Smart4RES collaborative analytics for renewable energy forecasting: federated learning and data markets

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IEA TASK 51 Workshop “State of the Art and Research Gaps”
Motivation

Increasing volume of geographically distributed data

Main Barriers

Data privacy and confidentiality

Lack of monetary and non-monetary incentives for sharing data

Lack of business cases for collaborative analytics
Collaborative analytics & RES forecasting

• **Federated learning models with data from different owners / data sources**
  - Privacy-preserving protocols
  - Different data exchange schemes

• **Algorithmic solutions for data markets**: data price as a function of use case specific value
Federated Learning

Centralized Model

Peer-to-peer Model

Central node
(Hub)

Agents
(RES Producers)
Federated learning concept

Privacy-preserving federated learning: RES forecasting

Non-linear relation between power and weather variables

Extension with additive models and kernels to capture non-linearities

Privacy-preserving federated learning: RES forecasting

\[
\begin{array}{ccc}
\text{Power WF}_1 & \quad & \text{data from WF}_1 \\
\text{Power WF}_2 & \quad & \text{data from WF}_2 \\
\text{Power WF}_3 & \quad & \text{data from WF}_3 \\
\end{array}
\]

\[
\begin{array}{ccc}
\text{Coef } & \quad & \text{Coef } \\
\text{WF}_1 & \quad & \text{WF}_2 \\
\text{WF}_3 & \quad & \text{WF}_3 \\
\end{array}
\]

Each variable is transformed in \( k \) variables:

\[
X_1 \rightarrow f_1(X_1), f_2(X_1), \ldots, f_k(X_1)
\]

Supported by our privacy-preserving protocol.
Privacy-preserving federated learning: RES forecasting

Each observation is transformed to the distance relative to the others

$$y|x = \sum_{t} K(||x - x_t||)B_t$$

$$\hat{B} = K^{-1}y$$

**Negative Distance Kernel (NDK)**

$$K(||x - x_e||) = -||x - x_e||^2$$

$$K = KA1 + KA2$$

$$KA1$$ Encrypted

$$MK_{A1}$$

$$KA2$$

$$MK_{A2}$$

$$YA1$$

$$MY_{A1}$$

$$YA2$$

$$MY_{A2}$$

$$\hat{B} = [M(KA1 + KA2)]^{-1}[MY_{A1}, MY_{A2}]$$

**Supported by our privacy-preserving protocol**

$$MK_{A1} + MK_{A2} = M(KA1 + KA2)$$
Numerical results: Improvement w.r.t. single owner data

- 60 wind turbines
- 2 years of historical data
- ECMWF-HRES
Numerical results: Splines and kernel performance

ms-splines over Gradient Boosting Trees (no privacy)

NDK over Gradient Boosting Trees (no privacy)
Data Markets

Data Market

Sellers

Buyers

Data Value Assessment

Knowledge Extraction

Collaborative Analytics
Data market concept for RES forecasting

**Objective:** Improve forecasting skill

Payment depends on the *gain* obtained by using market sellers’ data

**Objective:** Monetize their data

Revenue depends on the actual contribution to Buyers forecast skill

*Data value found through collaborative analytics*
Data market: No-regret mechanism

**Market Operator**

- Defines a market price (using info from t-1)
- **Data allocation** according to the difference between bid and market price
- **Payment** depends on the expected gain when using allocated sellers’ data
- **Payment division** according to the relevance of data

- Sellers’ loss when sharing their data is not considered

Data market: Social welfare maximization

**Sellers**
- S1
  - Data & min price
  - Payment
- S2
  - Data & min price
  - Payment
- S3
  - Data & min price
  - Payment

**Market Operator**
- **Data allocation and prices**
- **Social welfare maximization**
  - Max (buyers’ gain – sellers’ loss)

**Buyers**
- B1
  - Data & max price forecasts
  - Payment
- B2
  - Data & max price forecasts
  - Payment
Numerical results


Agent with highest reward for data sharing

Cumulative Data Market Revenue

Cumulative Extra Revenue from Electricity Market

Cumulative Payment

Agent DK1

Agent DK2

Agent SE4

Agents that maximize electricity market revenue due to “extra” data
Data market IOTA prototype

Market Agents APP (w/ wallet)

- A1
- A2
- A3
- A4

IOTA (DLT) token transactions

Open Market Session → Bid Placement → Payment Confirmation → Close Market Session

Market Account (database)

Market Wallet

In sync w/ IOTA Tangle

Use Exchange for FIAT ↔ MIOTA exchange

Run Market Clearing

Update Agents Token Balance

Store Agents Forecasts

Forecasts (database)

Access Forecasts

REST

Data Market Platform
Monetizing Customer Load Data for an Energy Retailer: A Cooperative Game Approach

Liyang Han, Jiatal Kazempour, Peter Pietsch

Abstract

The paper proposes a cooperative game framework for the strategic allocation of load data among energy retailers. The proposed framework integrates game theory, cooperative game theory, and optimization techniques to evaluate the benefits and costs of sharing load data among different segments of the electricity market. The proposed framework provides a systematic approach to quantify the potential benefits of load data sharing and to determine the optimal allocation of load data among different segments. The proposed framework can be applied to various electricity market scenarios and can help energy retailers to make informed decisions about the allocation of load data.
Concluding

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- Advantage: with federated learning & spatial-temporal models we only have 1 model to maintain

- Value of spatial-temporal information (power, NWP) is a proven result

- Different mechanisms are possible for data markets
  - Challenge: data value for the seller
  - To reach full potential, we need to go beyond the forecasting use cases

- Data sharing in the RES sector aligned with EU initiatives like GAIA-X and Common Data Spaces