Spatial-temporal pattern modeling of a weather imagery by Hidden Markov Model

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This study presents the framework for summarization and discovery of patterns from spatio-temporal data which is common in the geo-science field, based on clustering of spatial data via Self Organizing Maps and on statistical modeling of a time series via Hidden Markov model. The method is applied to the weather imagery over Japan islands to extract temporal pattern such as seasonal change and intra-seasonal change.

Hidden Markov Model consists of states that transit each other with a certain transition probability (in the 1st order case, depends only on the state one time step before) and signals emitted from each state at a certain probability. States are generally invisible, and instead signals are observed.

On HMM application to time-series weather imagery, signals correspond to image cluster Ids, and states are considered to be a period which emits the cluster ID (images) at the certain probability distribution, thus states are considered to correspond to the epoch such as rainy season and so on.

In the experiment, GMS-5 IR1 images are sampled at one-day time interval at 17hour JST between 1997 and 2001 (1335 images in total), clustered into 36 groups via SOM using 6x6 cell map, and this time series of cluster ID is used as the input of HMM. Since the number of states is unknown, multiple trials with the number of states ranging from 2 to 10 are conducted on HMM learning and the case with the best BIC is selected.

As a result of experiments, the optimized number of states is found to be five, and the obtained transition of states are described by a chain-like sequence of ({Spring, Fall}-{Winter}-{Spring, Fall, Rainy season}-{Summer, Fall}-{Summer}) by matching states with conventional season by referring images and its time occurrence.

This result is different from our conventional understanding of season, which indicates that multiple states exist in each season except for the middle summer and middle winter, and each state can occur in multiple seasons for cloud patterns, if we focus on only properties of images (thus cloud patterns) and its time sequence. Our current method is thus useful for detecting invisible states in an almost automatic way and also useful for prediction because it is a probabilistic model. We consider this method is also applicable to various kinds of geo-science data such as an output of numerical simulation.