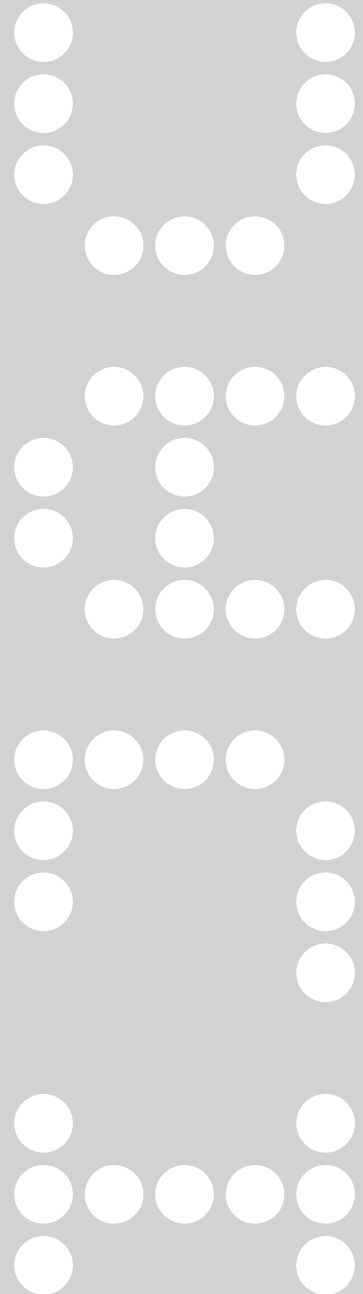# LibViz: Data Visualisation of the Old Library

K. Ruhland, M. Sedlmair, S. Bioletti
and C. O'Sullivan

LibViz: Data Visualisation of the Old Library

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The Old Library of Trinity College Dublin, built in 1732, is an internationally renowned research library. In recent decades it has also become a major tourist attraction in Dublin, with the display of the Book of Kells within the Old Library now drawing over half a million visitors per year. The Preservation and Conservation Department of the Library has raised concerns about the impact of the environment on the collection. The location of the building in the city centre, large visitor numbers, and the conditions within the building are putting the collection at risk. In developing a strategic plan to find solutions to these problems, the department has been assessing and documenting the current situation. This paper introduces ongoing work on a system to visualise the collected data, which includes: dust levels and dispersion, internal and external temperature and relative humidity levels, and visitor numbers in the Old Library. We are developing a user interface for which the data, originally stored in various file formats, is consolidated in a database which can be explored using a 3D virtual reconstruction of the Old Library. With this novel technique, it is also possible to compare and assess the relationships between the various datasets in context.

1. INTRODUCTION

Built in 1732, the Old Library at Trinity College Dublin (TCD) was originally designed to provide storage, reading and tutorial spaces for the growing College Library collection, staff and students. It was also designed in such a way as to maximise the use of some of the features of the building to provide protection for the books. Large sash windows provided natural light for reading, thus negating the need for oil lamps and allowing air circulation to prevent the possibility of mould; the Long Room itself was located on the first floor of the building, above a colonnaded walkway to reduce the risk of flooding. However, over the years, new risks to the collection have emerged which were not foreseen, including the growth in external pollution levels, the impact of continued exposure of collections to natural light, the effects of changing temperature and humidity levels on bindings and paper, and the new use of the building as a public space.

The Preservation and Conservation Department of the Library is collaborating with the Director of Buildings Office and various science departments in the College, to undertake a detailed assessment of the building, including a full structural survey and building performance review, a visitor impact study and a study of the environmental conditions. The results of these investigations will inform the Old Library Preservation strategy, which aims to protect both the building and its contents into the future.

Maintaining an appropriate environment for historical buildings with respect to preservation and usage has been the focus of many studies. At TCD, the Preservation and Conservation Department has been monitoring temperature and relative humidity in collection areas, and has recently commenced a study of Old Library Dust (SOLD), in partnership with the Geochemistry Laboratory in the Department of Geology. This study aims to identify the type, source, volume and distribution of particulate pollution within the building. An initial study was carried out to determine the levels and content of existing dust, prior to establishing the study of ingress rates and pathways and distribution patterns [19]. Other investigations include a study of the paper and dust interface (SPD) and the presence of volatile organic compounds in the Old Library, which are being carried out in collaboration with partners.

Related studies include an investigation into the ceremony room of the mediaeval palace in Padova, which focused on "the impact of lighting, heating and people in re-using historical buildings" [4]. Decorations on the walls, paintings on the ceiling and stained-glass windows are important features in the room, which is used as concert hall. Results of a microclimate study confirmed that the light from lamps and sunshine through the windows were damaging the frescoes. Scatter diagrams of the daily relative humidity and temperature cycles were used to illustrate the effect on the wooden coffered ceiling. Conclusions led to recommendations which would enable Padova to preserve the artwork as well as provide an acceptable environment for visitors.
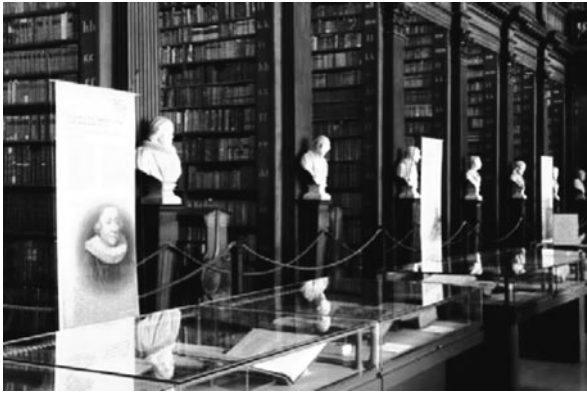
In this paper we present the LibViz system, collaboratively designed with the Department of Computer Science and the Preservation and Conservation Department of Trinity College Dublin. In LibViz, a 3D model of the Old Library is used, along with appropriate types of information visualisation methods that represent a variety of environmental and structural data in a graphic way. The aim is to allow the conditions of the Library to be analysed and interpreted as the user interactively navigates through the model.

The remainder of this paper is organised as follows. In the next section we provide background information. Section 3 gives an overview of our preparatory work, while Section 4 describes the current state and Section 5 the evaluation of the application. We conclude in Section 6 and discuss further ideas that could make the application as useful as possible.

2. BACKGROUND

The use of information and communication technologies for cultural heritage offers a lot of new potential. With the DigiCult project, the European Union supports research into accessing, experiencing and preserving cultural and scientific resources [7]. The main research topics covered are: digital library services for digitisation and restoration of cultural and scientific resources; discovering new digital representations and reconstructions of archaeological sites and artefacts; and new techniques to support the long-term preservation of cultural information [7]. The project AGAMEMNON [1], for example, involves the development of a 3G mobile application as an online guide for archaeological sites and museums. The application not only provides a personalised tour path based on a visitor's profile, it also assists in the preservation of cultural heritage. Through image-based monitoring techniques, the application can inform the user of signs of deterioration or erosion. Improvements to the site management can be made through tracing and analysing visitor's behaviour and preferences.

Another approach is to establish standards "for the use of 3D visualisation in the research and communication of cultural heritage" as

described in The London Charter [18]. Here, the aim is to provide a benchmark to ensure that the use of 3D visualisation methods is intellectually and technically rigorous. The charter also seeks to establish a platform to evaluate and understand the methods used for research and communication of cultural heritage, and to fully integrate these methods into this domain. Eight principles are presented: the subject communities, available aims and methods, relevant sources, transparency requirements, sufficient documentation, standards, long-term sustainability and accessibility.

Computer visualisation techniques are widely used to virtually reconstruct archaeological sites, to illustrate artefacts or to get an impression of how it could have looked hundreds of years ago. The virtual reconstruction of the Ancient Egyptian Temple of Kalabsha [17] made it possible to display the original location and orientation of the temple which had to be moved to prevent it from disappearing under the waters of the Nile. In [9], a virtual heritage system is used to generate 3D models of cultural heritage, manage the virtual models over a database system and provide an interactive presentation of the reconstructed environment.

Since we have to deal with a large amount of different kinds of data and their representation, information visualisation methods are particularly relevant for the development of LibViz.

A variety of conventional static visualisation techniques already exist to help users explore their data. Mapping time on a quantitative scale leads to Time Series Graphs in 2D or 3D and, depending on the available data, to Point Graphs, Line Graphs or Circle Graphs [15]. With a Change Chart or Stacked Bar Chart, the total amount of data is represented as a single bar and the increases at each time step as a colour or texture.

More advanced visualisation techniques include the presentation of multivariate data over time, where a data element at a specific time stamp covers data values of several variables. ThemeRiver™ [10], for example, was first developed for document visualisation, to identify the frequency and appearance of special words in documents. A "river" of themes flows left to right through time. Themes are distinguished by different colours. Changes in the bandwidth of the river indicate the overall strength of the selected themes. Equally, a change in the bandwidth of an individual theme indicates the theme strength at any time stamp. Another effective method to analyse more than one variable is MultiCombs or TimeWheels [15]. Time plots of each different variable are arranged circularly on the display, with the variable axis pointing outwards from the centre or with the time axes in the centre and the other axes circularly arranged around it.

These presentation methods can be used to explore a single dataset over time. A more advanced approach is the Calendar View [20]. This method allows the user to simultaneously identify patterns and trends on multivariate data. Similar daily data patterns are clustered and presented as a graph, with the corresponding days on a calendar (see Figure 2). The same colour is assign to corresponding clusters and patterns. The selection of a
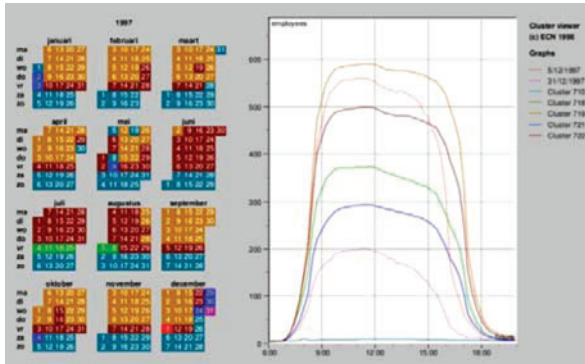
specific day in the calendar produces the visualisation of the day's graph. Otherwise, with a single button press, the user can recursively ask to highlight all days with similar properties. Besides using an isolated 2D presentation, the data can be presented in its spatial context. Lexis Pencil [3] is an example of a visual metaphor, where different time-dependent variables are mapped to the faces of a pencil which can be located in 3D space.

To switch between the various 2D and 3D data in multiple windows, an intuitive method must be found to propagate changes made in one window to the other ones. In the area of Coordinated and Multiple Views [12], various methods exist for interacting with and manipulating multiple windows. The user can filter or select displayed data and can change, for example, the colour map and how (s)he navigates through the system. With the so-called linking and brushing technique, the user can select an element in one view and simultaneously all information in the other views are adjusted [2].

3. PREPARATORY WORK

To satisfy the user requirements of this application, a list of basic functionality was compiled [13]. This list includes controls to navigate through a 3D model of the Old Library, cutaway views of the model to examine specific regions, the ability to visualise installed sensors and their values, and the ability to query information about objects, such as windows.

The 3D model of the Library was made in Autodesk 3ds Max and mostly consists of simple geometric forms. Since no accurate building plans were available for this project, the dimensions were either measured with a laser meter or calculated from images with the software Datinf® Measure [6]. A short animated film was made to provide an impression of the 3D model.* Rendering with the global illumination renderer Mental Ray, a daylight system casts patterns of sunlight through the windows onto the floor.

(A movie showing the model is available from http://isg.cs.tcd.ie/projects/OldLibrary/)

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The application itself was implemented in C++ and OpenGL. Using MAXScript, the built-in scripting language of 3ds Max, a script was written to export the model from 3ds Max to a custom file format which could then be loaded into our application. Similar to computer game controls, the mouse and keyboard keys can be used to control a free-roaming camera for navigating through the 3D model.

For user interaction we used GLUI, a GLUT-based C++ library [11]. The user can navigate through the 3D model with widgets for rotation and translation, or jump to a predefined location within the model, which is of benefit to users who are not used to computer games controls. The visualisation of the position of installed sensors is also possible, and by activating the clipping slider the user can cut through the building to inspect occluded locations. The user can also directly select an object on the screen by clicking on it.

Our basic version of LibViz provided several visualisation features. For example, the measured concentration of dust on each bookshelf in the Long Room can be visualised as spheres that are coloured according to concentration and positioned at the bookshelf where the measurement was taken. By selecting a window, the user can examine the state of each pane. Also, the locations of sensors that measure general data, light levels and relative humidity can be visualised [13].

4. CURRENT STATUS OF SYSTEM

Evaluation of the preliminary version of LibViz along with the identification of new requirements, led to the design of the second system prototype. The main components updated were: rendering the model, executing database requests, handling the plug-ins and visualising data.

The 3D model of the Old Library is made up of 1,028 objects, 248,952 vertices and 443,027 faces. The model is divided into three parts which are stored in individual files. One of them stores the texture names, vertices, faces and texture coordinates of the windows, which are rendered with a opacity of 70%; another stores the data for the bust model which is instantiated multiple times in the Long Room; and the third stores the rest of the building geometry. Various techniques are used to accelerate the rendering performance. We use OpenGL display lists extensively so that particular objects are optimised and stored on the graphics card for fast display. Given that thirty-six busts are located in the Long Room and each of them is made up of over 6000 faces, it would be costly in terms of performance to render them all in real-time in OpenGL. As the Long Room of the Library is symmetrical, display lists make it easy to replicate a single bust model at different positions along the aisles of the Library using simple OpenGL transformations. Further improvements were made through the use of view frustum culling techniques.

In preparation for visualising the necessary information and populating the system, the recorded data stored in a variety of file formats is

transferred into a database. The Preservation Department of the Library provided us with the information they wished to visualise in the form of multiple Excel spreadsheets and plain text files. For the purposes of comparing or filtering the data from various sensors, sliding through time or searching for specific data, the given files were not in a usable format. Therefore, these data was transferred to an SQL database, both by hand and with the help of proprietary data conversion tools. For the database software we chose SQLite [16]. Considering the volume of data to be used in LibViz, SQLite provides a small, fast alternative SQL database, which is simple to administer and implement and runs without a server or any complex configuration requirements. The resulting database can be processed directly by our application using SQL like syntax.

To make the application as extensible as possible, a special interface connects new plug-ins with the application. So far, seven plug-ins have been implemented which handle the information visualisation of the window survey, the dust survey and study, information of the light levels, temperature and relative humidity sensors and additional data about visitor statistics and external weather data. New plug-ins can easily be added without changing the main application. All plug-ins are stored as dynamic link libraries (DLL) in a separate directory. At run-time, the application scans the directory for available DLL files and registers these as plug-ins with the main application. Developing a new plug-in has to follow certain restrictions. Each plug-in is assigned a unique name, which appears as a label in the list of all plug-ins. Two functions have to be implemented; one draws 3D objects on the screen; the other draws and controls the plug-in GUI. The position of the plug-in widgets is calculated automatically by the application. This plug-in system enables third-party developers to extend the application or to update a single entry dynamically, thus reducing the size of the main application and allowing unused features to be easily removed.

Using GLUI as the graphical user interface for the application proved somewhat restrictive, as choosing between different tasks and providing a well arranged user interface requires special functionality. In LibViz, we developed our own GUI using an "immediate mode GUI" (IMGUI) approach, which differs from the traditional, retained mode approach used by GLUI and most other user interface toolkits [8]. This approach provided complete control over the appearance and placement of GUI widgets. In particular, since the information we visualise is read from a database and processed by plug-ins, it was important to provide a means to dynamically add, remove, and arrange widgets on the screen with as little overhead as possible. The IMGUI paradigm is suitable for this and does not require the user to arrange widgets using a layout editor ahead of time. Furthermore, it allows us to draw transparent widgets over the 3D model of the Library and the look and design of the GUI widgets and its elements (buttons, sliders, etc.) can be easily customised.

Initially two widgets appear in the application (Figure A.1). One widget contains global functions like navigation controls, a clipping slider and an exit

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button. The other shows a list of buttons that can be used to activate the various plug-ins. Selecting a specific plug-in opens an associated widget with detailed information. Selecting objects from the screen by clicking on a part of the building or a window displays the information corresponding to this object. The two initial widgets can be minimised and all other widgets can be closed as well.

In LibViz we make use of a variety of information visualisation techniques to help us answer questions such as:

- Where are there anomalies in the recorded temperature or relative humidity data?
- Are there correlations, e.g. between the inside/outside environment and the number of visitors?
- Why do environmental conditions drift outside given parameters at particular times of the year, or due to particular events?
- Is there a cyclical pattern to the observed data?
- Is there a relationship between influencing factors such as dust dispersion and visitor pathways, and/or building structure?

At this stage we provide the user with the following information:

Window Survey: The user can select a window by clicking on the "Window" button, which opens a list of all window names or by picking the window on the screen. The selected window is highlighted in the 3D model and a detail widget opens (Figure A.2). On the left hand side of this widget the state (cylinder, modern or cracked class) of each window pane is shown. The right side shows the window frame survey. The user can change between the details for the internal and the external frame.

Rough Dust Survey: Activating the Dust Sensor button causes coloured spheres to be drawn on the bookshelves in the Long Room model where the dust was measured, along with a description of the colour code used. The colour indicates the concentration of dust (slight, moderate and severe). Choosing a bird's eye view camera position and using the clipping slider (Figure A.3) allows the user to slice through the building to get a overall impression of the dust dispersion. Selecting a specific dust measurement point opens a widget with detailed information (Figure A.4).

Dust Accumulation: This option presents the result of the pilot scheme to monitor the rate and distribution of dust by reflectivity or "loss of gloss". Forty glass slides are distributed in the Long Room and the Gallery. In three monthly intervals new measurements are taken. The locations are visualised as spheres with the colour code of the last measurement (Figure A.5). In addition, the visitor data and external weather data is displayed in a separate widget. Sliding through time adjusts the colour of each sphere to the new measurement and the additional data. Two bar graphs can be chosen to display the rate of "loss of gloss" over the stalls in the Long Room and the Gallery. A time graph shows

the changes between the measurements for specific selected slides. Like the rough dust survey, the user can inspect the data in the virtual environment.

Temperature and Relative Humidity: Activating the Temperature and Relative Humidity button causes coloured cubes to be drawn at the position where the sensors are located in the building. In addition, a list of all sensors is presented. Selecting a sensor, either from the list or by direct clicking on the cube in the 3D environment, opens the "Calendar View" with the time graph for temperature over the year (Figure A.6). Moving the mouse over a graph point displays the exact value. Initially the "Calendar View" shows the colour code of the average temperature for each day. Using check boxes, the user can decide if the calendar and the graph should show temperature, relative humidity or both. Additional data about the visitor numbers and external weather data is shown in a separate widget. Selecting a specific year, month, week or day changes the visualisation of the graph, the additional data and the colour code of the sensor cubes in the 3D environment. The sensor cubes always show the colour code of the average data over the selected time frame for temperature in the lower half and relative humidity in the upper half.

Extra Data: As soon as a date is set, a separate widget opens to present the visitor numbers and external weather data of this date (Figure A.6). The weather data is provided by the Irish Meteorological office and contains temperature, relative humidity, sunshine hours, amount of rainfall, maximum wind speed and wind direction.

Light and Data Sensors: Activating one of these functionalities over the corresponding button causes coloured spheres (yellow, grey) to be drawn at the exact position of the sensor category in the building. In addition, a list of the activated sensors is drawn.

5. EVALUATION

A user study was conducted to determine if the design of the application meets the needs of its target users and how effectively the users could complete given tasks. The user study was performed in three phases: In the first phase, the user had to perform a trial with four tasks. Following the first trial, the user was asked to fill out a questionnaire. Finally the user had to show how fast (s)he learned to use LibViz in a second trial with slightly modified tasks.

The given tasks directed each user's attention to specific details in the application. The user had to open a particular feature and was asked to look for a given dataset of this feature, after which they wrote down their answer. For example, using the temperature and relative humidity sensor feature, the participant had to record the colour code, internal temperature, external temperature and the weather icon of a given sensor on a specific day. The second trial was designed to find out how well the user learned to

First Trial ▬ Second Trail ▬
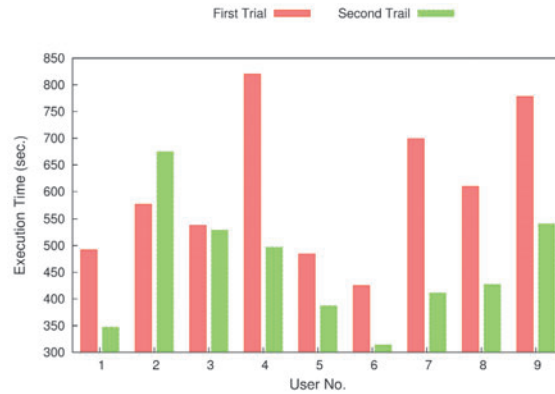
use the application and if less errors were made. The expectation when comparing both trials with each other was that the execution time and the errors would decrease during the second trial.

In the questionnaire, we asked each participant for opinions of the application, the user interface and the overall usability of the application. They expressed their agreement or disagreement on a five-point scale, where five indicates the most positive impression. In addition, the user could provide comments and suggestions.

Figure 3 compares the approximate execution times between the two trials. Users one to four are library staff, while users' five to nine have a computer science background. As expected, there was a decrease in task execution time in the second trial.

The evaluation of the answers showed differences between the two groups. The library staff had fewer wrong answers, probably due to the fact that they are more familiar with the terminology and the ongoing processes. Errors also arose from switching between the different types of information visualisations. The user had to navigate in the 3D environment and to switch between different panels to identify the correct information. It could be observed that users found it difficult to select the sensors they were asked for. However, once the sensor was selected, the users filtered the correct information from the features. The design and colour code was understood immediately.

Overall the impression was positive and the tasks were completed without major problems. The users completed the second trial considerably faster and learned how to use the application well. The user interface was found to provide suitable responses to user actions. Minor usage problems arose with the sliders and scrollbars, which were too small and sometimes reacted inconsistently.

Some users criticised the small font size of the text, which they also found hard to read on the transparent background. While evaluating the answers on the use of the applications we found differences between the library staff and computer science persons.

All users agreed that selecting an object from a list is more practical than navigating through the 3D environment and searching for the right object.

Overall, the feedback via the questionnaire was very positive. All users confirmed that they had fewer problems with the second trial, indicating that they learned how to use the application quickly. They found that the individual features were easily accessible. The library staff reported that the major advantage of the application lay in the consolidation and display of various information sources in one place.

6. CONCLUSION AND FUTURE WORK

In this paper we have presented LibViz, an application to visualise recorded data in the Old Library of Trinity College Dublin. Based on a 3D model of the Library, the user can navigate through various information sources relating to dust dispersion, temperature, relative humidity and visitor numbers. We have presented a stable system design to deal with the performance-related management of the Library's large 3D model and demonstrated the integration of 2D information via selectable plug-in widgets. Seven plug-ins were implemented to offer detailed information about the recorded data. Our plug-in approach is fully extensible and provides a simple interface for third-party developers. Furthermore, we consolidated the dispersed data sources and integrated them into a single database to offer consistent information access. The user study we conducted provided positive feedback on a number of issues including: easy to use application, data presented in an understandable way and the ability to compare different datasets from various sources. For future work, we plan to enrich our concept with further information visualisation techniques.

Assisting the Library in studying the impact of environmental conditions on the building and its contents will be the main goal for the future. Thus, our work will also address the use of computational fluid dynamics (CFD) to analyse the fluctuations of temperature and relative humidity, which will help to identify the most vulnerable regions in the Library. CFD in combination with predictive modelling could also help guide recommendations for changes to the Library. Similarly, studying the effects of alterations to the building layout, or the heating and ventilation systems, would benefit the preservation strategy. Further information about the movement of visitors in the Library, extracted from videos, could help to identify why certain areas have higher levels of dust. It would be interesting to simulate the settling pattern of dust after it is dispersed by people's footsteps, or to answer questions about the average length of a visit in the Long Room and the way in which visitors move through the space.

The integration of the sensors' live data stream from the Library into the system is also of great interest. Browsing the data in real time would allow the user to react immediately in the case of an anomaly or a possibly hazardous situation.

The incorporation of further visualisations methods will allow LibViz to become an effective tool to assist in the future preservation of the Old Library and its collection. The application will grow over time as its user base increases and more functionality and features are needed.

Acknowledgements

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APPENDIX A. SCREENSHOTS

◀ Figure A.1. LibViz: Front View.

◀ Figure A.2. LibViz: Window Survey.

► Figure A.3. LibViz: Dust Survey (Birds Eye View).
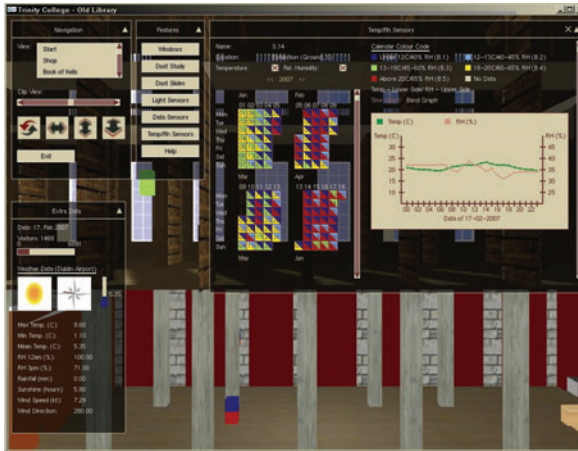

► Figure A.4. LibViz: Dust Survey.

► Figure A.5. LibViz: Old Library Dust (SOLD) Study.

◄ Figure A.6. LibViz: Relative Humidity Sensors.

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