MEETING REPORT

Prospective applications of artificial intelligence/machine learning techniques in earth sciences*

Over the last decade, rapid developments in artificial intelligence (AI) and machine learning (ML) framework have reached a point where these techniques can be used for solving complex problems and to bring new insights to predictive capabilities. Now it is an opportune time to utilize these concepts in earth sciences problems such as weather/climate forecast, climate change, geophysics and other domains. The Ministry of Earth Sciences (MoES), Government of India (GoI) is keen to apply these technologies in improving the weather forecast generated from numerical models.

For kicking-off such activities at MoES, a three-day meeting on the application of AI/ML to earth sciences problems was conducted. The main aim of the meeting was to gather researchers working on AI/ML and scientists from different areas of earth sciences to exchange knowledge, and develop innovative ideas and strategies to demonstrate a wide range of open problems utilizing the potential of AI/ML. Thirty-four delegates from research organizations, industry and academic institutions participated in this meeting. The meeting was inaugurated by the Secretary, MoES, who highlighted the explosive growth of data availability in the field of earth sciences. He emphasized the need of extracting scientific information from these data, and mentioned that computational resources required for such data analysis are now available and AI/ML can offer efficient techniques to retrieve useful information. However, one needs to identify specific areas where these techniques could be used and also the persons/groups who can develop AI/ML tool to address such problems.

The delegates shared their opinions about prospective work that could be pursued on topics related to earth sciences. Few of these are mentioned below.

Availability of remotely sensed and in situ observations, the time has now come for earth system scientists to leverage new advances in data-driven ML to improve their dynamic models. There are several ways in which dynamics-based data-driven modelling systems can be developed and utilized. Some of these are:

(a) Big data techniques may be utilized to analyse the vast database of dynamic model outputs to drive insights, thereby (machine) learning the parameters and for tuning of the dynamic models.

(b) Big data platforms and data engineering could enable running massive ensembles that rigorously quantify the uncertainty in forecasts.

(c) Novel ML techniques could be developed to minimize the error between prediction and observation, for example, through data-driven turbulence closure schemes.

(d) ML and AI hold great promise in improving real-time data assimilation without throwing away or thinning of data.

(e) Statistical learning theory could be efficiently applied for problems in downscaling, data gridding, initial and boundary condition estimation from a suite of multi-sensor and multi-model data, rigorously accounting for known uncertainties and climatology.

(f) Repetitive tasks in running dynamic models may be automated by the application of ML paradigms.

Most importantly, the successful application of AI/ML techniques to develop dynamics-based data-driven modelling, predicting and observing systems for earth sciences problems requires computational equipment and trained interdisciplinary researchers. Individual researchers or collective teams must have expertise not in one subject area but in three areas, namely data science, geosciences and computational science.

Meeting conclusions. During this meeting it was acknowledged that there is a lack of trained people available in the country. Moreover, experts from this area should be connected to each other by working under one umbrella. Therefore, it is important to create a community of researchers working on applications of AI/ML, specifically targeted towards weather, climate and related areas.

It also stressed that researchers in the community should share their ideas on AI/ML as well as on the data. MoES can list its strategic goals for AI/ML and invite proposals for the same. These goals may also include management/decision-making problems, which an AI/ML expert can easily solve, and these well-defined problems can be floated as open challenges. A joint framework allowing such free exchange would be ideal. Another point raised was to publish such meeting/workshop reports in journals to apprise the scientific community.

At the end of meeting an open panel discussion was held that aimed to understand the state-of-the-art applications of AI/ML techniques for weather/climate forecasting and other earth sciences problems. This discussion provided a valuable opportunity to develop better understanding of the challenges involved in applying AI/ML techniques in the following areas: (i) Improving weather forecast modelling; (ii) Hydro-climate database management; (iii) Oceanography modelling; (iv) Management of big data obtained from numerical models; (v) Data-driven problems from geoscience and seismology; (vi) Remotely sensed data; (vii) Flow computations.

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