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A Service Oriented Architecture for Weather Forecasting Using Data Mining

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ABSTRACT

Weather forecasting is a crucial application in meteorology. Weather is a continuous, data-intensive, multidimensional, dynamic process that makes weather forecasting a formidable challenge. This paper proposes a novel method to develop a service oriented architecture for a weather information system and forecast weather using data mining techniques. Web services provide a way of using software as a service. Developing service oriented architecture enables this software to be used anywhere at anytime and on any device. Data mining is an interesting field of computer science that can be used for various applications. This proposal aims at developing a weather information system as a web service that can be used by any type of application and uses the prediction techniques of data mining for weather forecasting.

Keywords – Data mining, Service Oriented Architecture, Weather forecasting, Web Services.

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1. INTRODUCTION

At present, the increasing demand for computing power in meteorological applications is addressed by either using supercomputers, or by using high-performance computer networks. With the emergence of computer networks, the paradigm of distributed computing was born. This decentralization minimized bottlenecks by distributing the workload across multiple systems. It provided flexibility to application design. For fail-over and scalability issues, a third tier was introduced, separating an application into a presentation part, a middle tier containing the business logic, and a third tier dealing with the data. This three tier model of distribution has become the most popular way of splitting applications. It makes application systems scalable [1]. But the introduction of middleware still had the problem of interoperability because the components were tightly coupled. This problem was solved by the introduction of web services. Web Services are self describing and modular business applications that expose the business logic as services over the Internet through programmable interfaces and using Internet protocols for the purpose of providing ways to find, subscribe and invoke those services.

2. Web Services for Pervasive Computing

Web Service's mission is to provide a Remote Procedure Call (RPC) interface for client applications to call class methods on the server side. In order to create a Web Service, class methods are created with standard input and output parameters and the specific methods are made exposable over the Net. Web Services are used to expose functionality of a server to other applications. The client applications may be a Fat Client Windows application, a Fat Server Web application that runs a standard Web backend such as ASP, Cold Fusion, Web Connection etc., a browser based client application using script code, or even Java applet running in a browser on a Unix machine or a thin client application. As long as a client application has support for the Simple Object Access Protocol (SOAP) it can call the remote Web Service and return data for it, assuming the user is authorized [16]. Therefore web services are supported by both thin and fat clients that make them compatible for any application running on any device. Web services follow typical web rules. Web services are stateless. They use the standard Web architecture. Web services support the standard transport protocols like http which is used in the web. Thus web services support pervasive computing by being available anywhere, at any time and on any device.

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There are certain scenarios that require exposing a web service from an application that is not running in IIS; for example, running a Windows Forms desktop application that receives callbacks from a remote server. From version 1.0 of the .NET Framework, it has been possible to host the web service in any process, such as a console or Windows Forms application. **HttpListener** facilitates the process to do so. Version 2.0 of the .NET makes it easy to host ASP.NET and ASMX services in a managed application using the new HttpListener class which sits on top of http.sys and handles listening for incoming HTTP requests within the application. Figure 1 shows a high level architecture of how a managed application uses HttpListener to host ASMX services.

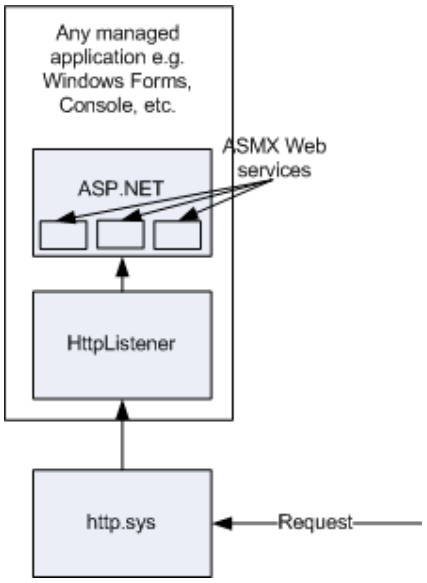

Fig. 1. Architecture of a Managed Application with HTTPListener

2. Simple Object Access Protocol

SOAP is the protocol that is responsible for routing messages between the client and the server. It is a light-weight XML-based messaging protocol. SOAP is based on XML and thus it provides good interoperability between applications. SOAP implementations provided by vendors typically consist of two pieces: a client side Proxy that handles the SOAP message creation and result message cracking to return the result data, as well as a server piece that implements the Web Service logic. The server piece tends to be an application server that calls out to custom Web Service classes that is created on the server side and that contain the business logic of the Web Service. The server code essentially consists of simple methods to handle inputs and outputs via parameters and return values respectively. The logic in the actual method may contain any functionality. In essence it is the breaking of the business tier from the presentation tier [16].

3. Web Services in .NET

The .Net framework introduces Web Services as an integral part of the architecture, making it very easy to create and consume these services with minimal amounts of code written. In .NET framework, Web Services are featured as the new component architecture in the distributed age where not only Internet exposure is handled through them but also common reusable business and application services. The .Net framework abstracts most of the internal logic that handles the remoting details of method calls over the wire and Visual Studio.Net builds support for Web Services directly into the development environment. Thus server side logic is made easily available to client applications. There are three major components that make up a web service.

- The Web Service on the Server side
- The client application calling the Web Service via a Web Reference
- A WSDL Web Service description that describes the functionality of the Web Service

A Web Service in .Net consists of a .asmx page that either contains a class that provides the Web Service functionality or references a specific external class that handles the logic in an external class file. Classes are standard .Net classes and the only difference is that every method that is exposed to the Web is prefixed with a [WebMethod] attribute. Once the .asmx page has been created, the Web Service is ready for accessing over the Web. .Net provides a very useful information page about the Web Service showing all the methods and parameters along with information on how to access the Web Service over the Web.

5. Client Application

Client applications can be any type of application from a Web backend aggregating data to display custom content to clients to a Fat Client application running Windows forms. The process of connecting a client application in Visual Studio.Net is always the same though you set up a Web Reference, add the Web Reference namespace and then simply call the methods of the Web Service. The method call actually calls a proxy object, which invokes the remote Web Service. The proxy base class contains all the black box magic that performs the SOAP call over the wire and the proxy class simply calls work methods in the base class.

6. Weather Forecasting

Weather forecasting plays a significant role in meteorology. Weather forecasting remains a formidable challenge because of its data intensive and frenzied nature. Generally two methods are used to forecast weather: a) the empirical approach and b) the dynamical approach. The first approach is based on the occurrence of analogues and it is often referred to as analogue forecasting. This

approach is useful in predicting local scale weather if recorded cases are plentiful. The second case is based upon equations and forward simulations of the atmosphere and is often referred to as computer modeling. The dynamical approach is useful to predict large scale weather phenomena and may not predict short term weather efficiently. Most weather prediction systems use a combination of both the techniques [2].

Data mining is an interesting technique that can be implemented in various areas to generate useful information from the existing large volumes of data. Data mining has thus far been successfully implemented to bring success in commercial applications. Some of the applications of data mining include discovery of interesting patterns, clustering of data based on parameters and prediction of results by using the existing data [3],[4]. There are diverse techniques and algorithms available in data mining that can be implemented for various applications. This paper proposes an efficient data mining technique for weather forecast [5].

7. Proposed Approach

In this approach, a web service is developed using .NET to create a weather information system. The business logic is implemented and a front end is created as a web application. This is used as a weather information system. Using this service, the weather reports can be obtained for any major city in Tamilnadu. The data obtained from this service is mined to forecast the weather using prediction techniques.

A web service is created in .NET which extracts the weather data of all leading cities in India from the web. A web application is created as a front end and this web service is added as a Service reference. As the data is extracted through this service, a real time dataset is obtained and the mining process is performed.

Support Vector Machine algorithm relies on statistical learning theory. The principle of Support Vector Machines is to map the original data X into a feature space F with high dimensionality through a non linear mapping function and construct an optimal hyper plane in new space [6]. SVM techniques may be applied to both classification and regression. In classification, an optimal hyper plane is found that separates the data into two classes, whereas for regression a hyper plane is to be constructed that lies close to as many points as possible [7].

Support Vector Regression (SVR) predicts the maximum temperature at a location. Regression is the problem of estimating a function based on a given data set. Consider a data set

$$G = \{(x_i, d_i)\}_{i=1}^{N}$$

where x_i is the input vector, d_i is the desired result and N corresponds to the size of the data set. The general form of Support Vector Regression estimating function is

$$f(x) = (w.\phi(x)) + b$$

where w and b are the co-efficients that have to be estimated from data. f(x) is the non linear function in feature space [8], [9], [10].

The weather data is retrieved online through the web service for a year and is used to build the models. The database includes the data of several weather parameters recorded at every hour interval. The daily maximum temperature is extracted from the web service and is used for this work. The real world databases are prone to noisy and missing data. The data extracted from the service is preprocessed to improve the quality of data and thereby it improves the prediction results. In this research work, the maximum temperature of a day is predicted based on the maximum temperature of previous n days where n is the optimal length of the span. The value of n is found by experimental iterations. The service is implemented with .NET and SVM models are implemented with WEKA.

8. Experimental Results

The web service is developed with .NET and the results of the SVM models are obtained using WEKA. Weka is a collection of machine learning algorithms to perform data mining tasks. The algorithms can either be applied directly to a dataset or called from the users own Java code. Weka has the options for data pre-processing, classification, regression, clustering, association rules, and visualization.

Figure 2 shows a web application implementing the .NET web service. It serves as a front end for using the web service. The screen shot in Figure 2 shows a sample data of fetching the weather details corresponding to a major city in India namely, Calcutta. Online data is fetched by the web service and the result is obtained as a SOAP message. The SOAP message is converted into a form that can be shown in the application. The results are depicted in the figures 3 & 4. The data thus extracted is mined using the data mining tool WEKA after preprocessing. This research work uses the Support Vector Machine algorithm for forecasting the weather. The results are shown graphically.

Figure 2 lists all the countries starting with the letter C and it fetches the online weather data. It is shown using a web application that uses the web service for gettting the weather data. The weather data for any major country can thus be obtained using this user interface. The underlying web service enables to fetch the weather information and displays it using the web application that serves as a user interface.

The web service has been implemented using the .NET framework. The user interface has been developed using ASP.NET. The output is obtained as a SOAP message and is displayed as text in the web application.

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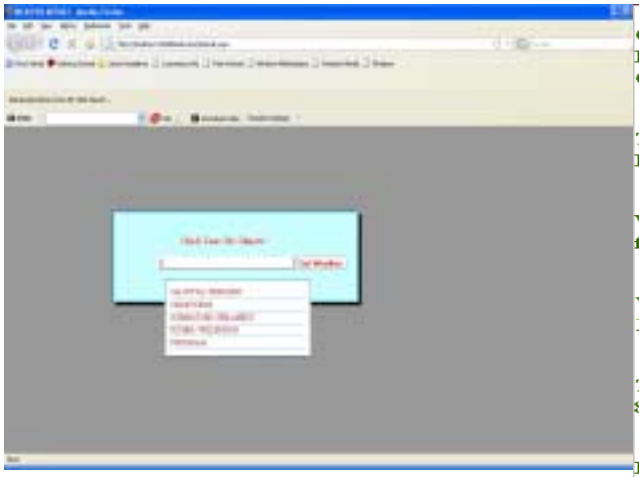

Fig. 2. Web application using weather information service

Figure 3 shows the SOAP message that describes the complete weather details.

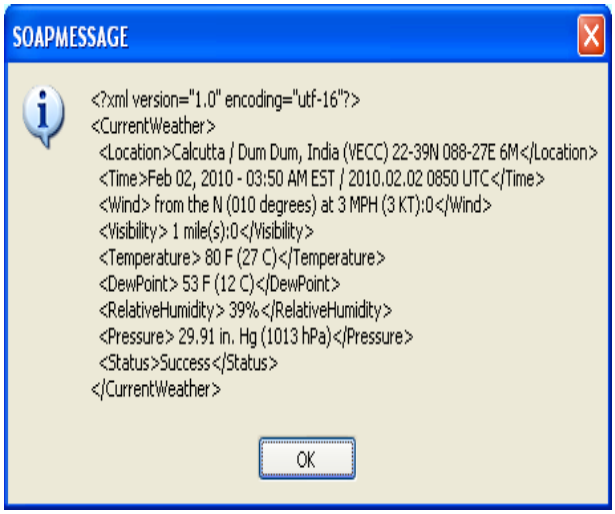

Fig 3. SOAP message from web service

Figure 4 shows the online weather data as displayed in the web application. The web service was used to fetch the weather data for an year and the data were mined using Support Vector Machine algorithm to forecast the weather. Data were mined using the data mining tool Weka and the results were obtained. Some of the graphical results are given below.

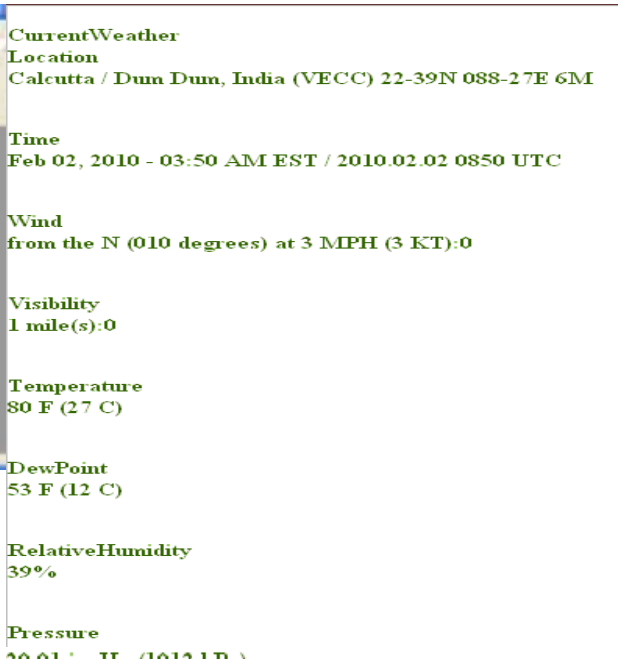

Fig. 4. Online Weather Data

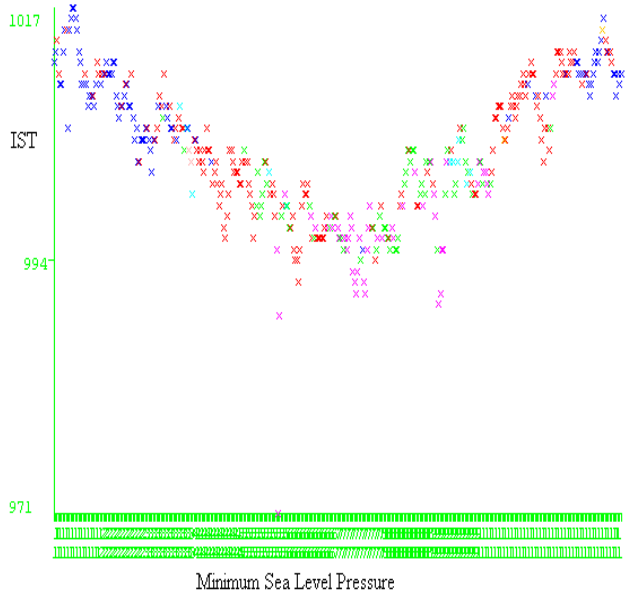

Fig. 5. Mean sea level pressure distribution with SVM

Figure 5 shows the minimum sea level pressure distribution for a year where blue dots denote fog and green dots denote rain-thunderstorm and red dots denote no special event.

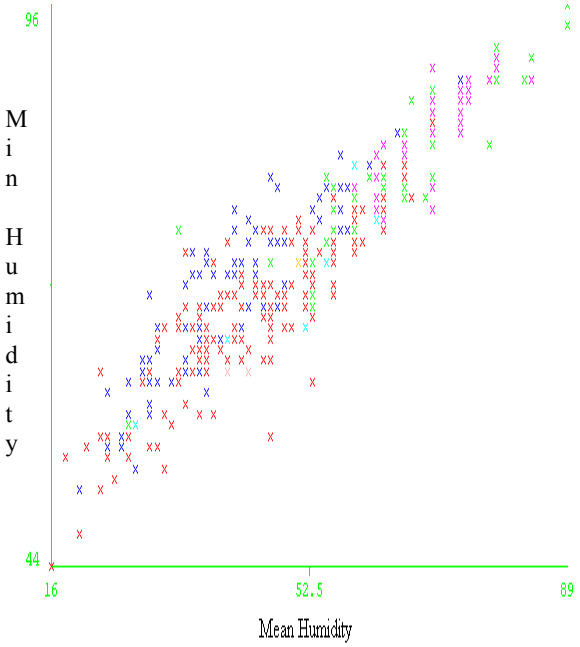

Fig 6. Mean Humidity distribution with SVM

Figure 6 shows the mean humidity distribution for a year where blue dots denote fog and green dots denote rain-thunderstorm and red dots denote no special event.

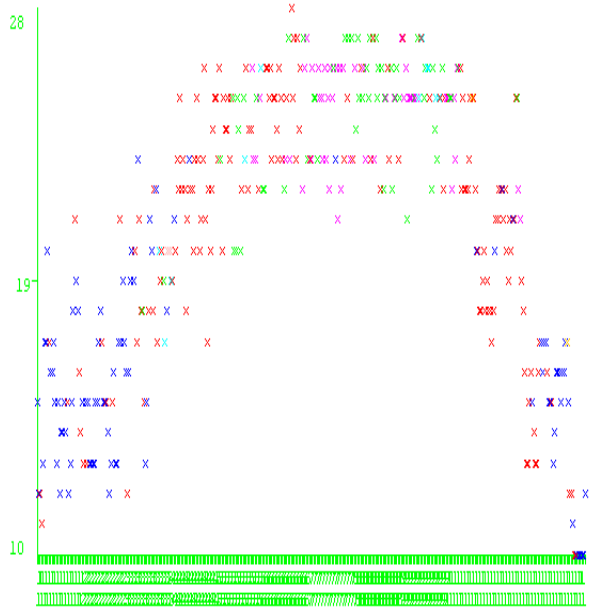

Fig. 7. Mean dew point distribution with SVM

Figure 7 is a plot of IST versus mean dew point. It depicts the mean dew point distribution for a year where blue dots denote fog and green dots denote rain-thunderstorm and red dots denote no special event.

9. Conclusion

In this paper a web service is developed in .NET for getting the weather data status from the web. Mining process is performed to obtain the knowledge from the data set and predict the weather. Support vector regression is used for atmospheric temperature prediction in this paper. The results are simulated using the WEKA toolkit.

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