Reconciliation

- **MinT :** minimize the variance between reconciled values and base forecast error.
- **ERM :** minimize the error between actual values and reconciled values.

Base model for prediction

- **XGBoost + MinT**
  - Handles Climate Data
  - Hierarchical Coherence Guaranteed
  - Highly interpretable

Base model for prediction

- **Neural Network- Based**
  - Handles Climate Data
  - Hierarchical Coherence NOT Guaranteed
  - Low interpretability

Prediction

Classification

Clustering

Classification

- The hierarchy is not a constraint to be fixed.
- Supervised task, needs to assign Labels.
- Labeling is different for each approaches.

Approach 1
Feature-Based

Feature-Based Classification

- Create tabular data based on avg of past days.
- Assign label to each row as YES/NO.
- Apply a model to train on the data. [Random Forest]
- Classify based on level:
  - Animal at risk ? (Yes/No)
  - High stress event? (Yes/No)

Feature-Based Classification : Labeling

Goal: Predict a "High SCC Event"

High SCC Event ➔ SCC > 250

Animal_ID	Farm_ID	Day	Milk	SCC	THI
A-101	Farm-A	1	20	100	22
A-101	Farm-A	2	19	110	23
A-101	Farm-A	3	18	120	26
A-101	Farm-A	4	17	150	27
A-101	Farm-A	5	15	**260**	28
A-101	Farm-A	6	14	200	25

Feature-Based Classification : Labeling

Goal: Predict a "High SCC Event"

Train on the new table.

Animal_ID	Day	scc_lag_1	avg_THI_last_3_days	Farm_ID (Hierarchical)	event_in_next_2_days (Label)
A-101	3	110	**23.7**	Farm-A	**1 (Yes)**
A-101	4	120	**25.3**	Farm-A	**1 (Yes)**
A-101	5	150	**27.0**	Farm-A	**0 (No)**

Approach 2
Native/Deep Learning

Native/Deep Learning Classification

- Takes fixed-length snippet as input [3-day, 7-day]
- Assign label to each snippet based on whether high-risk event occurred in 2 days later.
- Apply a model to learn on the data. [1D-CNNs or LSTMs]

Native/Deep Learning Classification : Labeling

Goal: Predict a "High SCC Event"

High SCC Event ➔ `SCC > 250`

Animal_ID	Farm_ID	Day	Milk	SCC	THI
A-101	Farm-A	1	20	100	22
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Native/Deep Learning Classification : Labeling

Goal: Predict a "High SCC Event"

High SCC Event ➔ `SCC > 250`

X (The 3-Day Input Snippet)	Label
[[20, 100, 22], [19, 110, 23], [18, 120, 26]]	**1 (Yes)**
[[19, 110, 23], [18, 120, 26], [17, 150, 27]]	**1 (Yes)**
[[18, 120, 26], [17, 150, 27], [15, 260, 28]]	**0 (No)**

Animal_ID	Farm_ID	Day	Milk	SCC	THI
A-101	Farm-A	1	20	100	22
A-101	Farm-A	2	19	110	23
A-101	Farm-A	3	18	120	26
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Prediction

Classification

Clustering

Clustering

- The hierarchy is not a constraint to be fixed.
- The hierarchy levels provide different "lenses" for clustering.

Animal-Level

Clusters individual animals

- Cluster 1: "Resilient Animals”.
- Cluster 2: "Vulnerable Animals".

Farm-Level

Clusters entire farms

- Cluster A: "High-Performance Farms".
- Cluster B: "Poorly-Managed Farms".

Approach 1
Feature-Based

Feature-Based Clustering

- Creates a profile for each animal/farm based on avg features.
- Applies K-means on the profiles.
- Clusters animals/farms based on different types.

pros

- Highly interpretable and Computationally fast

cons

- It uses Average of features instead of day-to-day data

Approach 2
Shape-Based

Shape-Based Clustering

- Extracts fixed-day data and compare with others.
- Applies dynamic Time Warping to find similarity.
- Clusters animals/farms based on behavioral patterns:
  - Cluster 1: “Fast Recovery”
  - Cluster 2: “No Recovery”

pros

- Finds Behavioral Patterns
- Works on raw data
- Less bias

cons

- Computationally Expensive

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