Optimized Newspaper Delivery Using Mixed Memory Markov Models

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Objective

To reduce the number of newspapers returned from sale points to distributors and no decrease in sale. This is equivalent of predicting demand.

Data Set

- 2840 outlets
- 261 week of sale and return information starting from 2009, July
- **Assumption:** Demand is equal to the sale and forms a time series for each outlet and day of week. It is not observed in case of sold-out.

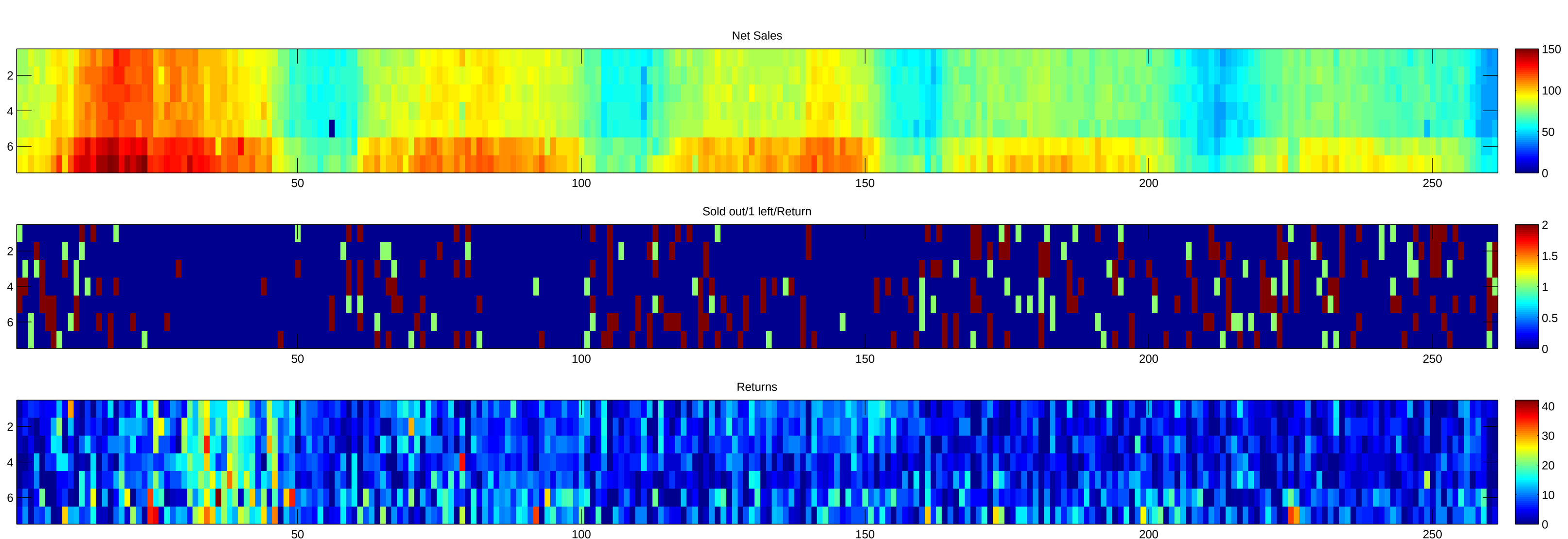

Figure 1: (i)Net sale, (ii)Return status (sold out (red), just one return (green), more returns (blue)), (iii)Return count

Method-1: Higher Order Markov Model

Parametrization of a higher order Markov model, say K, by convex combinations as such:

$$P(i_t|i_{t-1:t-K}) = \sum_{k=1}^{K} \alpha(k) a^k(i_t|i_{t-k})$$

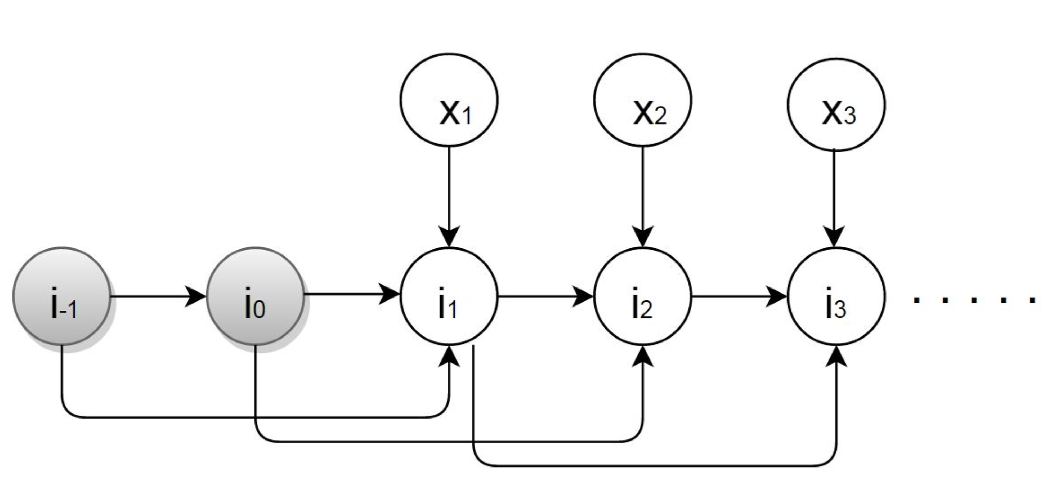

Figure 2: DAG for the mixture where $K = 2$

EM Updates

$$\alpha(k) \propto \sum_t p^{old}(x_t = k|I)$$

$$a^k(i_t = j', i_{t-k} = j) \propto \sum_t p^{old}(i_t = j', i_{t-k} = j, x_t = k|I)$$

Method-2: Factorial Markov Model

Here, each time series is first order and the correlation between time series is reflected as

$$P(I_t|I_{t-1}) = \prod_{v=1}^{K} P(i_t^v|I_{t-1})$$

$$P(i_t^v|I_{t-1}) = \sum_{k=1}^{K} \alpha(v,k) a^{vk}(i_t^v|i_{t-1}^k)$$

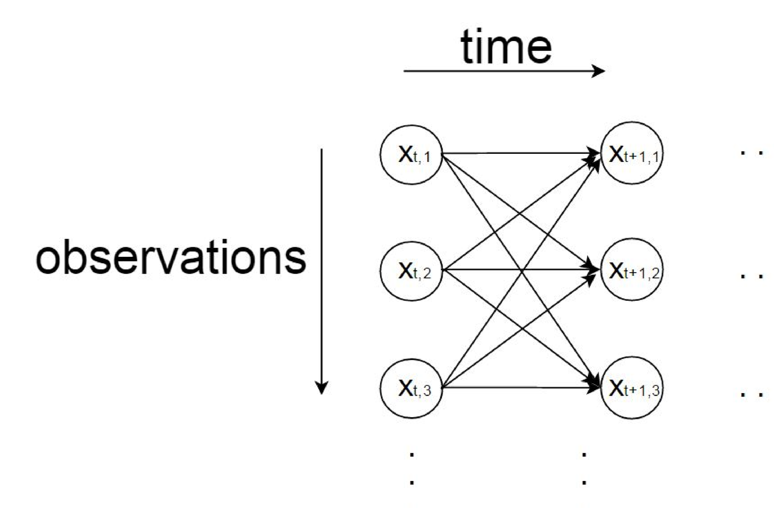

Figure 3: DAG for the factorial model

EM Updates

$$\alpha(v,k) \propto \sum_t p^{old}(x_t^v = k|I)$$

$$a^{vk}(i_t^v = j', i_{t-1}^k = j) \propto \sum_t p^{old}(i_t^v = j', i_{t-1}^k = j, x_t^v = k|I)$$

Results

As the table below illustrates, it is possible to reduce return count. However, this causes a decrease in sale, which is certainly not desired.

Method	# of Sale	# of Return
Current Delivery	88270	14977
Higher Order MM	83093	9015
Factorial MM	82645	10213

References

[1] Lawrence K. Saul and Michael I. Jordan. Mixed memory markov models: decomposing complex stochastic processes as mixtures of simpler ones, 1998.