No notable forecasting accuracy gains were be obtained through a complex state space model for retail demand forecasting, in comparison with simpler models

Intro: In her Master’s thesis *Forecasting the demand of retail stock keeping units using a negative binomial state space model*, Saara Kaijala (B.Sc. in Tech., Aalto University) studied a probabilistic machine learning model that was originally formulated for industrial-scale demand forecasting. Given the recent advancements in computational techniques and methods, increasingly complex forecasting methodologies are being utilised across a variety of applications. However, there is an ongoing debate on whether the theory and the practice of the modern forecasting practices have drifted too far from each other. This served as a motivation for the thesis as well. The objective of the study was to assess whether the modelling framework — while theoretically very promising — is appropriate for battling the real-world challenges of the retail demand. It turns out that while some accuracy gains could be obtained, the simpler methods were still able to beat the model in many of the scenarios.

The retail industry is a progressively competitive field where the data masses are enormous and efficient optimization methods are in high demand. Because of the data intensiveness of the retail processes, the recent advancements in computational resources have affected many practices of the field, such as demand forecasting. Modern machine learning methods can potentially allow for more efficient exploitation of the available data, and aid in automating the forecasting procedures. However, implementing the most complicated model frameworks is often very laborious. Moreover, when it comes to forecasting models, complexity does not always translate into increased accuracy. Hence, the trade-offs on the accuracy-complexity spectrum should be carefully determined before starting costly implementation projects.

Since demand forecasts are needed for millions of products on a monthly basis, scalability is a real issue when considering new methodologies for the task. Hence, many of the models have traditionally been relatively simple. While modelling-wise more refined and flexible, the estimation times for the complex models are also notably longer than for the simpler models. In order to employ such methodologies for industrial-scale applications, the robustness and the performance of the models need to be assessed first.

Much of the recent research has therefore been focused on determining the possibilities as well as the challenges of the newly formulated machine learning models. This was the main objective of the thesis of Kaijala as well. The original model specification by Chapados (2014)\(^1\) is especially designed for demand forecasting. The negative binomial state space model studied in the thesis is a probabilistic model, which means that it produces estimates of the probability distribution of the studied variable (here, the demand of a product). The model seems very potent for capturing the complex patterns typical of retail demand processes, such as varying length seasonalities and alternating trends. The thesis aimed to validate the conclusions of the original work by Chapados (2014) about the forecasting accuracy as well as the model estimation times available through the framework.

Unfortunately, mixed results regarding the forecasting performance of the model were obtained in the study. Holt-Winters’ exponential smoothing, which is a very simple yet well-established forecasting method, was able to surpass the performance of the negative binomial state space model in many of the test scenarios. The differences were especially clear for the so-called slow-moving products of which the demand is intermittent. This is worrisome because a substantial cut of retail products exhibit some intermittency in their sales. As a conclusion, some improvements to the model are needed in order to utilise it for real-world applications. Some suggestions for these modifications were sketched in the thesis. However, given the complexity of the framework, the exact reasons for the poor model performance remain unclear.

The results of the thesis highlight the fact that assessing the usefulness of the modelling choices beforehand is essential for determining the practical value of complex models. Similar observations regarding the most complicated forecasting models have been done by many researchers. However, assuming that through some of the proposed modifications, the accuracy crashes of the model could be avoided, such a modelling

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setup could be very useful for automating the demand forecasting procedures in industrial applications. Hence, more research could be placed on making such frameworks more robust and accurate.

Two-sentence summary for social media.

Advancements in computational methods have brought a wide selection of complex machine learning models available also for retail demand forecasting. However, complexity does not always translate into increased accuracy, concludes Saara Kaijala in the Master’s thesis *Forecasting the demand of retail stock keeping units using a negative binomial state space model.*

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