Application of GIS and RDBMS to Numerical Atmospheric Meteorology/Chemistry Models

A contribution to subproject GLOREAM

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Summary

Geographic Information System (GIS) associated with a Relational Database Management System (RDBMS) can make an important contribution to environmental modelling. Together they can be used to manage and provide necessary input data and to analyse and visualise the model results.

The article describes a class system that provides access to tabular data stored in a relational database and associated geo-data using RDBMS and GIS capabilities. They form an interface to the information system GSfM - GIS Support for the Multiscale Climate-Chemistry-Model (MCCM) that has been developed at the Institute for Atmospheric Environmental Research, Garmisch-Partenkirchen, Germany. GSfM is used to provide various input data for MCCM such as land use, soil texture, digital elevation, anthropogenic emissions, and to process its output in related mapping activities. The interface allows a major quality improvement of a BVOC inventory by provision of plant species–specific land use, foliar biomass data and emission rates.

Introduction

Development, operation, validation and comparison of meteorology-chemistry models and other environmental models are only possible if high resolution digital input data on soils, land use, elevation, vegetation as well as anthropogenic and biogenic emissions are available. Such data are often available but not in shape required by the models. Geographic Information System (GIS) associated with a Relational Data Base Management System (RDBMS) has adequate means to store, manipulate and process such digital information and to provide it in appropriate format to the models. In addition, both GIS and RDBMS provide various tools to ensure data integrity as well as data security.

The article describes the GIS/RDDBMS interface of the information system GSfM - GIS Support for the Multiscale Climate-Chemistry-Model (MCCM). The interface is used to provide various input data for MCCM including anthropogenic emissions, to process its output in related mapping activities and to provide input data for modelling biogenic VOC emissions .

Objectives

Comprehensive applications in environmental modelling, such us anthropogenic and biogenic emission inventories or meteorology and chemistry transport models, cannot directly be coupled with GIS/RDBMS. They require additional tools and methods of data processing that interface the models with the databases and GIS using built-in GIS/RDBMS functionalities. Appropriate tools are also needed to enable processing of auxiliary data from other sources

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and databases that might be in different formats. Major goals of the GIS/RDBMS Interface are:

- **To provide input data for MCCM and the BVOC model**. The interface should be able to process land use data compilation for an specified area as well as for specified domain and sub-domain systems according to MCCM requirements. In addition it should provide plant species specific land use data and vegetation parameters, such as biomass, leaf area index (LAI), vegetation index (VI) and VOC emission factors for modelling biogenic VOC emissions. The BVOC model implemented at IMK is described in detail by Richter et al. (1998). Further data are digital elevation models (DEM) and soil texture data.
- **To provide appropriate emission data for use with MCCM.** MCCM requires temporally and spatially resolved emission data. Hourly emissions of NOx, SOx, CO, PM10, PM2.5 and VOC divided into the chemical species used by a chosen chemical mechanism (i.e. RADM2) are required. The data must be geographically disaggregated into the grid cells of the domains and sub-domains of the MCCM. The interface must also provide additional information on the location of point sources, including source elevation and stack parameters. The background of the MCCM model is described in detail by Grell et al. (2000).
- **To provide information and tools for data presentation as maps, tables, graphs and queries**. Data visualization and dissemination are important issues in communication of environmental issues within authorities and to the public.

Activities

The GIS/RBMS interface has been completely rewritten using object-oriented programming techniques. Figure 1 depicts the class diagram of the GIS/RDBMS interface in the UML (Unified Modeling Language) notation. The interface gives access to both tabular feature data stored in a relational database and to a geo-database stored in a file system.

Corner stones of the interface are the two classes *GIS* and *Dbdata* (see Figure 1). *DBdata* defines interface methods allowing connect to a database as well as select and retrieve of data. The *GIS* class provides interface methods to the GIS. Both classes are independent of the employed RDBMS/GIS software following the OO-paradigm. The implementation of the defined methods related to the available software is provided by the classes *Database* and *Arcinfo*. Class *Gissoap* extents the class *Arcinfo* and provides means to employ distributed computing within a network using Simple Object Access Protocol (SOAP)(Box et al., 2000). The class *Database* uses a Perl DBI:Oracle module to access the Oracle RDBMS. It inherits from class *Databasefile* that provides the same methods but reads from files allowing the use of the system even if the data (i.e. emissions) are not stored within the RDBMS.

The access to the ArcInfo – GIS is facilitated via ArcInfo Macro Language (AML). The class *Arcinfo* writes all required commands into an AML file and executes the AML on the operating system level. Intensive use of built-in functionalities of the RDBMS and GIS, such as projection change, intersect, statistics and many others saves a lot of programming time.

One of the strengths of the presented interface is the exact replication of the MCCM modelling domain. The starting point is the definition of an object representing the mother domain (class *Domain*). Its characteristics are name of the object, the number of rows and number columns, grid size, name of the map projection and the geographic co-ordinates of the centre point.

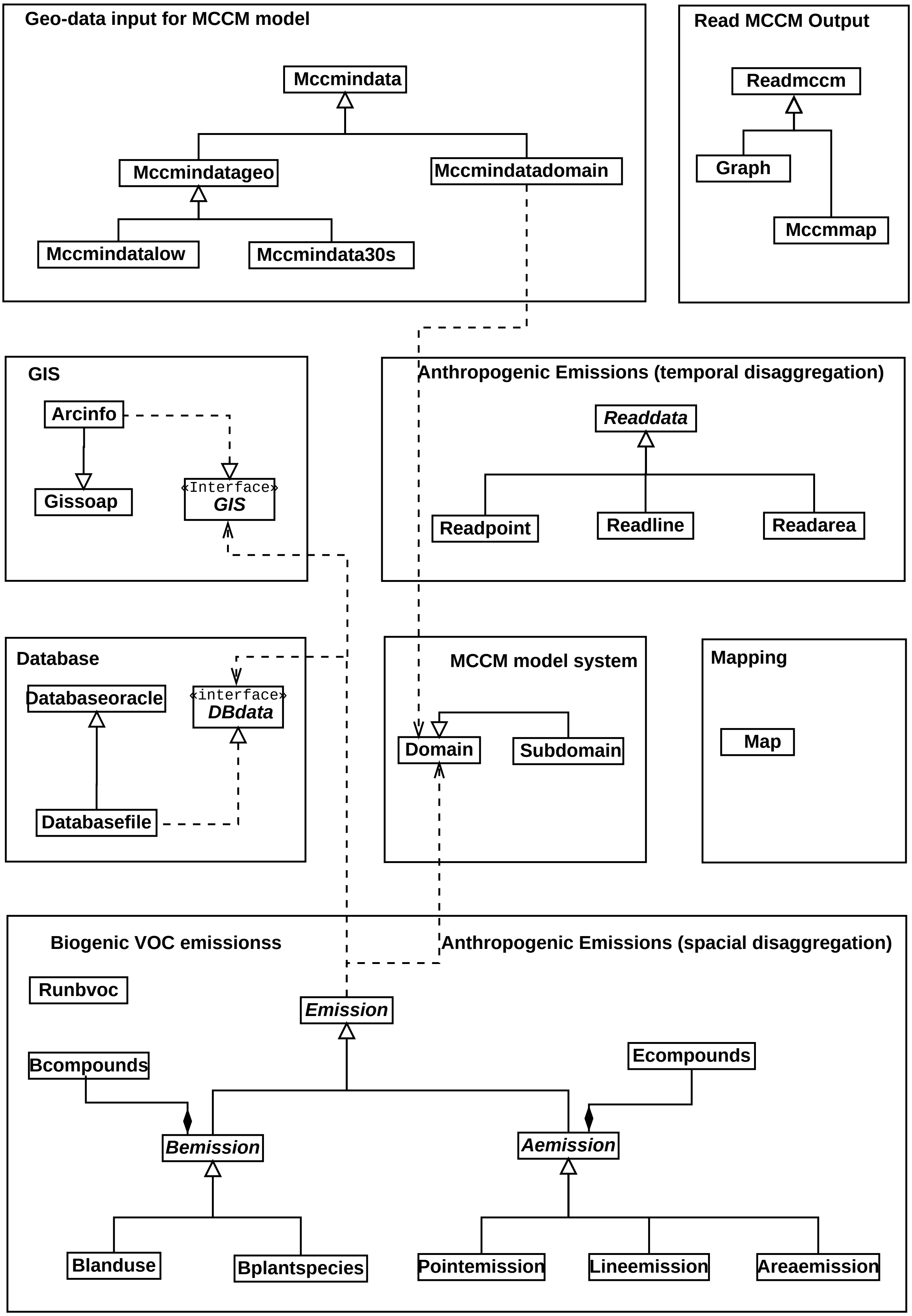

Figure 1. Class diagram of the GIS/RDBMS Interface

The class *Subdomain* inherits from the class domain and implements the creation of objects representing the subdomains (nests). In the OO-paradigm the objects life is limited to the runtime of a program. However, the GIS can only handle persistent objects. Thus, vector coverages representing the domain and subdomains are saved on to disk. In addition, the class *Map* provides means for visualisation of the domain/subdomain system using GIS capabilities.

Usually anthropogenic emission inventories refer to administrative units and to a time frame of one year. Two parts of the interface process such emission data providing tools for their temporal and spatial disaggregation. Classes *Line-*, *Point-*, and *Area-emission* inherit from the classes *Aremission* and *Emission*. They contain methods to perform the geographical disaggregation of anthopogenic emissions data. An abstract class, *Bemission*, allows an easy extension of the class system to data provision for modelling biogenic VOC emissions. *Ecompounds* represents the chemical compounds including categories used by the chemical mechanism (i.e. RADM2). The biogenic VOC emissions part of the system can process plant species-specific data as well as general land use and provides appropriate foliar biomass data and emission rates. The setup of the BVOC model environment (class *Runbvoc*) and a link to the output of the MCCM model allows to run the BVOC inventory model from the GIS/RDBMS interface. The BVOC part of the information system is described in detail in Smiatek(2001). Additional classes provide methods for geodata processing for use within the MCCM model. They include land use data in various formats as well as soil and digital elevation (DEM) data.

Conclusions

The presented GIS/RDBMS interface forms a set of classes and methods that help to manage and provide data for modelling with MCCM and for modelling biogenic VOC emissions. The major advantages are the exact replication of the modelling domain and its ability to use the built-in features of GIS and RDBMS. The BVOC part of the system can process plant species-specific data as well as general land use and provides appropriate foliar biomass data and emission rates. Temporal and spatial disaggregation of anthropogenic emissions data as well as its ability to provide land use, soil and DEM data tailored to the MCCM model are further major advantages.

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