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Recurrent Embedding Kernel for Predicting Stock Daily Direction

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***Abstract*—Stock price movement is typically affected by a lot of hidden factors. Predicting stock price direction, especially short-term direction, is very challenging and consistently attracts researches. Deep recurrent neural networks, such as Long Short-Term Memory, typically outperform statistical time series models and traditional machine learning approaches with their mechanisms of learning to vectorize historical information. However, encoding entire history into a vector may unavoidably causes information loss regardless of memory learning and updating mechanisms, especially for those tasks where decisions need to be made on the current time point and similar historical time points are of great references to the decision making. In this paper, we propose a new deep architecture called Recurrent Embedding Kernel(REK) that can learn to make optimal decisions by referring to the entire history instead of just current memory vectors. Experimental results on multiple stock ETFs with different long-term trends show that REK outperforms RNN, LSTM, and GRU, on predicting daily price direction.**

***Index Terms*—deep learning, recurrent architecture, recurrent embedding kernel, time series, stock prediction**

I. Introduction

Stock price predictions are interesting, potentially profitable, yet very challenging tasks that have attracted a lot of researches over the decades. Analytical methods, including statistical time series models, traditional machine learning approaches, and the more recent deep recurrent neural networks have been used in modeling and predicting stock price directions [1] [2] [3] [4] [5] [6] [7]. The study in [3] showed that machine learning approaches surpasses traditional time series models in precision on financial series prediction. The study in [4], [6], and [7] further demonstrated that recurrent architectures such as Long Short-Term Memory (LSTM) or Gated Recurrent Unit (GRU), as a state-of-the-art technique for sequence learning, outperformed those memory-free machine learning approaches. In this paper, we analyze the limitation of those recurrent neural networks and propose a novel deep architecture called Recurrent Embedding Kernel that is able to outperform LSTM and other recurrent neural networks on predicting stock daily price direction.

Statistics models for time series include Box-Jenkins Autoregressive Integrated Moving Average (ARIMA), State Space Model (SSM), Autoregressive Conditional Heteroskedasticity (ARCH) and Generalize ARCH (GARCH) [8]. In general, these models require making certain assumption on the data (e.g., ARIMA models assume the series to be stationary), and may fail if their assumptions are not met. Moreover, statistical models cannot handle nonlinearities in the data without user's specifications (e.g., selecting the differencing term in ARIMA). Both facts help statistical methods achieve good interpretability, but also limit their predicting power. Traditional machine learning approaches such as Support Vector Machines (SVM) [9], Random Forest (RF) [10], and Multi-layer Perceptron (MLP) [11] come with less to no data assumptions and provide more power in modeling nonlinearities of data. Therefore, they often outperform statistical models in prediction accuracy. However, those machine learning models still require certain important controls from users. For examples, SVM needs the selection of a kernel function and the tuning of hyper-parameters; SVM, RF, and MLP cannot automatically determine how much historical data is needed for decision making.

Recurrent neural architectures were particularly designed for learning from sequential data with variable lengths. Common types of recurrent architectures include vanilla Recurrent Neural Network (RNN) [12], Long Short-Term Memory (LSTM) [13], and Gated Recurrent Unit (GRU) [14]. This type of recurrent architectures uses hidden states and/or gates to learn to encode a historical sequence into a memory vector which is then used for decision making at the current time point. However, encoding the entire history into a vector may unavoidably causes information loss regardless of memory learning and updating mechanisms. For those tasks, where decision needs to be made on the current time point and similar historical time points are of great references to the decision making, it may be more beneficial to keep the entire history for decision making instead of vectorizing it.

To address the issue of limited memory capacity of recurrent neural networks, we propose a novel deep architecture that is called Recurrent Embedding Kernel (REK) and apply it to predict stock daily price direction. Unlike RNN, LSTM, and GRU, REK makes decision based on the entire history to minimize information loss. REK consists of two components, a Recurrent Embedding Network (REN), and a Kernel Network (KN). The REN component learns to vectorize the memory state of each time point in the given sequence; whereas the KN component learns a kernel function that implicitly maps

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