Meat sales forecasting (Panvita Group)

ESGI SI: European Study Group Mathematics With Industry Workshop 2017
Bled, Slovenia

ESGI Slovenia was supported by COST Action TD1409, Mathematics for Industry Network (MI-NET)

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Problem Background

- Meat production
- Goal:
  - Freshly prepared meat for consumers
  - Reduce the quantity of discarded meat
- Solution:
  - Predicting the quantity of meat sold per day
  - The forecasting model for few days ahead

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Problem Procedure

- Worker makes an estimation for the procurement of meat
  - Experience
  - Movement of orders
- The procured meat is processed
  - Expiry date of 8 days
- Transport of prepared meat
- Procedure time: 2 days

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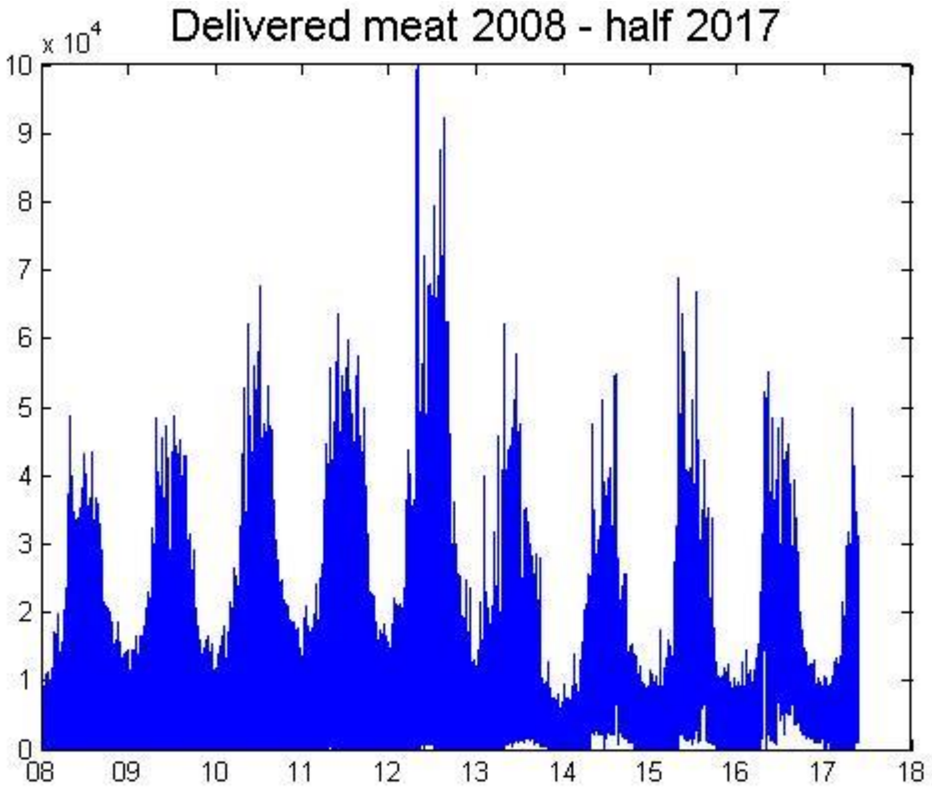
Problem Data

- Daily orders from 2008 onwards
- Daily supply from 2008 onwards

- Clear seasonal patterns with spikes in the summer



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Bibliography overview

Modelling techniques:

- Neural Networks (Classical, Adaptive, Fuzzy, Self Organizing Maps, various inputs)
- Regression (linear, logistic, ARIMA, support vector machines),
- Model Trees (Cluster and forecast models),
- Genetic Algorithms (combined with ANN),
- Combinations.

Input Feature Sets:

- Time (month, day of week)
- Autoregressive (day before, week before, weeks before)
- Weather (temperature, solar irradiation/cloudiness).

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Statistical tools used

- Different models have been employed: Multiple Linear Regression, Support Vector Regression, Autoregressive models

- Goodness of fit benchmarked through Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE)

$$MAPE = \frac{100}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right|$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{Y}_i - Y_i\right)^2}$$

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A starting point ...

Brute force approach: regress, regress some more & check goodness of fit

MLR models making use of whole data

Description	MAPE	RMSE
MLR + weekdays, months, incomes, holidays (all)	81.92	7158.92
MLR + weekdays, months, incomes, holidays (BIC)	81.68	7167.11
MLR + weekdays, months, incomes, holidays, weather (all)	83.18	7179.68
MLR + weekdays, months, incomes, holidays, weather (BIC)	83.16	7201.38
MLR + weekdays, months, incomes, holidays, weather, supply before (all)	39.18	5140.61
MLR + weekdays, months, incomes, holidays, weather, supply before (BIC)	43.35	5254.39
MLR + months and supply 3, 14, 21 and 28 days before	37.22	5276.60

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Problem data … a closer look to patterns

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Weekday	Week n	Week n + 1
Monday	4933.568	4716.28
Tuesday	7251.472	10411.67
Wednesday	4301.298	5694.955
Thursday	7574.879	9042.782
Friday	10935.74	11492.02
Saturday	4202.074	5455.222
Sunday	0	0

Similar patterns throughout the weeks

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Different model for each day of the week?

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MLR models for Monday

Description	MAPE	RMSE
MLR + weekdays, months, incomes, holidays, weather, supply before (all)	56.13	6111.01
MLR + weekdays, months, incomes, holidays, weather, supply before (BIC)	51.30	5459.23
MLR + supply two days before	26.51	5508.53

MLR models for Friday

Description	MAPE	RMSE
MLR + weekdays, months, incomes, holidays, weather, supply before (all)	18.15	5798.07
MLR + weekdays, months, incomes, holidays, weather, supply before (BIC)	15.01	5421.85
MLR + supply one, two, three, seven and eight days before	10.90	4859.27
MLR + supply one, two, seven and eight days before	10.98	4821.86

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Support Vector Regression (SVR)

SVR models making use of whole data

Description	MAPE	RMSE
SVR + weekdays, months, incomes, holidays (all)	44,41	6809,05
SVR + weekdays, months, incomes, holidays (BIC)	46,11	6799,67
SVR + weekdays, months, incomes, holidays, weather (all)	45,59	6986,72
SVR + weekdays, months, incomes, holidays, weather (BIC)	43,69	6770,83
SVR + weekdays, months, incomes, holidays, weather, supply before (all)	30,49	5037,80
SVR + weekdays, months, incomes, holidays, weather, supply before (BIC)	29,96	5012,11
SVR + months and supply 3, 14, 21 and 28 days before	33,94	5363,89

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SVR models for Monday

Description	MAPE	RMSE
SVR + weekdays, months, incomes, holidays, weather, supply before (all)	41.05	4878.24
SVR + weekdays, months, incomes, holidays, weather, supply before (BIC)	53.20	5234.54
SVR + supply two days before	27.34	5450.64

SVR models for Friday

Description	MAPE	RMSE
SVR + weekdays, months, incomes, holidays, weather, supply before (all)	15.69	6600.47
SVR + weekdays, months, incomes, holidays, weather, supply before (BIC)	14.70	5164.36
SVR + supply one, two, three, seven and eight days before	11.46	4124.32
SVR + supply one, two, seven and eight days before	11.55	4311.40

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Alternative approach for future research

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Season-based models instead of day-based ones

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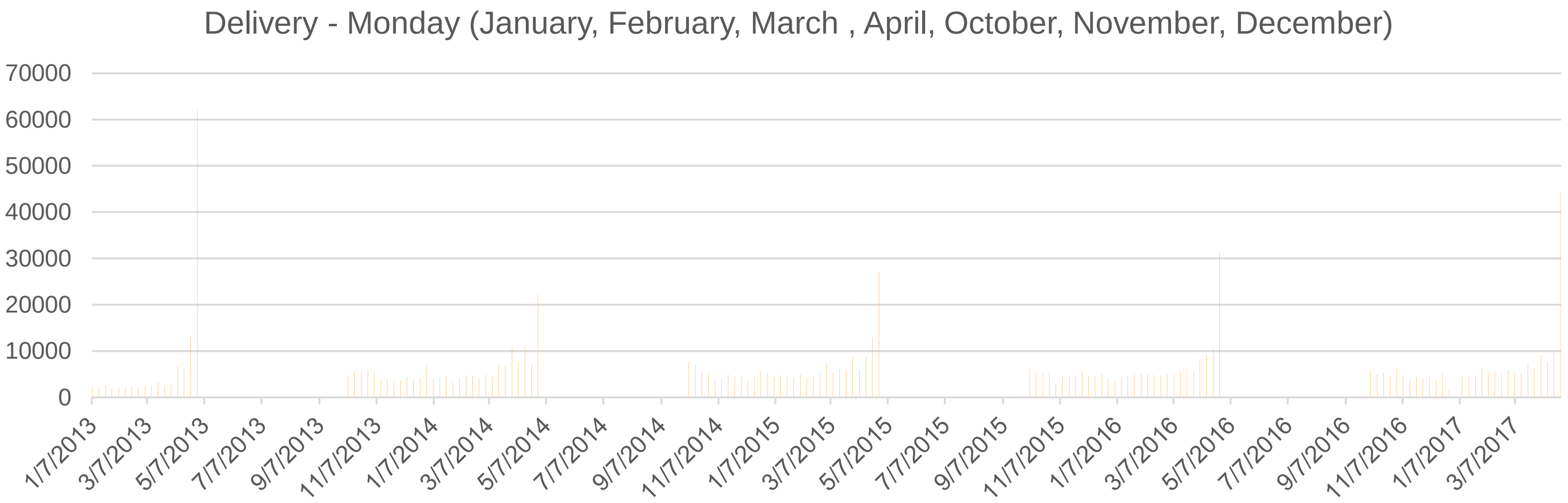
Problem data … a closer look to patterns



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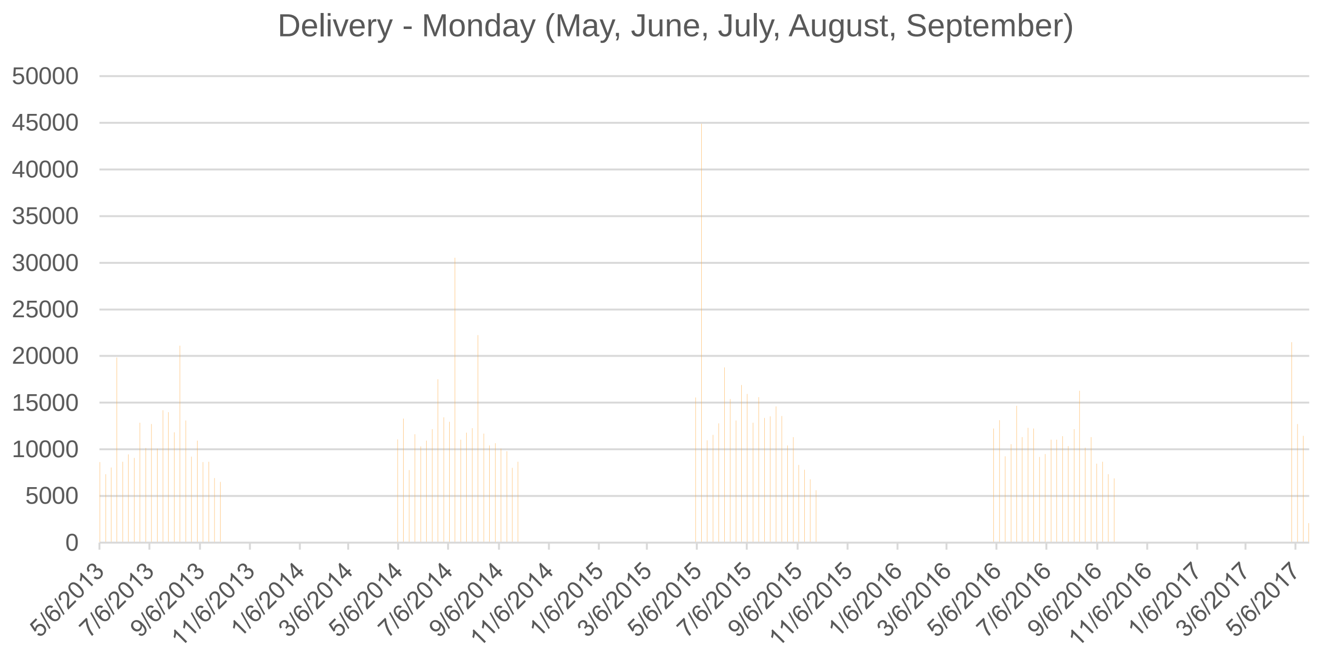

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Autoregressive (ARIMA) models

- They describe a stationary timeseries by means of two polynomials: one AR (autoregressive) and one MA (moving average). AR involves regressing the variable on its own lagged values, while MA models the timeseries through error terms occurring in the past

- Tests with various parametrized ARIMA models have revealed that their power lies in forecasting the data only on short period of times. They are not suitable for long-horizon forecasts.

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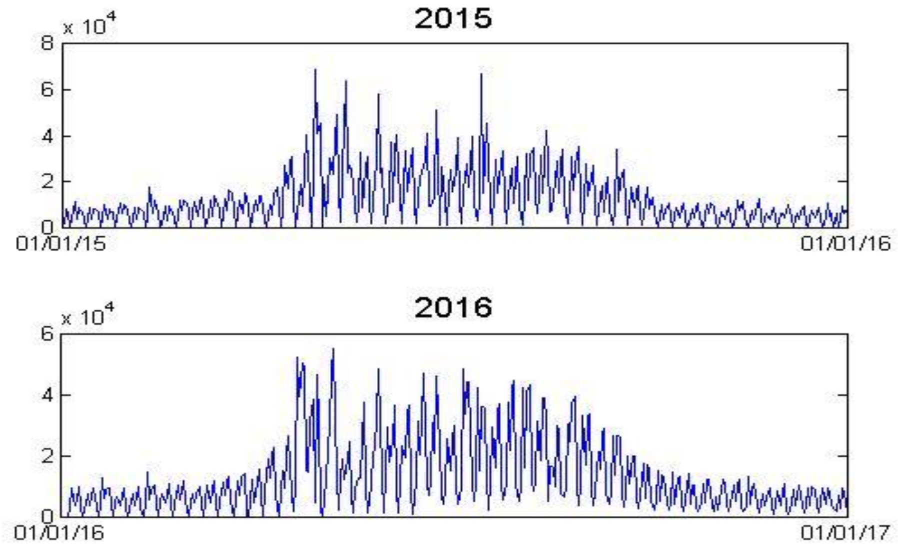
Problem data …
another closer look to patterns



Similar patterns throughout the years

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Use past year data to predict current values?

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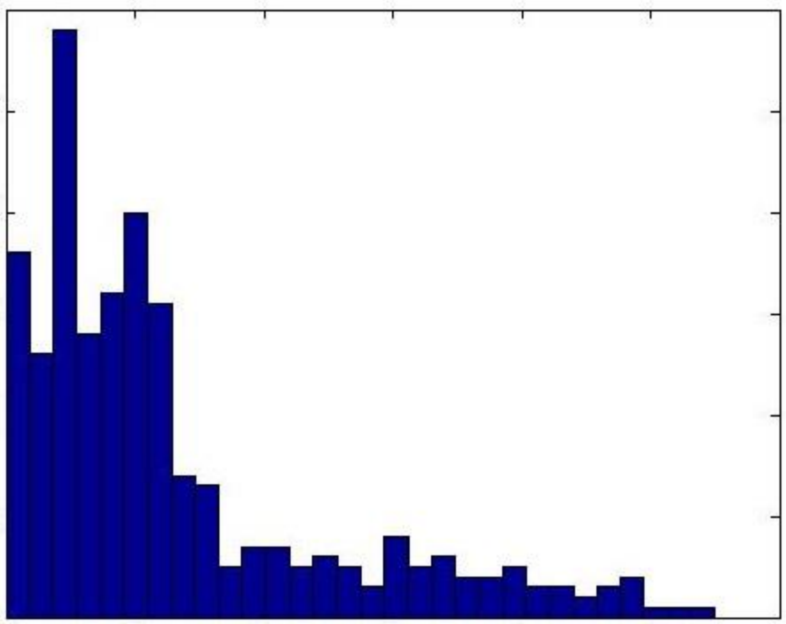
Adding some stochasticity

Weekday	3° Week 2015	3° Week 2016
Monday	4185.9968	4795.9418
Tuesday	7173.2672	8705.5872
Wednesday	3070.9200	3438.3000
Thursday	6731.0924	8141.1722
Friday	5371.9748	7350.1120
Saturday	5019.3528	6661.0704
Sunday	0.0000	0.0000



Sales distribution in 2016

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Geometric Brownian Motion

Let X be the delivered quantity and let it be governed by the following stochastic differential equation:

$$dX(t) = \mu(t)X(t)dt + \sigma(t)X(t)dW(t)$$

where $W(t)$ is a Brownian motion. Then X is driven by the following relation:

$$X_t = X_{t-\Delta t} e^{\left(\mu_t - \frac{\sigma}{2}\right)\Delta t + \sigma_t \sqrt{\Delta t} Z_t}$$

$X_{t-\Delta t}$ can be the one of the previous year and parameters μ and σ can be calibrated on previous month deliveries to keep track of recent developments in the market.

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