Knowledge-Based Systems 71 (2014) 279–289

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Hybrid multi-model forecasting system: A case study on display market

Chen-Chun Lin [a], Chun-Ling Lin [b,*], Joseph Z. Shyu [a]

[a] Institute of Management of Technology, National Chiao Tung University, No. 1001, Ta Hsueh Rd., Hsinchu 300, Taiwan
[b] Department of Electrical Engineering, Ming Chi University of Technology, No. 84, Gongzhuan Rd., Taishan Dist., New Taipei City 243, Taiwan

ARTICLE INFO

Article history:
Received 10 January 2012
Received in revised form 5 August 2014
Accepted 5 August 2014
Available online 11 August 2014

Keywords:
Hybrid multi-model forecasting system
Prediction
Display markets
Mean square error (MSE)
Mean absolute percentage error (MAPE)
Average square root error (ASRE)

ABSTRACT

This paper provides a novel hybrid multi-model forecasting system, with a special focus on the changing regional market demand in the display markets. Through an intensive case study of the ups and downs of the display industry, this paper examines the panel makers suffered from low panel price and unstable market demand, then they have changed to react to the rapid demand in the market or have lower panel stock for keeping supply and demand more balanced. In addition, this paper suggests a co-evolution forecasting process of sales and market factor. It can automatically apply various combinations of both linear and nonlinear models, and which alternatives deliver the lowest statistical error and produce a good estimate for the prediction of markets.

Moreover, this article shows how the system is modeled and its accuracy is proved by means of experimental results; and judged by 3 evaluation criteria, including the mean square error (MSE), the mean absolute percentage error (MAPE), and the average square root error (ASRE) were used as the performance criteria to automatically select the optimal forecasting model. Finally, the results showed that the proposed system had considerably better predictive performance than previous and individual models. To summarize, the proposed system can reduce the user's effort for easier obtaining the desired forecasting results and create high quality forecasts.

1. Introduction

The flat-panel display (FPD) is a landmark sector all over the world in terms of technology innovation. This market is growing based on the competitiveness of three major technologies: thin-film transistor-liquid crystal displays (TFT-LCD), plasma display panels (PDP) and organic light-emitting diodes (OLED). TFT-LCD has the largest market share. This technology dominates the market, as it can be used in different types of applications, ranging from small devices including mobile phones to large applications including televisions.

However, TFT-LCD manufacture has high risk and low affixation. Because high-risk industry where failure for market estimation can lead to the elimination of an enterprise and where a timely, large-scale investment is essential; industry where large companies that should have the capacity to mobilize large capital are fully equipped with necessary parts and materials.

Research on flat panel displays (FPD), which started in the 1960s, has finally reached the commercialization stage in the form of large plasma display panels (PDPs) and liquid crystal displays (LCDs). Japanese companies led initial technological development in the LCD upstream industry in the 1990s. But since 2000, Korea and Taiwan have made bold investments, and they are leading the global market. In 2010 China started to join this market, global manufacturers of TFT-LCD panels have established the majority of LCD module assembly plants in China to take advantage of lower labor costs. With investment in display production facilities likely to decline in other countries, production of TFT-LCD manufacturing equipment in China will account for a greater share of the world market. Now China has become a major hub in TFT-LCD manufacturing, and the TFT-LCD industry is one of the most dynamic industries.

Major manufacturers by country are Korea (Samsung, LG Display), Taiwan (AUO, Innolux, CPT, Hannstar), Japan (Sharp, TMD, NEC, Hitachi), China (BOE-OT, CEC-Panda, CSOT, Tianma), etc. Now the industry has diverse upstream markets as following: (1) small and mid-sized products including smart phones, IT products (i.e. monitors, tablet PC, desktop PC, laptops and automotive heads-up display) and (2) large-sized products including household appliances (i.e. LCD TV and monitor).

After the fall of 2008 and the European debt crisis, which began in late 2009, the shift still significantly influences the demand ratio of the TFT-LCD regional markets in the world until now. The

* Corresponding author. Tel.: +886 2 2908 9899x4819.
E-mail address: ginnylin@mail.mcut.edu.tw (C.-L. Lin).

http://dx.doi.org/10.1016/j.knosys.2014.08.004
0950-7051/

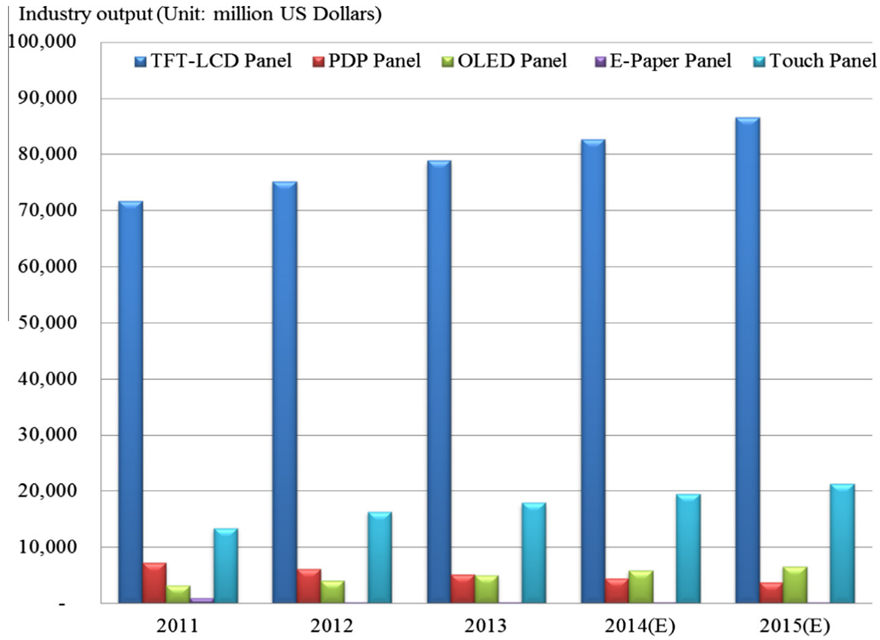

Fig. 1. The global flat panel display industry output (Data Resource: Photonics Industry and Technology Development Association (PIDA) in Taiwan, 2014. http://www.pida.org.tw/usub/en/index.asp.).

TFT-LCD industry also has witnessed drastic changes in the intensity of competition in 2008–2010. This industry is undergoing a turbulent transformation as it becomes a mature industry as Fig. 1. However, TFT-LCD panel manufacturers are undoubtedly looking forward to sustainable growth, but they cannot simply wait for demand to increase and then react to that increase to generate revenue. These companies should examine the various revenue sources in the regional markets and seek new opportunities to increase revenue, or builds a sound foundation in shaping effective output planning for the potential market. Hence, the future forecast should analyze historical data and forecast projections to deliver the most detailed information and insights available.

Due to those reasons mentioned above, this research hopes to develop an efficient process, and a functional tool to predict the rapid development of the TFT-LCD market. Of interest to note is forecasting is a problem that arises in many economic and managerial contexts, and hundreds of forecasting procedures have been developed over the years for many different purposes, both in business enterprises and elsewhere. Previous forecasting studies relied on qualitative methods or patent analysis, which can be quite useful for other forecasting problems but have been shown to be inappropriate for industrial development forecasting [5,29]. Recently, both theoretical and empirical results have suggested that combining forecasting methods can be an effective way to achieve better predictive performance over individual models [9,23]. Contributions from many researchers have improved the quality of the predictions and provided combined forecasting models for decision makers [1,16,26,30,35]. As a result, there have been profound changes in the forecasting field. Combining various linear and nonlinear models offers solutions in which models are combined in an optimal way and can be applied in real-world situations such as forecasting macroeconomic time series [32], tourist demand [6], and exchange rates [2].

Based on the parameters selected, the combined forecasting models can be roughly classified into three categories: (1) linear/equally weighted combined forecasts; (2) nonlinear/unequally weighted combined forecasts; and (3) combined forecasts from linear and nonlinear models. Linear methods such as the Bayesian method typically place equal weight on each of the sub-classifiers in each time frame, regardless of their global or local accuracy [4,12,15,18,38]. Nonlinear methods apply unequal weights for the averaging of past observations (i.e., more recent observations are given more weight in forecasting than older observations); examples include neural networks, adaptive neuro-fuzzy inference systems, and fuzzy set methods [20,24,25]. Combining linear and nonlinear methods can retain the robustness while reducing the complexity considerably, such as in the combination of artificial neural networks (ANNs) and auto-regressive integrated moving average (ARIMA) methods. Among these, nonlinear combined forecasts and combined forecasts from linear and nonlinear models have proven to be very effective for demand forecasting in addition to other linear or nonlinear applications [6,27,34].

Several algorithms commonly found in the literature have the potential to surpass the performance of an individual predictor by combining the outputs of a collection of complementary predictors. In bagging, various methods are generated by applying a learning algorithm to independent bootstrap tests of the primary training data [3,17]. Boosting is another popular ensemble algorithm and was originally developed for classification problems. A sequence of models is obtained from a given dataset using an adaptive learning algorithm and different parameters for various training cases [17]. Adaptive neuro-fuzzy inference systems (ANFISs) outperform other individual methods, and the forecasting accuracy can be improved effectively using combined forecasts, as was done for a panel manufacturer [39].

Based on the forecasting performance of combined methods, Wang and Nie [41] proposed the combination of a back-propagation neural network (BPNN) and support vector machines (SVMs), which have the best forecasting performance, and showed that the combined forecasting model can greatly enhance the accuracy of predictions of a stock index. Other research showed that the adaptive neuro-fuzzy inference system method outperforms other methods in forecasting panel demand [39], automobile sales [40], and the demand for telecommunication technology [21].

However, none of these methods is a universal model that is suitable for all situations because it is difficult to completely know the linear or nonlinear characteristics of the time series data in an actual problem. An important motivation to combine the forecasts