Cyclone Frame Prediction by Gaussian Mixture Modeling of the Three Penultimate Time-Lapse Frames

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Cyclone Frame Prediction by Gaussian Modeling of Most Recent Spatio-Temporal Data

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***Abstract*— A fast cyclone frame prediction is proposed in this paper that models the most recent spatio-temporal data in the cyclone video using a Gaussian Mixture followed by the fuzzy regression procedure outlined in [1]. Unlike the previous work which models the entire history on a per pixel basis we model the entire 3D space within the last three frames making the process faster and more accurate. The increase in accuracy is attributed to the fact that cyclones evolve over time making the most recent data the only one most reliable to predict the next frame. We also propose a technique of finding the optimal number of components in the Gaussian mixture based on maximum likelihood principle. Our results on the recently occurred Nargis cyclone that hit the Indian seas show a high accuracy of frame prediction.**

Keywords- Fuzzy Gaussian Regression

I. INTRODUCTION

The prediction of future frames of a cyclone video is crucial to timely intervention on the part of the authorities for preventive measures and relief operations. Since the frames of the video captured by the satellite are about 30 secs apart, future frame prediction based on the current video frame/frames finds relevance for guiding rescue operations. Several cyclone frame prediction schemes can be found in literature. In [1] Verma and Pal proposed Gaussian mixture modeling of the entire history of each pixel for each of the color R,G,B channels. A fuzzy regression procedure was used to successfully predict the future frame intensities with the weights of the rules being the prior probabilities of the Gaussian components. An improvisation that involves the learning of cyclone data from past history pixel by pixel using artificial neural networks and dimensionality reduction was proposed in [2]. However the study of extreme storms in [3,4] indicates that the severe cyclone behaviour deepens explosively with no warning whatsoever and a prediction based on the current situation alone would increase the accuracy of cyclone frame prediction. Also the recent 3D data in the entire spatial domain needs to be studied for predicting the cyclone effect at a point. Based on this axiom we propose to model the 3D data in recent frames over the entire spatial domain using a single Gaussian Mixture Model, with the optimal number of mixture components determined for from the maximum likelihood graph. Case studies are abundant in literature on existing cyclone prediction models such as NOGAPS in the Pacific [5], COAMPS-TC of US-Navy [6] and TC-LAPS of Australian Meteorology centre [7]. All studies generally observe that the prediction is heavily dependent on the reference frames. The organization of this paper is as follows: The proposed cyclone frame prediction scheme is described in Section II, the results are discussed in Section III and the conclusions are drawn in Section IV.

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II. PROPOSED CYCLONE FRAME PREDICTION USING FUZZY REGREESION

We consider the last three frames overall to predict the next frame. The recent past of each pixel together with its current value comprise its 11 features. For a pixel of the current (and available) frame t denoted by (x,y,t), its past would comprise of (x,y,t-1), (x,y-1,t-1), (x-1,y,t-1), (x,y+1,t-1), (x+1,y,t-1), (x,y,t-2), (x,y-1,t-2), (x-1,y,t-2), (x,y+1,t-2), (x+1,y,t-2) and together the 11 intensities would form the feature vector. The Gaussian mixture modeling of the 11D data samples follow next. A single model is created opposed to the procedure in [1] where a pixel by pixel modeling is done. The Gaussian mixture model probabilities are used as the weights of the fuzzy rule base regression [1] used for the future frame prediction of (x,y,t+1) based on the 10-D input of (x,y,t), (x,y-1,t), (x-1,y,t), (x,y+1,t), (x+1,y,t), (x,y,t-1), (x,y-1,t-1), (x-1,y,t-1), (x,y+1,t-1), (x+1,y,t-1) obtained from past two frames t and t-1.

The algorithm for proposed cyclone frame prediction is given below customized to predict the future frame from the past three frames.

- *For predicting the 193^{rd} frame from the 192^{nd}, 191^{st} and 190^{th} frames, do:*
  - *For each R,G,B, channel do:*

1. Create a eleven-dimensional feature set for each pixel position comprising of the center pixel of the 192^{nd} frame, center pixel and 4 neighboring pixels of the 191^{st} frame and the center pixel and 4 neighboring pixels of the 190^{th} frame.
2. Model the 11-D data from all pixel positions using a Gaussian Mixture Model with the number of components initialized to 2.
3. Plot the log-likelihood of the mixture model as an instantaneous graph.
4. If the log-likelihood has attained a peak that is positioned between two valley points, then the number of mixture components is set to the number of components at the location of the peak, else increase the number of components by one and repeat steps 2 and 3.
5. Based on the mean, standard deviation and probability weights of the components of the Gaussian mixture model that is optimized by Expectation Maximization, we achieve next frame intensity prediction by using fuzzy regression.

- *Combine the RGB values to form a color image and compute the metric values pertaining to error of prediction*

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The satellite video of *Nargis*, the severe cyclone that hit the shores of Myanmar in 2008 is used for our experimentation. The coding was done in MATLAB 7.10 on a 2.6 GHz PC. The proposed algorithm successfully predicted the 193^{rd} video frame as shown in Fig. 1 as compared to the original fuzzy rule based Gaussian regression [1]. For the results of [1] we set the number of components to four (as per example of a case given in [1]) per mixture per pixel to save computations and time. We have also compared our result for the same setting as well as optimal number of components which is automated procedure without any manual intervention. The saving in computations over [1] is tremendous since the optimality is for a single model while in [1] the optimality is done for each pixel in the image. The prediction accuracy in terms of the CIM index for R,G,B channels are shown in Table 1 and reiterate our claim that the proposed method predicts cyclone frames most accurately from more relevant and recent reference frames. Comparison with the fuzzy rule based Gaussian regression [1] indicates a superior performance for our method.

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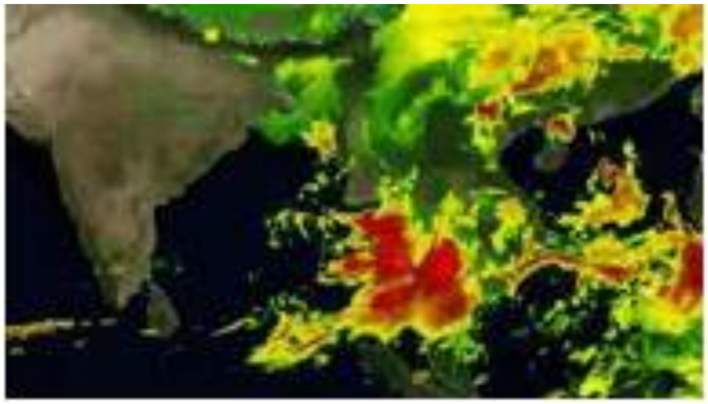
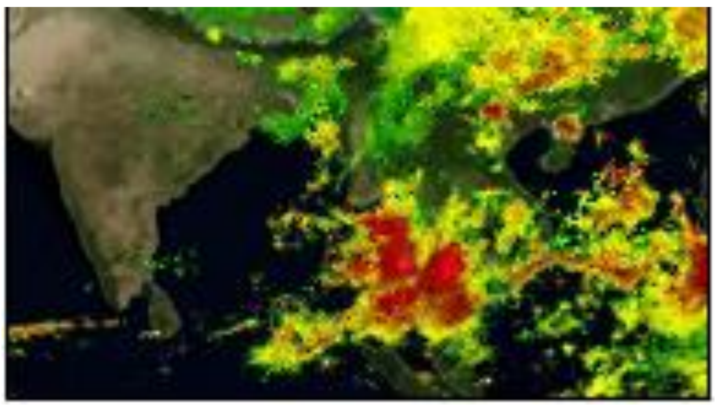
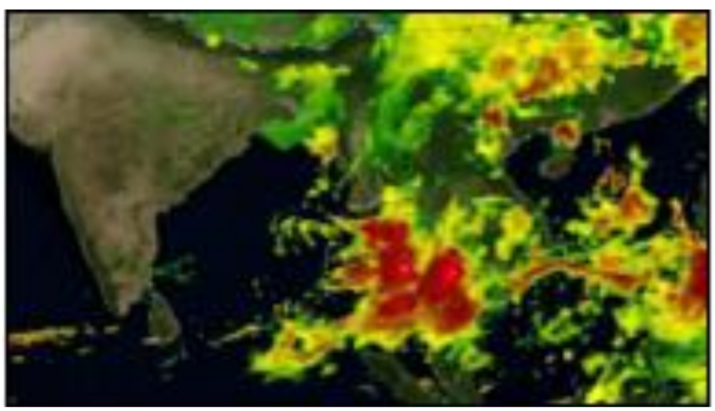


(a)



(b)



(c)

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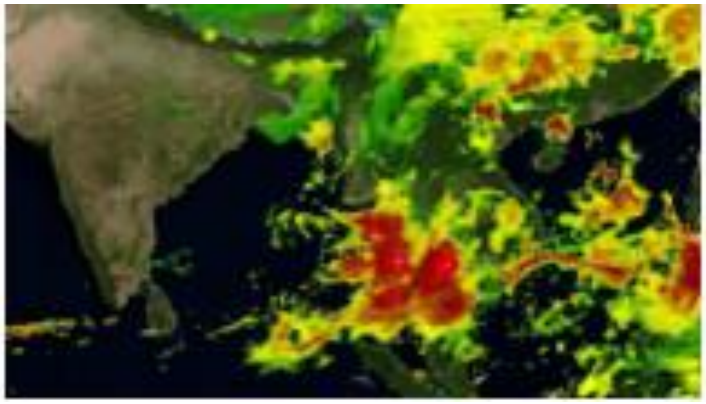

(d)

Fig. 1 (a) Original 193rd frame (b) Frame predicted using fuzzy rule based Gaussian regression with four components per pixel (c) Frame predicted using proposed method with four components per pixel (d) Frame predicted using proposed method with optimal number of components

Table 1: Accuracy in prediction for various methods for the 193rd frame using CIM index

Method	CIM-Red	CIM-Green	CIM-Blue
Fuzzy rule based Gaussian regression [1]	0.9806	0.9327	0.7874
Proposed method	0.9984	0.9882	0.7927

IV. CONCLUSION

A fast and accurate cyclone frame prediction is proposed in this paper that uses Gaussian mixture modeling aand fuzzy rule based regression on the most recent spatio-temporal data in the cyclone video. The optimal number of components of the mixture is determined from the first maxima of the log-likelihood of the mixture. Comparison of our results with existing methods on a recent cyclone video that affected the Indian Peninsula affirms the efficiency of our approach.

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