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State-of-Art-Review (SAR-Invited)

Mathematical Neural Network (MaNN) Models
Part IV: Recurrent Neural networks (RecNN) in bio-/chemical- tasks

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ABSTRACT

Recurrent- (Rec_) NNs contain partial or full backward connections between layers of feed-forward (FF-) NNs. Here, in addition to the present input, past values of inputs/outputs/intermediate states influence the final output. Hopfield NN, proposed in 1982 by John Hopfield, has cyclic architecture and employs Hebbian learning. It brought back life to NN methodologies which were dormant since 1969. Partial recurrent NNs, for instance, Elman with feedback from hidden to input layer and Jordon from output to input layer won laurels to I/O transformation of dynamic systems. NNs with feedback connections have intrinsic dynamic memory that reflects the current output as well as the previous inputs in the transformed space, while feed-forward-NNs (MLP, RBF) do not have previous associated "memory". Rec_NNs models temporal as well as long term behavior in a dynamic system. The typical training algorithms employed in Rec-NNs are Back propagation through time (BPTT), Real-time recurrent learning (RTRL), Atiya-Parlos recurrent learning (APRL), Alopex, long short term memory (LSTM) and extended decoupled Kalman filter (DEKF). Rec-NNs have been extensively used in the data analysis with time series and state-space models with better performance even for systems with more non-linearities. Evolution is a timely modification, invention, discovery in nature. Man desires and achieves the target now and then within in short span through pooling up intelligence of intelligentsia, might of mighty and deep rooted micro-processes of a process from the mother-nature. Rec-NNs not only mimic the popular ARMA, NARMA, NARMAX, Weiner, Hammerstein and Volterra time series models, but also predict more complicated profiles. The impact of Rec_NN approach in medicine- / chemo- / enviro- / dieteto- /quali- metrics rendered modeling of partially understood dynamic systems viable for in depth understanding/control. The key applications are in nuclear power plants, environmental monitoring, weather forecast, greenhouse control, food quality, multi-variate-multi-response calibration, chemometrics, fuel cells, fermentation, ECGs, Schizophrenia, epilepsy, dementia, sleep apnea, HIV, ICU, robots, autopilot mode of aircraft landing, fault detection, communications, linguistics, seismic signal processing etc. The theoretical stability analysis proved the convergence, reliability of this class of NNs. The reported limitations of Elman_NN are a focus for improvements in training algorithms, hybridization and new intermediate means for trial solutions. The solution methods for linear projection equations and quadratic programming tasks are realised with this NN. Rec NNs with IFR and IIR filter characteristics and those for multiple time series made a mark in engineering tasks. Fuzzy and SOM paradigms are hybridized with rec-NN resulting in Rec-Fuzzy-NN and Rec-SOM-NN. Multiphase processes are modeled by hierarchical Rec-NNs. A few advances in Rec-NN worth mentioning include multi-feed-back-layer-, and higher order recurrent-neuro-fuzzy-NNs. The future prospects of recurrent NNs in chemical, biological sciences, chemo-informatics, and genomics are multifold.

Keywords: Recurrent _neural_ networks, Elman_Jordan_Hopfield_architectures, Time series, NARMAX, IIR_FIR_ filters, Rec_Fuzzy_NNs, Applications, Chemistry, Medicine, Engineering.
