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A Short-Term and High-Resolution System Load Forecasting Approach Using Support Vector Regression with Hybrid Parameters Optimization

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Background

- **Background**
  - Many load forecasting approaches exist, but few of them focus on load forecasting in distribution systems.
  - In transmission systems, the aggregated loads are always fairly smooth.
  - In distribution systems, the load profile characteristics are different. For example, the impact of electrical vehicles indicates that the abruptly stochastic load deviation is a feature of distribution systems.
- **Solutions**
  - A support vector regression (SVR) based forecaster with a two-step hybrid parameters optimization method.

Background - SVR

- Objective function

$$\min_{b,w,\varepsilon,\varepsilon'} J = \frac{1}{2} w^T w + C \sum_{n=1}^{N} (\varepsilon_n + \varepsilon'_n)$$

s.t. $-\epsilon - \varepsilon_n \leq y_n - w^T z_n - b \leq \epsilon + \varepsilon'_n, 0 \leq \varepsilon_n, 0 \leq \varepsilon'_n$

- Lagrange Multipliers and KKT Conditions (Convex)

$$\min \frac{1}{2} = \sum_{n=1}^{N} \sum_{m=1}^{M} (\alpha_n - \alpha'_n)(\alpha_m - \alpha'_m) k_{n,m} + \sum_{n=1}^{N} ((\epsilon - y_n) \cdot \alpha_n + (\epsilon + y_n) \cdot \alpha'_n)$$

s.t. $\sum_{n=1}^{N} 1 \cdot (\alpha_n + \alpha'_n) = 0, 0 \leq \alpha_n \leq C, 0 \leq \alpha'_n \leq C$

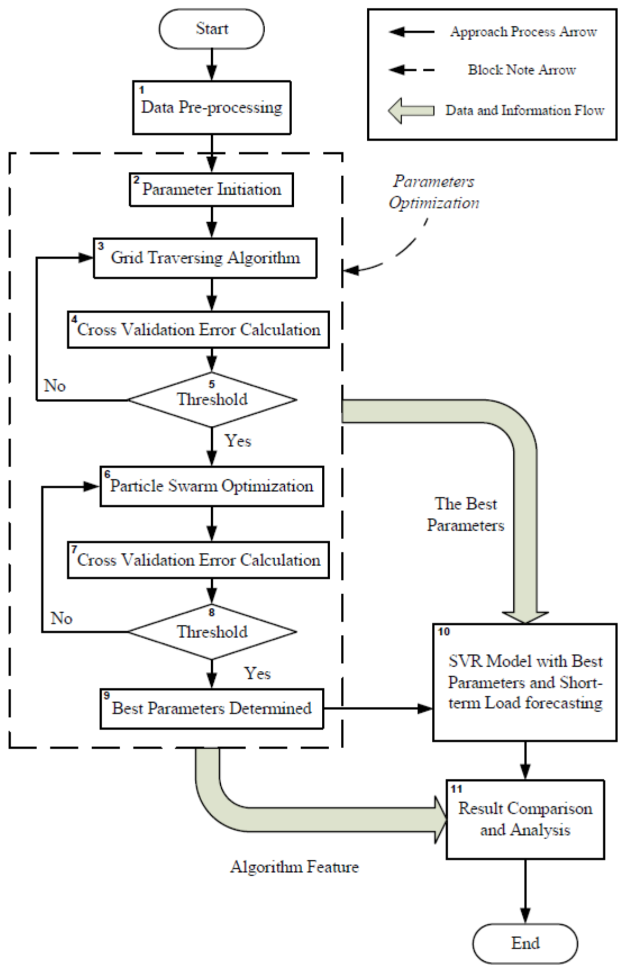
- Parameters still need to optimize (Nonconvex)

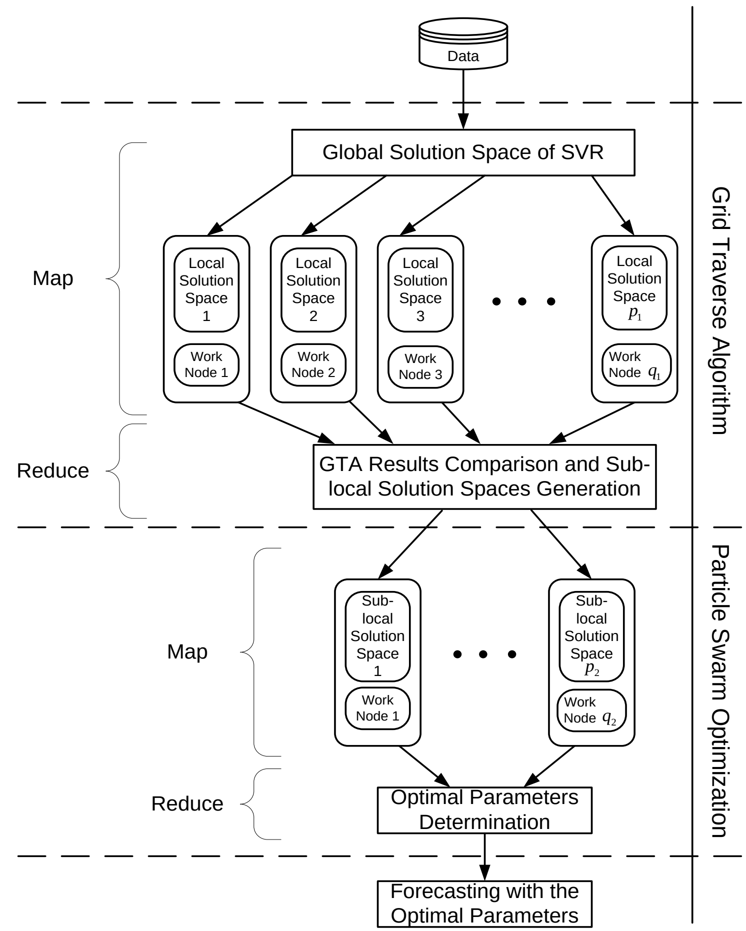
C a trade-off parameter

γ a parameter of the Gaussian radial basis function (RBF) kernel

ϵ a parameter for the threshold of the tube

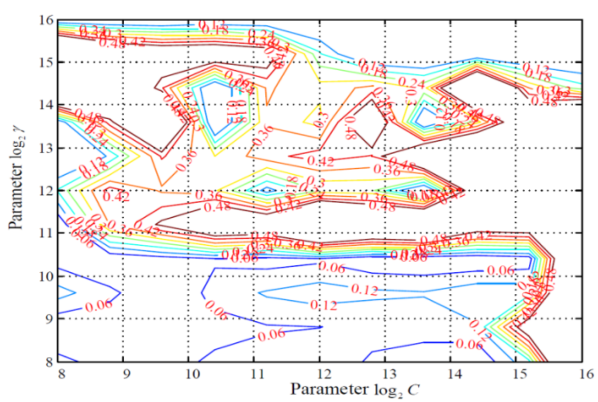
Flowchart of the load forecasting approach

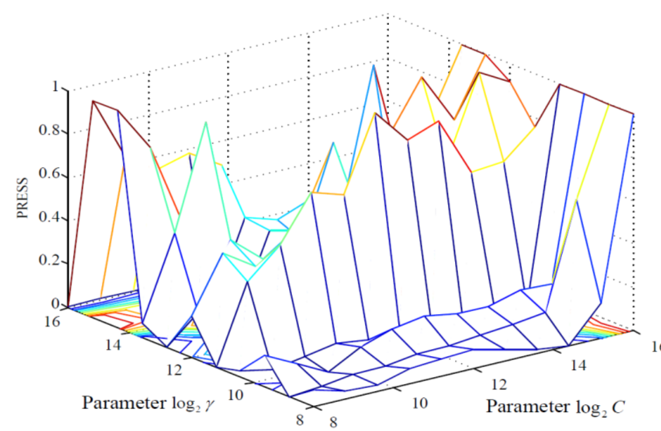




GTA for Parameter Optimization

- **Objective**: Transfer the global optimization problem to one or several local optimization problems.
- **Initialization**: Initialize γ, C, and ε; then compute Λ_j, and build the traverse vector **H**.
- **Grid Traverse Searching**: For the element factor H_{j2},
- $H_{j2} \in \mathbf{H}$, $j_2 \in \{1, 2, \ldots, m_1 \times m_2 \times m_3\}$, the R_{CV} *can be computed.*
- **Determine Local Solution Space**: With the generated contour map, the local solution space with minimum R_{CV} is selected for next step of optimization.





PSO for Parameters Optimization

- Initialization

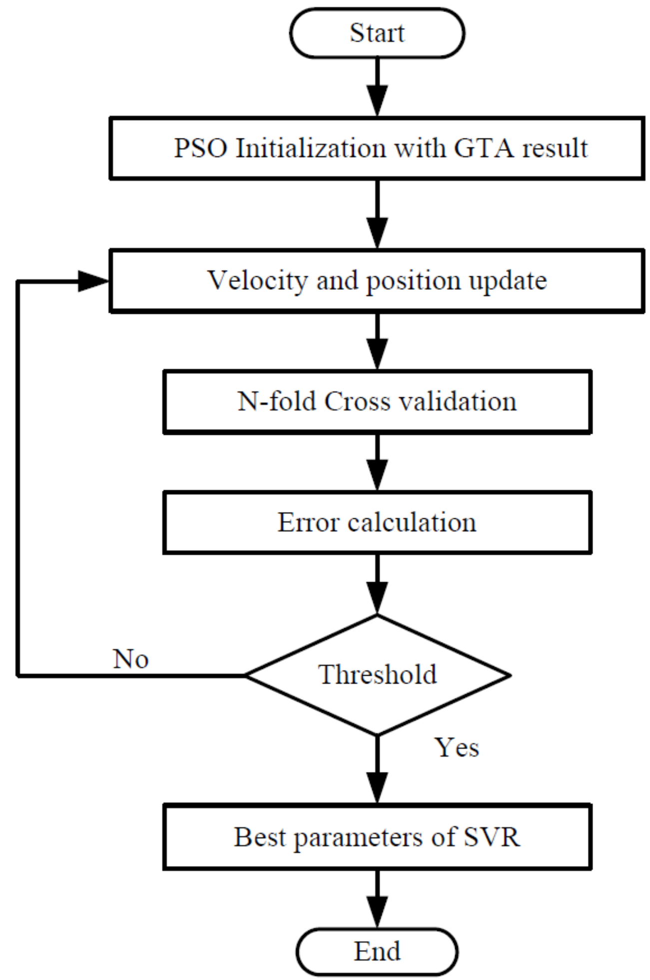
$$\boldsymbol{\alpha}_{i_4}^{\Omega} = [\alpha_{i_4,1}^{\Omega}\alpha_{i_4,2}^{\Omega}\cdots\alpha_{i_4,n_{OBJPSO}}^{\Omega}]$$
$$\boldsymbol{\nu}_{i_4}^{\Omega} = [\nu_{i_4,1}^{\Omega}\nu_{i_4,2}^{\Omega}\cdots\nu_{i_4,n_{OBJPSO}}^{\Omega}]$$
$$\boldsymbol{\eta}_{i_4}^{\Omega} = [\eta_{i_4,1}^{\Omega}\eta_{i_4,2}^{\Omega}\cdots\eta_{i_4,n_{OBJPSO}}^{\Omega}]$$

- Velocity Updates

$$\boldsymbol{\nu}_{i_4}^{\Omega}(t) = \boldsymbol{\nu}_{i_4}^{\Omega}(t-1) + \varphi_1\theta_1(\boldsymbol{\eta}_{i_4}^{\Omega} - \boldsymbol{\alpha}_{i_4}^{\Omega}(t-1)) + \varphi_2\theta_2(\boldsymbol{\eta}_{g}^{\Omega} - \boldsymbol{\alpha}_{i_4}^{\Omega}(t-1))$$

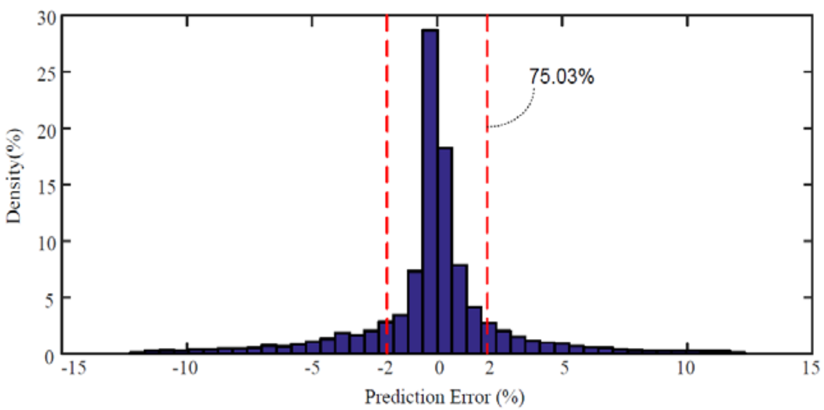
- Position Updates

$$\boldsymbol{\alpha}_{i_4}^{\Omega}(t) = \boldsymbol{\alpha}_{i_4}^{\Omega}(t-1) + \boldsymbol{\nu}_{i_4}^{\Omega}(t)$$



Numerical Results

- The tested data set composes 80 days of load captured from a partner utility's distribution feeder. It includes data from winter (Dec.-Feb.), spring (Mar.-May.), summer (Jun.-Aug.), and autumn (Sep.-Nov.) for 20-days each season. With the sampling rate of 1 Hz, the total data length is 6,912,000.



Minutes-ahead forecasting

Methods	Max. Error (%)	MAPE (%)
ARIMA	31.25	11.21
GA based SVM	21.16	5.27
ANN	25.97	6.62
Proposed	14.11	2.53

Performance Comparison

Methods	20 minutes (S)	4 hours (S)
ARIMA	11.25	77.21
GA based SVM	45.16	1412.7
ANN	40.9	683.62
Proposed	12.89	83.53

Time Consumption Comparison

Conclusions

- An effective short-term load forecasting approach with high resolution is proposed for the aggregated loads of a small section of distribution feeder load.
- Although many SVR based forecasters exist, the proposed two-step hybrid global optimization method can determine the best parameters effectively with acceptable time complexity and computation loads.