TRNDB: A Web Database and Web Site for Storage and Process of Building Energy Analysis Data

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**ABSTRACT**

In this paper, the design and development of a web database for the purpose of storing and processing data produced by a complete building energy analysis is presented. Additionally, a web site that provides access to the database as well as a set of processing functions is outlined. The data stored are read from special input files produced by the TRaNsient SYstems Simulation suite known as TRNSYS.

The database and the web site that offers access to it provide safe storage and retrieval of TRNSYS projects while also allowing sharing between users to promote cooperation and to fasten solving. The use of Internet in this application allows users around the world to access the database anytime, lifting the constraints of local storage using hard disk drives or portable storage solutions.

1. **INTRODUCTION**

The continuous changes in the global energy market lead nowadays more and more companies and industrial plants to research ways for more efficient administration of the energy used (Thumann et al., 2003). Reducing the usage cost is the most effective and feasible way to reduce the operating cost.

Many large energy consumers organize energy audits conducted by specially-trained engineers in order to check and prove that a project to reduce the energy consumption will in fact have the expected results. The calculation of energy consumption, whether it concerns offices, residential buildings or industrial plants, is a complex task, thus it is always supported by specialized software. TRNSYS is a software suite that belongs to this category. In most cases i.e. sensitivity analysis, energy rating procedures, etc., a huge number of simulations is needed in order to extract useful information and data. This process can be accelerated and automated with the integration and interaction of the specialized software with database technology.

TRNSYS (TRaNsient SYstems Simulation program, (University of Wisconsin, 2005)) is a powerful simulation suite for transient systems. To simulate multi-zone buildings, TRNSYS library includes the TYPE 56 component (Transsolar, 2006). The process of creating input files for the TYPE 56 component is time-consuming and complex. This leads to the need for effective and safe storage of the work done so that it is possible anytime to retrieve a project whether to update the data contained or to use the project as a reference for other projects. In addition, a continuously growing community of TRNSYS users has been around for many years, consisting of engineers, researchers and professionals who have a varying level of experience in the field of TRNSYS simulation. The cooperation between the members of this community facilitates quick problem solving, novice user guidance and trouble reporting and discussion.

The scope of this paper is the development of a web database for the storage and process of building energy analysis data, as they are produced by TRNSYS in order to facilitate and accelerate the simulation process for a vast number of buildings and organize the simulations’ output. It also includes a web site that acts as the front-end for the database, providing data access and data-related functionality. The application offers safe storage and retrieval of TRNSYS projects and at the same time provides users a way to share their projects, promoting cooperation for the purpose of quick problem solving. Any user with Internet access can access the database anytime, lifting the constraints of local and portable storage.

The application, in its basis performs the following operations:

− reads TYPE 56 input files and/or TRNSYS simulation results
− extracts the complete information contained in them
− converts the information appropriately
− stores the information in the database.

Due to the large variety of information contained in these files, the application has to be designed to recognize and store all kinds of data that can be found in a
multi-zone building described using TRNBuild. Moreover, due to the application being basically a file reader, it can be adapted to support the reading and storing different file types that contain the same range of data as TYPE 56 input files.

The rest of the paper is organised as follows: In the second section, the database design is outlined by briefly exploring the information that needs to be stored and by examining the class diagram for the database. The third section includes the web site’s description, first by examining the services offered and then by analysing the activity diagrams for each service as well as presenting the final layout of the web site. Finally, in section 4, we discuss the conclusions of our work and offer plans for future work and suggestions for future uses of the application.

2. DATABASE DESIGN

The first goal in the course of the database design for this application is to determine the full extent of the information that is stored on the TYPE 56 input files. The files are briefly described below:

- .inf file: contains a detailed description of the building as well as the values of the transfer function coefficients for each wall type of the building, which are produced by TRNBuild.
- .bld file: keeps only the numeric data of the .inf file, excluding all text information. The data is written in scientific format.
- .inf file: contains only the values of the transfer function coefficients in higher precision than in the .inf file.
- .bui file: contains almost the same information as an .inf file, up to the detailed description of the zones. From TRNSYS version 16 onward, it is the only file that is requested as an input file, instead of the three ones previously mentioned, as these are internally produced by TRNBuild, without user interference.

The information included in these files is obviously directly dependent of the building in examination. To make sure that the database will be capable of storing any data that could possibly be contained in the TYPE 56 input files, we conducted a study for a seven-storey office building and at the same time examined carefully all the different options offered in the TRNBuild environment and all the variables that are included in the Fortran code that is used to create the input files.

As it has become obvious, the complexity, variance and volume of the data at hand, increases the complexity of the database itself. Therefore it is necessary to categorize the data and find the attributes for each data group as well as the relations between different data groups. This task can be assisted with the use of an object-oriented modeling language, such as UML (Booch et al., 1999) and more specifically the use of a class diagram (Fowler et al., 2000). Each distinct data group corresponds to a class in the diagram, which in turn is translated to a table in the database. For example, all data related to wall types in a building project are organized under the “Wall_Type” class and those data are stored in the “wall_type” table of the database. When a new project is stored in the database, the input files are processed and the database tables are filled-in with data extracted from these files. A brief description of the main data classes that constitute the database follows.

- Project: It is the main database table and virtually all other tables are connected to it. It contains basic information for the project and the building that is examined, i.e. name and address of the building etc.
- Account: It contains information about the users of TRNDB. Through its connection to PROJECT, it is possible to determine which user has uploaded which project.
- Output, Balance and Summary: These tables contain all data saved by TRNSYS in various output files.
- Properties: It contains constant values used throughout the project, i.e. air density, relative surface temperature etc.
- Input: In this table, data corresponding to user-specified project inputs are stored.
- Schedule_Type: Included here are data for all schedule types (daily and weekly) that are defined in projects.
- Zone: This table contains general information for all thermal zones defined in projects, i.e. zone volume, zone humidity model etc.
- Coefficient: This table contains the values of transfer function coefficients for all wall types contained in projects.
- Orientation: Each project has a limited set of possible surface orientations. This table is created to store the orientation names.

- Layer_Type, Wall_Type and Window_Type: All types of layers that compose the walls of project buildings are stored in Layer_Type while data concerning the walls themselves and not their structure are stored in Wall_Type. The window types are implemented similarly.
- Window_Pool and Pool tables: The feature of window pools, included in TRNSYS ver. 16, contains many different data groups which are stored in these tables.
- Ventilation_Type and Gain_Type: All data that are related to ventilation and thermal gains are stored in Ventilation_Type and Gain_Type respectively.
- Infiltration_Type, Comfort_Type, Cooling_Type and Healing_Type: The regime for each thermal zone is determined by the connection of the Zone table to each of these tables.
3. WEB SITE DEVELOPMENT

The web site that is included in the application presented here acts as an interface between the user and the database and provides a complete set of access services to retrieve and store data. To determine the services that are offered by the application, it is necessary to address the needs of the potential user of TRNDB. First of all, it is important that the web site provides a registration procedure to limit the access to registered users only and to provide personalized services depending on the user’s activities. To this end, the first three services that were considered for implementation were:

- TRNDB services description
- New user registration
- System Login/Logout

The first service addresses unregistered users that wish to be informed of the functions offered by TRNDB. The second one provides a familiar registration interface and aids users to complete the registration process. Finally the system login service allows only registered users to connect to the database and the system logout disconnects users from TRNDB when they wish to.

The main role of the web site is to provide a way to interact with the database. Three services were implemented to realize this interaction:

- Store project in database
- Download project from database
- Delete project from database

The first service consists of a series of steps that carefully explain to the user which files he needs to upload so that all data contained in a TRNSYS project are correctly read and stored in the database. The opposite procedure is provided by the second service and allows the users to obtain copies of the original files that they uploaded while storing their project.

Apart from its role as a means to safely store TRNSYS projects, the web site aims to promote user interaction and project sharing by supporting a user community. However, the decision to share one’s projects is left to the users. To facilitate project sharing, the following services were included:

- Set viewing permissions
- Search for stored projects

The first service allows the users to determine which projects are private, thus accessed only by their creator and which will be publicly available. The search function is the means to find and access all publicly available projects. The results are narrowed by a few search criteria. Finally, an additional service that is available only for TRNSYS 15 projects is the simulation execution through the web site. For those users that have a copy of TRNSYS 15 installed in their computer, it is possible to execute the simulation through the web site. However, TRNSYS 16 disallows the external execution of a simulation, so the scope of this service is limited.

To examine and find all possible scenarios that can take place during the interaction between the user and the system, we used the methodology of use cases and activity diagrams (Fowler, 2000) (Christodoulakis, 2005) (Schneider et al., 1998). Here, we will briefly examine the activity diagrams for some of the services mentioned above. In other words, the steps behind each service will be described in detail.

3.1 User Registration

The first service we are going to examine is the new user registration. The system must obtain from the user all necessary information through the use of form filling. In case of a mistake, the user is informed of the error in filling the form and he is prompted to correct it. After a user has finished successfully the registration process, he can start using the application to upload his TRNSYS projects and store them in the database.

3.2 Project Upload

The uploading procedure consists of a series of upload boxes and the system makes sure that all required files are requested so as to make sure that the copy of the project in the database is complete.

3.3 Project Download

We will now examine the opposite procedure, the downloading process. In this case, the user specifies a path in his hard disk so as to store all files exported by the application.

3.4 Project Deletion

In case an error occurs before all project files are uploaded during the uploading process, the project is stored incomplete in the database. For this reason, the application provides a way to delete any project a user has uploaded. As a result, a user can delete an incomplete project, or any project he feels that he doesn’t want to keep anymore in the database.

3.5 Project Search

The final service we are going to present is searching. Users can search and find projects that their respective uploaders have allowed them to be publicly viewable. The search is based on a number of criteria, including keywords and uploader user names. Any resulting projects can then be downloaded.

In Figure 1, the layout of the web site is shown. The layout consists of the following parts:

- **Header**: The upper part of the page. It contains the application title and the main menu. The bottom right
part of the header is user to display information and error messages, as they are more likely to be observed by the user in that particular area of the page.

- **Left Pane:** The left part of the main area, it contains information and links for actions such as user registration, searching and simulation execution. This part of the main area is differentiated from the right part by its distinctly darker background.

- **Body:** This area occupies the major part of each page. Here, all information that needs to be presented to the user is presented. While all other parts of the page layout contain relatively similar information, in the body the information varies from page to page.

- **Footer:** The bottom part of the page. It is the only part of the layout that remains exactly the same in all pages. It contains links to the home page, the site map and the contact page.

4. CONCLUSIONS – FUTURE EXTENSIONS

4.1 Conclusions

The work presented in this paper resulted in the implementation of a fully operational web database and a web site that provides access to it. The application was initially designed to support storing of TRNSYS version 15 projects. In the midst of the implementation, TRNSYS 16 was released and the design goal was revised to include version 16 projects while keeping the support of older projects, as many users might not make the transition to the new version. The final application fully supports version 15 and 16 projects, or in other words files that have been created using or according to PreBID version 5 and TRNBuild version 1, thus supporting all multi-zone building systems.

The database offers through the web site a series of functions for storing, retrieving, searching and deleting projects, while providing the users with a sharing environment. The uploading and downloading procedures is fairly easy, given that the TRNSYS user is definitely familiar with the simple mechanism of a web site and is not a novice user in computers. The duration of these procedures is directly dependent of the size of the project and the amount of information that it contains. For example, the building we simulated as a case study included 45 thermal zones and the uploading procedure excluding the output files, lasted 1.5 min while the downloading procedure lasted considerably less, about 20 seconds. For smaller projects, the uploading and downloading time is diminished. On the other hand, if the output files are included, the time is increased because output files are usually very large files and for that reason the user is able to store a project without the output files. For example, the project we used as case study produced an outputs file that was 4.14 MB, which, if uploaded would considerably increase the duration of the process.

The search function offers a set of criteria that make it easier to find projects whether users are searching for their own projects or for other users’ projects. The ability to change the viewing permissions for each project gives the users the right to decide which projects should be publicly displayed and which should be kept private. In general, TRNDB offers a set of functions that extend the functionality of the TRNSYS suite and TRNBuild in particular, and provide previously local projects with a web presence. TRNDB does not, in any case, substitute the original way of creating TYPE 56 files and was not designed to. The goal is to store and retrieve projects that were created either using TRNBuild or a word processor. TRNDB can be used from novice and experienced users alike, as well as user groups. Expert users who have created many TRNSYS projects can store them in the database to be able to access them anywhere and anytime. New users, that are still learning how to create TYPE 56 files using TRNBuild, can use the stored projects as reference. User groups that cooperate in a research project but are not possibly in the same workplace can use the database to store their progress in the project so that their partners can examine the updated project and adapt their work accordingly. In addition, the ways that TRNDB can be expanded and which are presented after, guarantees that the functionality of the application can be broadened to offer new capabilities to users.

4.2 Future Extensions

The expandability of TRNDB became apparent from the early parts of the implementation when it was necessary to support the new version of TRNSYS that was just released. This leads to the fact that the application can and should be updated to be current and consistent with any
changes that are applied to future TRNSYS versions. TRNDB can also be extended to support data from other components that are part of the vast TRNSYS library. One example that is directly related with multi-zone building is the addition of air quality data produced by the linking of TRNSYS with COMIS. COMIS offers an airflow model for multi-zone buildings that is related to TRNSYS due to the fact that they are both implemented using FORTRAN. TRNSYS and COMIS can be linked in many ways and TRNDB can be adapted to read input files that contain airflow data and store them in the database and also export those files.

A third category of extensions that could be a separate application as well, involves studying the TRNSYS multi-zone building model in depth so as to implement it as part of an application server. This would allow TRNDB to be independent of TRNSYS, as it would be possible to execute simulations through the application server, without the need of having TRNSYS installed in the local disk. Finally, TRNDB could be further expanded to support file types that aren’t necessary formatted according to the standards of TYPE 56 and/or TYPE 157 (COMIS). The system could be adapted to support files that contain, for example, results from Monte Carlo simulation of existing data. Users could produce using Monte Carlo simulation data for many projects by interpolating existing data from few projects. The data produced could be formatted according to a specified standard that the system supports and they would then be stored in the database. However, when the user downloads them, they would be formatted according to the TYPE 56 format, providing the user with a large number of projects, which would otherwise be very difficult and time-consuming to create. Thus, the user could easily produce TRNSYS simulation results for many buildings, while having actual data for few ones, essentially helping the researcher or engineer in his work.

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