Machine learning approaches to predicting severe storm tracks and intensities

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Motivation

In recent months, a sequence of Atlantic hurricanes surprised and crippled several highly inhabited areas. Cuba had very little warning of the updated track of hurricane Irma before it was hit [1], and Puerto Rico was just reeling from hurricane Irma, when it was devastated by hurricane Maria two weeks later. Better understanding and predicting the development and movement of such severe storms (hurricanes, cyclones, typhoons: names differ by region) is critical to protecting communities and ecosystems. This project seeks to explore the capacity of machine learning approaches to improve predictions of severe storms: their geographical movement (tracks), and their intensification into severe storms.

Research question: Can machine learning contribute to understanding and predicting the tracks and intensity of severe storms (hurricanes, cyclones, typhoons)?
Sub-question: is deep learning an effective approach to such problems?

Novelty and prior art

Machine learning approaches to storm track and intensity prediction are quite novel in the field of meteorology, as many existing forecasting systems have human “operators” in the loop, e.g., the cyclone and typhoon warning systems of the US Navy. “The method of analogs,” a.k.a. nearest-neighbor, is sometimes used in predicting the future track of a storm, which we can compare to as a benchmark. There has been some success of machine learning in the tornado domain [2], and deep learning (convLSTM) has recently been applied to the precipitation domain [3]. Recent work used a deep architecture (CNN) for supervised learning of cyclones [4]. However, this work used a highly curated “easy” data set, and only studied classification of static images, as opposed to addressing time series.

In addition to meteorology, we expect this project to contribute to machine learning research. We hope to make progress in methods for pattern extraction from tensor data (in our case: spatial fields evolving with time). Algorithms for deep learning from tensor data is an active area of research [5]. Furthermore, in this application we are interested in learning to track and predict patterns that can change over both time and location. Questions of tracking highly deformable objects, e.g., temporal patterns in fluids, is largely open in the fields of machine learning and computer vision, to our knowledge. A subtask of this project will be a related literature survey.

Team: The team leaders combine Monteleoni’s expertise in climate informatics and algorithms for learning in the presence of spatial and temporal non-stationarity, with Charpiat’s expertise in deep learning architectures and applications. A successful student could potentially pursue a PhD with either of the mentors (in the USA or France).

Project tasks

1. Survey related work in machine learning and vision
2. Collect/curate data sets for storm track and intensity prediction
3. Deep learning implementation
    a. Interesting twists: temporal data, multi-scale dependences
4. Comparison to other machine learning approaches
    a. e.g. nearest-neighbor, online learning

Data types

- Storm track data
- Multidimensional fields evolving with time
    a. Observation data (e.g., satellite imagery, and temperature/pressure fields)
    b. Simulations output by physical models (e.g., of temperature/pressure fields)

Note: meteorological data sources are available freely online.

Expected skills of the candidate (Master level)

- Machine learning & Optimization; in particular deep learning experience would be appreciated, though not crucial
- Programming skills (Python will be involved)
- Mathematics/Physics skills are always welcomed (in particular probabilities/statistics, derivatives, fluid mechanics...), though not crucial
- English speaking and writing.

References

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3. Xingjian Shi, Zhourong Chen, Hao Wang, Dit-Yan Yeung, Wai-Kin Wong, Wang-chun Woo: Convolutional LSTM Network: A Machine Learning Approach for Precipitation Nowcasting. NIPS 2015.
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