**Time Series Modeling and Filtering Literature Report**

Minzhe Zhang

# **Time-Series Approaches for Forecasting the Number of Hospital Daily Discharged Inpatients**

## **1. Summary**

Many healthcare systems in China confront the problem of overcrowding and service capacity management. The authors selected a typical hospital – West China Hospital (WCH) as an example to study bed management, of which accurate predictions of inpatient bed capacity are especially useful for capacity reservation purposes. The number of discharged patients during the day is a key factor that will affect the expected bed capacity next day, whereas the fluctuations from autocorrelation, trend, seasonal and special-day effects complicate the decision optimization. The authors employed a time series approach to model the patient daily discharge for better bed reservation and patient admission scheduling. Three ARIMA based models were proposed: a seasonal regression ARIMA (SRARIMA) model, a multiplicative seasonal ARIMA (MSARIMA) model, and a combinatorial model of MSARIMA and weighted Markov Chain models. Models were trained and tested by three years of discharge data of WCH. Performance measures containing the normalized mean squared error and mean absolute percentage error are utilized to capture the prediction accuracy in model selection. The results indicate that the combinatorial model outperforms the single SRARIMA and MSARIMA model. The paper provides evidence on the applicability for forecasting patient daily discharge, which support the decision of patient admission scheduling and bed planning.

## **2. Combinatorial Model**

SRARIMA and MSARIMA model has overall good prediction accuracy, however the residuals still exhibit periodical fluctuation, which suggests there is still unexplained seasonal effect remained. ARIMA based models have advantage of fitting time-series trend in linear space, while they are poor at fitting and forecasting performance of time series at large random fluctuating point. Markov chain approach is a method with respect to stochastic processes with discrete time and state, and is capable of reducing errors obtained from extrapolated prediction. The authors incorporate Markov chain into MSARIMA model to represent the relative under- and over-prediction degree of fitted values against observations across time series. Based on mean-standard deviation, the relative error sequence were categorized into five class, overestimated, slightly overestimated, moderate deviation, slightly underestimated and underestimated. The state-transition probability was described by four five by five matrix, each reflect the autocorrelation of each lag. The respective weights are calculated by normalizing the autocorrelation coefficient at each lag. For a predicted state, a weighted sum of the state interval will be calculated to estimate the relative error, which will then be used to adjust the forecasted value obtained from MSARIMA.

## **3. Discussion**

It is a clear way to use Markov chain to capture unexplained random fluctuation of linear time-series model. The author modeled and modified the fitted residual sequence of the MSARIMA model to realize a double precision correction, and then backward compute fitting values of the combinatorial model. And indeed, the combinatorial showed considerable improvement in forecasting performance. However, concern also exists with regards to overfitting, since the combinatorial model increases the number of parameters.

Another concern about this study is the available bed capacity of the next day is not only related to discharges the next day but also related to the left beds today. As the objective is to obtain the daily bed capacity for reservation purpose by forecasting daily discharges, without the information of the left beds at the end of each day, it is not helpful for capacity reservation decision making several days ahead.

Overall, the paper provided a method to forecast short-term hospital bed availability to support bed management decision making.