KI Service Zentrum by Hasso-Plattner-Institut

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Time Series Forecasting

1.10 Probabilistic Forecasting

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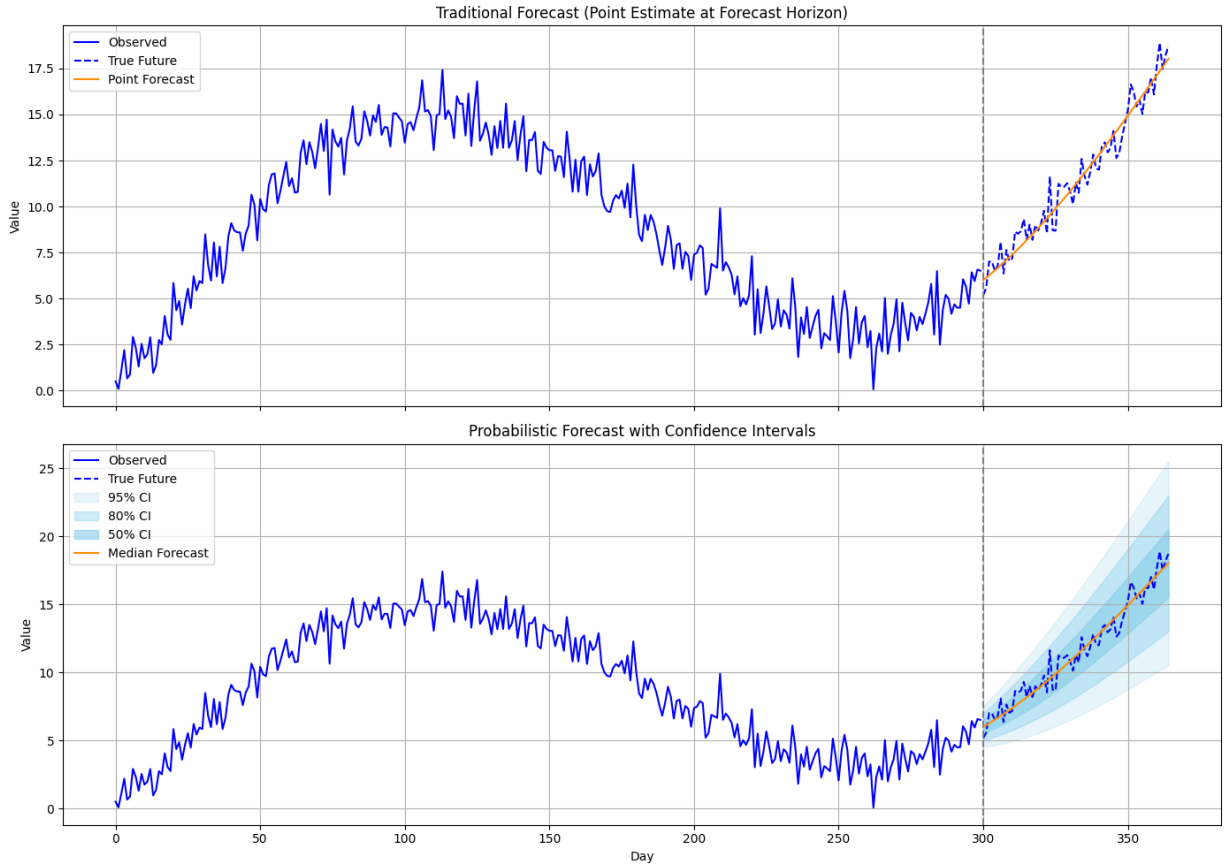
Design IT.
Create Knowledge.

What we'll cover in this video

- Understand what probabilistic forecasting is and why it matters.
- Learn key concepts like prediction intervals, confidence levels, and quantiles.
- Explore methods to generate probabilistic forecasts.
- Discover ways to visualize uncertainty effectively.
- Learn how to evaluate forecast quality using calibration and scoring rules.

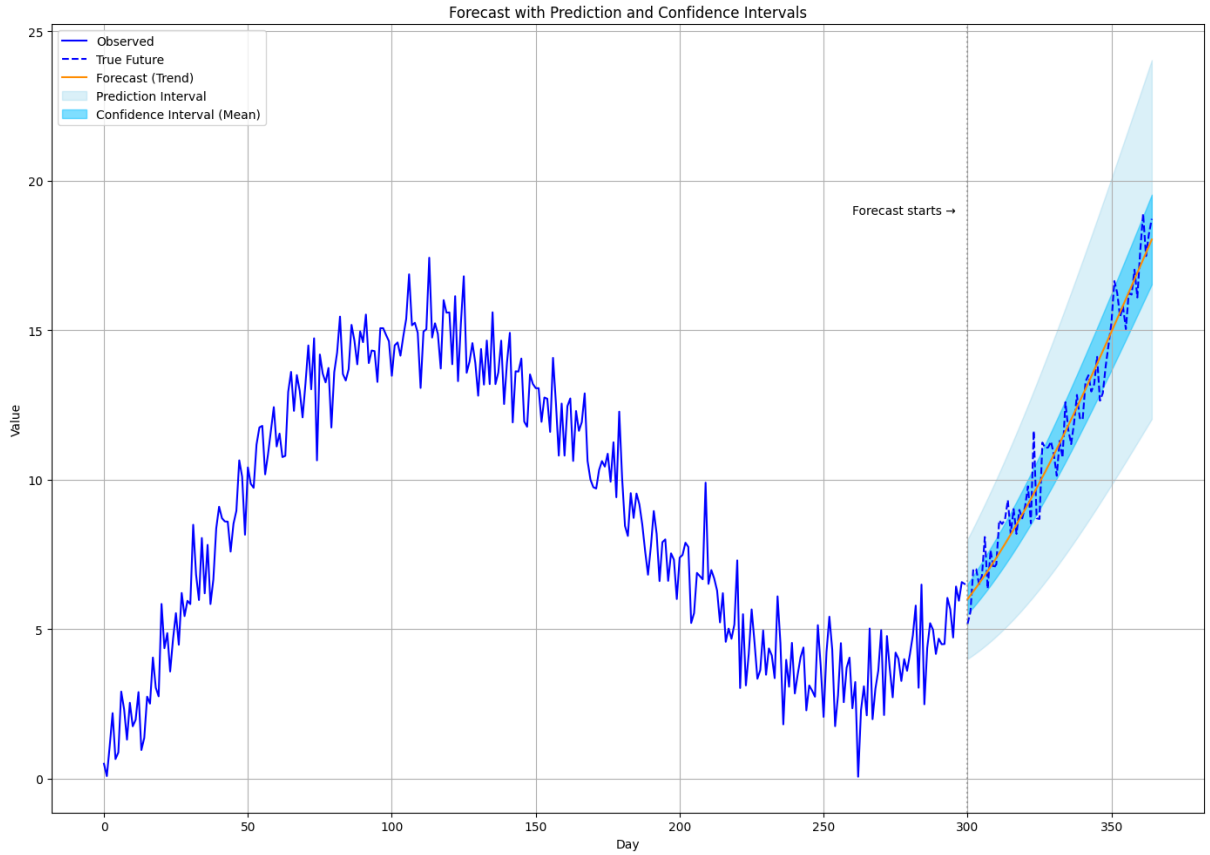
Why Probabilistic Forecasting?

- Probabilistic forecasting predicts a range of possible outcomes, not just a single value. It assigns probabilities to different future scenarios.
- Contrast with Deterministic Forecasting
- Captures uncertainty in complex systems
- Supports better risk-informed decisions
- Enables scenario planning and resource optimization



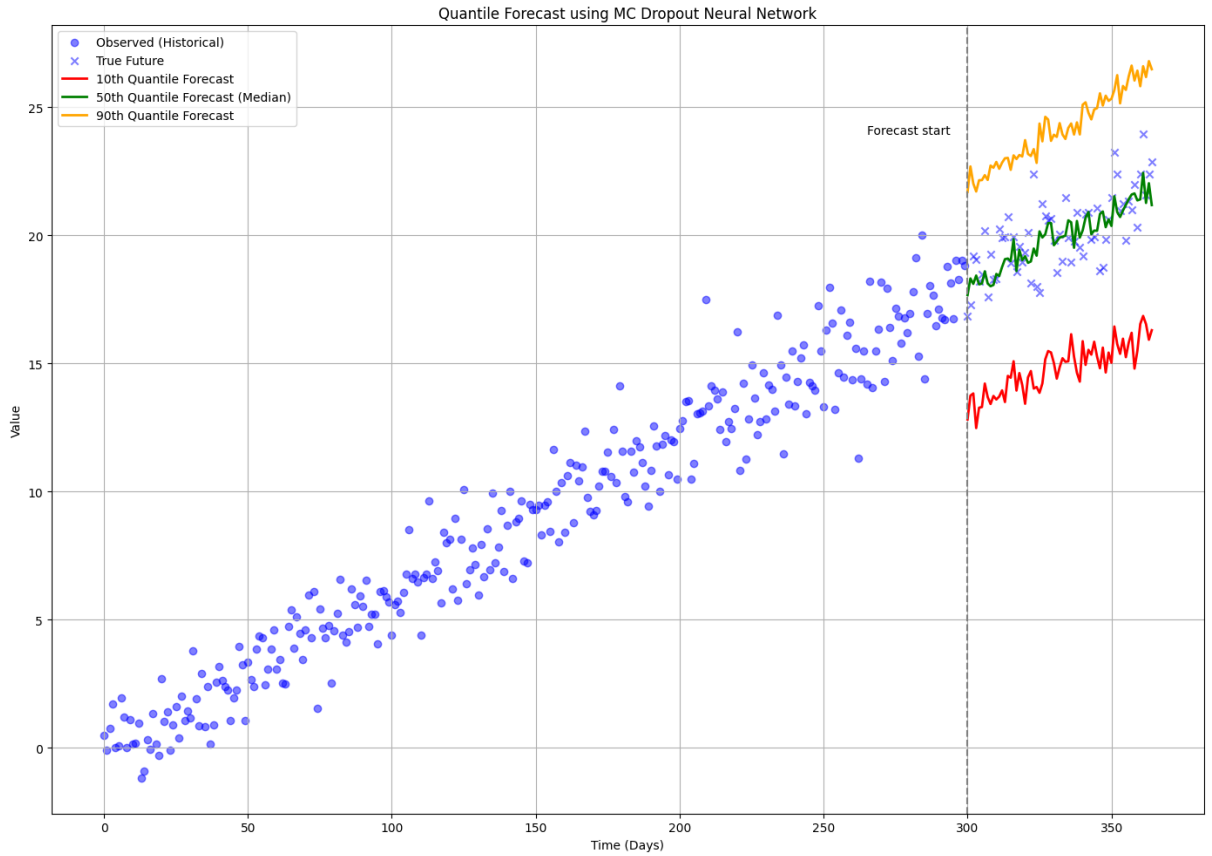
Understanding Predictive Uncertainty

- **Predictive Uncertainty**: The range of possible outcomes a model expects — not just a single guess.
- **Prediction Intervals**: A range (for example, a 90% interval) that should contain the true future value most of the time.
- **Confidence Levels & Error Rates**: A 95% confidence level means about 5% of actual outcomes will fall outside the predicted interval.
- **Quantiles**: Specific points in a probability distribution used to define prediction intervals — like the 5th and 95th percentiles.



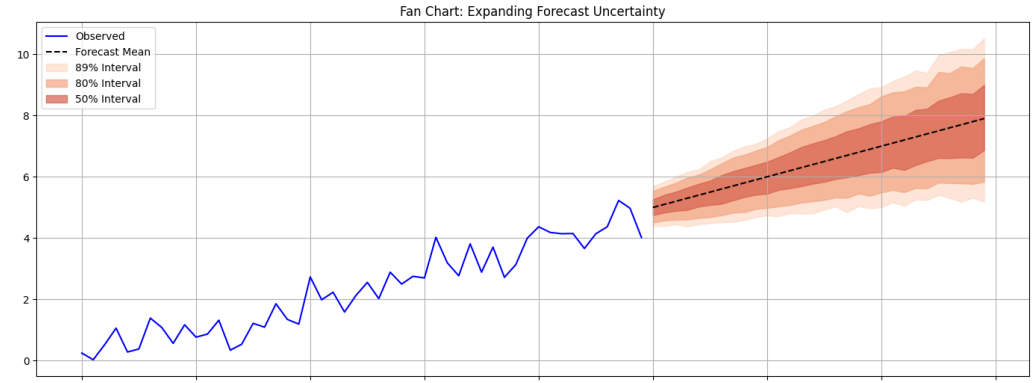
How do we generate Probabilistic Forecasts?

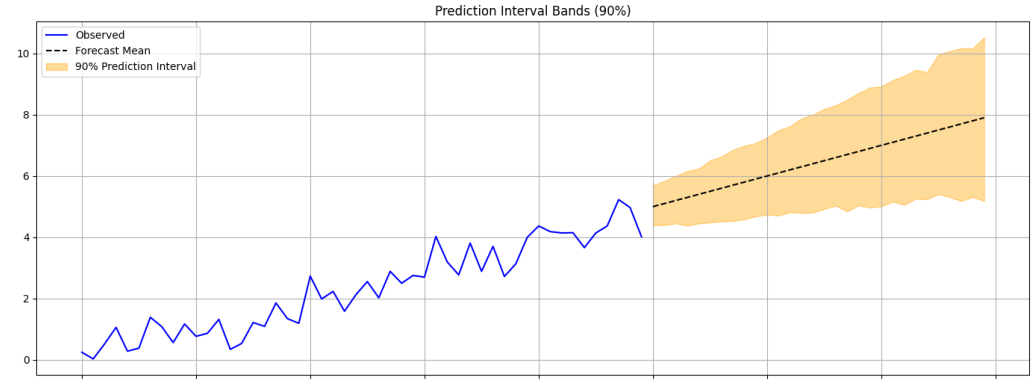
- **Quantile Regression:** Models specific quantiles (e.g., 5th, 50th, 95th) directly, giving prediction intervals
- **Bayesian Methods:** Use probability distributions over model parameters to express uncertainty
- **Ensemble Methods:** Combine predictions from multiple models to capture variability and uncertainty
- **Monte Carlo Dropout:** Use dropout during inference to approximate Bayesian uncertainty in neural networks
- **Conformal Prediction:** A distribution-free method providing valid prediction intervals with finite-sample guarantees

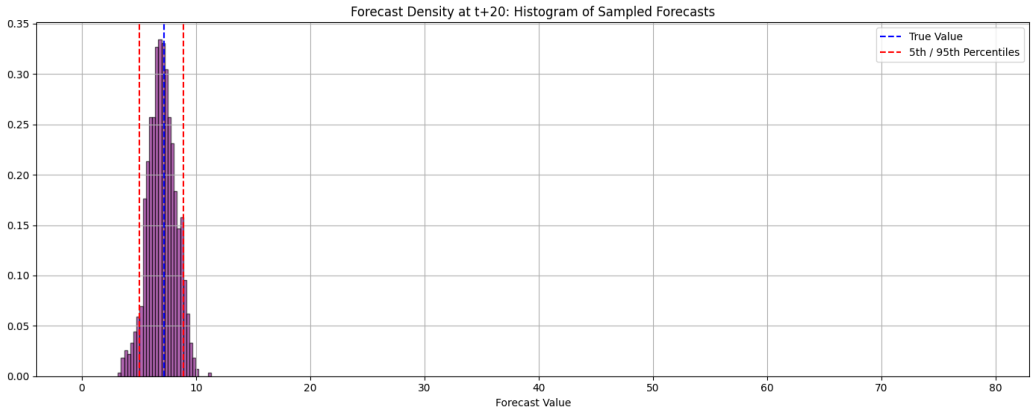


Visualization Techniques

- **Fan Charts**
  - Show expanding uncertainty over time. Wider “fans” indicate growing unpredictability
- **Prediction Interval Bands**
  - Shaded areas on a time series plot showing confidence ranges (e.g., 90% prediction intervals)
- **Density Plots / Histograms**
  - Display full probability distributions. Useful when forecasting a single time point or value

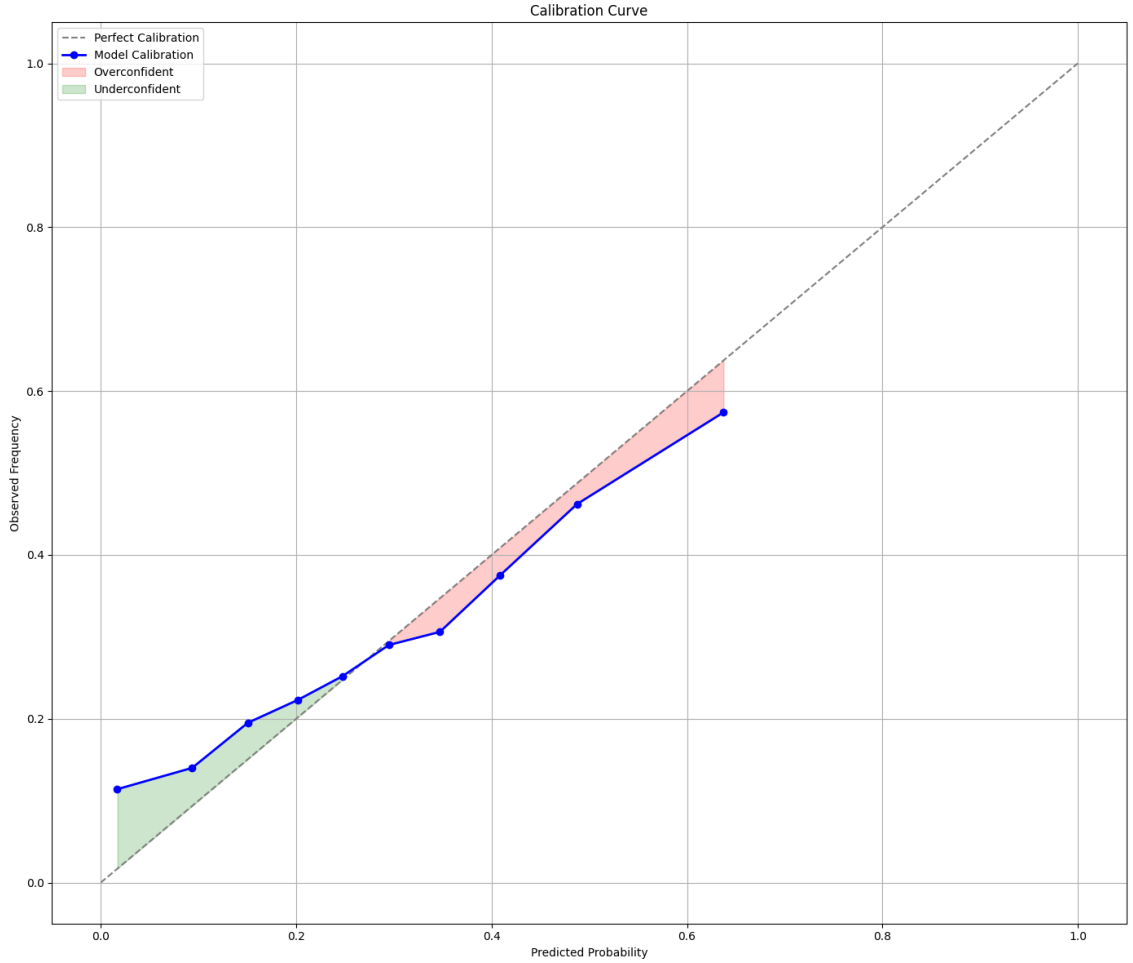






Visualization Techniques

- **Calibration:** Are we getting it right on average? Do actual outcomes fall within predicted intervals as often as they should?
- **Sharpness:** How narrow are our intervals? Tighter is better, but only if we're still calibrated!
- **Proper Scoring Rules**
  - **Continuous Ranked Probability Score (CRPS):** Measures the difference between predicted and actual cumulative distributions
  - **Brier Score:** Measures the accuracy of probabilistic classification (like yes/no events)
  - **Logarithmic Score (Log Score):** Rewards high probability on the true outcome; penalizes overconfidence in the wrong outcome



What we‘ve learnt

- What probabilistic forecasting means and why it matters
- Key concepts: prediction intervals, confidence levels, quantiles
- Methods to generate forecasts: quantile regression, Bayesian methods, ensembles, Monte Carlo dropout, conformal prediction
- Visualization tools: fan charts, interval bands, density plots
- Evaluation metrics: calibration, sharpness, and proper scoring rules