A Scalable Framework for Location Services

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Date: May 13, 2005

Introduction

The Building Model Generation (BMG) group in the MIT Computer Graphics Group is currently researching the problem of transforming 2D floor plans of the MIT campus into 3D models. Although the BMG pipeline currently processes most buildings on campus, the geometric and meta data produced is not always accurate and is difficult to access. Newer buildings like the Stata Center cannot currently be processed due to limitation in the pipeline. Currently, only room and path information is available to client applications by means of the LocationServer, which is a Java RMI Server that serves location information to client applications. My Master of Engineering thesis aims to solve many of these engineering problems by creating a scalable framework that allows client applications to access geometric and meta data through a well-defined web interface. Many of the ideas can be used beyond MIT.

Background

The Building Model Generation (BMG) group in the MIT Computer Graphics Group is currently researching the problem of transforming 2D floor plans of the MIT campus into 3D models. Although the BMG pipeline currently processes most buildings on campus, the geometric and meta data produced is not in a form that is easy for client applications to access. Currently, only room, portal, and adjacency information is available to client applications by means of the LocationServer.

The process of creating 3D models begins with floor plans, which are provided by the MIT Department of Facilities in DXF format. Extraneous layers of the DXF files are removed and the geometric data is filtered and corrected. This ensures that walls are continuous and meet at corners. Next, the information is processed by a program called “walls” that extrudes the 2D floor plan into a 3D model. At the same time, an adjacency graph is created to represent connections between rooms for path finding. Next, the 3D models of each floor are combined to form models of entire buildings. Finally, a program called BaseGen creates the BaseMap upon which the buildings are placed.

To allow client applications to use the location information, a program called LocationServer is run on a server connected to the Internet. This JavaRMI application accepts connections from client applications and exposes an API to retrieve location information. Web applications such as MITQuest and ActiveSigns use this data to perform path finding and present location-aware information.

However, the data produced by the BMG pipeline is currently not fully exposed to clients. No standardized API exists for retrieving the 3D geometric data contained within the 3D models.

Additionally, many of the data structures are not designed to be used in a high-performance web environment.

Proposed Work

The current Building Model Generation project will be improved and extended in a number of ways.

1. The method of importing geometric data will be made more robust by using GIS web services provided by the MIT Department of Facilities.
2. Data structures used to store BMG output will be redesigned to increase scalability and extensibility.
3. Heuristic-based search algorithms will be added to facilitate quick and accurate path finding.
4. A path finding web application will be created to allow users to visualize a route through campus and view landmarks along the way.

These four improvements are described in more detail below.

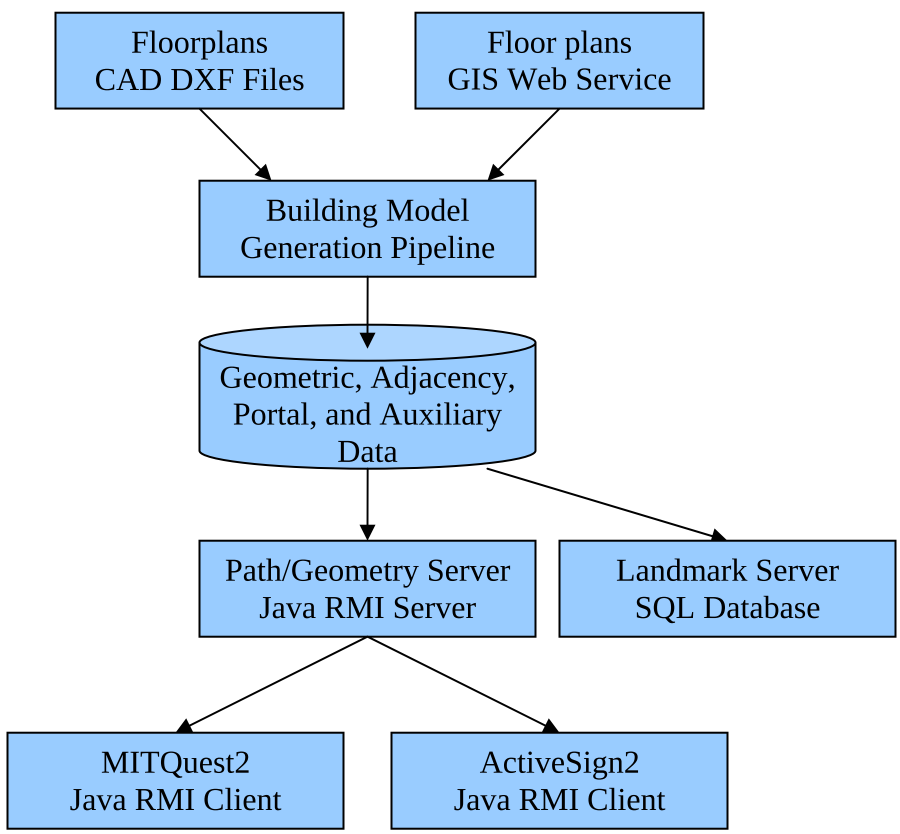

Figure 1: BMG System Architecture

Robust Method for Importing Data

Although the building model pipeline works great for traditional buildings that have vertical and straight walls, it fails when run on input containing irregularities. The Stata Center and Simmons Hall are two examples of buildings on the MIT campus that exhibit curved walls. Creating a 3D model of the Stata Center is of particular interest because of the amount of pedestrian traffic and number of events that take place there.

Thus, one component of the project will be the addition of a robust method for importing campus data into the BMG pipeline. One approach may involve the incorporation of MIT's Department of Facilities GIS (Geographic Information Systems) web service that allows geometric information to be retrieved via an XML interface. Another approach, though less attractive, may involve modifying the current "walls" program to detect curvature in the walls and process those cases independently.

Scalable Data Structures

With thousands of rooms and MIT in a continuous state of construction, it quickly becomes apparent that scalability is paramount. The data structures used to represent rooms, spaces, and portals must be scalable. Although system memory capacity continues to increase, it is desirable to create a system that minimizes the memory footprint while running.

One possible approach is to use external memory data structures. Currently the LocationServer loads all data into memory upon startup. An improved approach would swap portions of the adjacency graph into and out of memory as needed. Ideas from adaptive grid acceleration in computer graphics may help in the process of breaking up the data into manageable chunks.

The proposed framework will also be designed to support scalable, auxiliary information. Auxiliary information is defined as information that is in some way tied to a geometric feature of the underlying campus model. For example, the MIT campus police may provide a list of locations that have emergency telephones. The registrar may provide a list of classes, rooms, and times. The MIT Property Office may provide a mapping of rooms to list of assets. This data must be stored in a way that is fast to access and can be paged on demand.

Intelligent Algorithms

One obvious use of this framework is finding a route between any two locations on the MIT campus. This application requires an adjacency graph of all buildings and outside areas at MIT. The search algorithm used must employ heuristics and lazy execution to speed up the queries. For example, if a route requires traversing the infinite corridor, the search algorithm should be smart enough to avoid searching all rooms and floors along the way.

The majority of the information about the MIT campus remains constant from day to day. Thus, researching methods for caching shortest routes or combining subsections of precomputed routes may substantially improve performance on search queries.

Web Services

To make the 3D campus data accessible to users, two web applications will be created. The first application will allow a user to find a route between any two locations on the MIT campus satisfying a list of criteria such as accessibility or route features. This route will then be visualized using a first or third person camera perspective to walk the user from the source to the destination. The second application, based on the existing ActiveSign project, will visually show campus events on a 3D map of campus. These two web applications are detailed below.

Path Visualization – MITQuest2

With a 3D representation of the MIT campus an obvious application is visual path finding. MIT's Department of Facilities and Information Services and Technology (IS&T) currently host a web site[1] to locate features on a top-down, 2D view of campus. Searches can be performed by building number, building name, residence hall, or specific room. However, this system only locates lecture halls and does not have a path finding feature.

MITQuest2 is a web application that will allow a user to select two arbitrary rooms on campus and find a path between them. Furthermore, a camera will be placed at the starting location and an animation will be created from start to finish. Landmark information will be visually incorporated into the route to allow a user to remember the path taken.

While searching for a given path, parameters such as desired accessibility and environment can further refine the paths shown. For example, a user in a wheelchair may request to see only routes that do not use stairs. Another user may request to minimize the amount of time spent outside if it is cold or rainy. Yet another user may request their path contain a mailbox on the way to their destination.

In addition to providing information to the user, this framework can use input from the user to influence the environment. One example is that of guiding lights. This form of navigation requires an infrastructure of remotely controllable LEDs. These LEDs would be positioned along paths on campus. When a user searches for a path and decides to travel it, the system will begin pulsing the lights in a manner that suggest movement in a given direction. Since the network of LEDs is centrally managed, this pulsing process can appear locally near the user and move as he/she follows a path. Although the full implementation of guiding lights is a research topic on its own, this current framework will provide a solid foundation for future work.

Event Visualization – ActiveSign2

With so many seminars and talks at MIT it is often difficult to remember when and where events take place. ActiveSigns2 will help alleviate this problem by creating a web application that takes event feeds via RSS and other sources within MIT and displays them on a 3D representation of the campus. This application could be projected onto a screen in a high traffic area or shown on an information kiosk in the Stata Center or Student Center. Events may be selected by time, topic, or proximity.

[1] http://whereis.mit.edu/

Milestones

The goals listed above will be carried out under the supervision of Prof. Seth Teller. The following schedule shows a tentative timeline from fall 2005 to spring 2006.

Fall 2005	September	Floor plan information imported via GIS
	October	Robust method for importing data for all campus buildings including Stata
	November	First prototypes of scalable data structures using external memory
	December	Finish scalable data structures
Spring 2006	January	Proof-of-concept web applications
	February	Improved location server, using lazy execution
	March	Intelligent path-finding algorithms
	April	Visual route and event applications
	May	Testing, deployment, and final documentation

Conclusion

The proposed project will provide an application that helps students, staff, and visitors find their way around the MIT campus in a more intuitive manner. Improving on the Building Model Generation (BMG) project, this project will create a framework to support location-aware applications. Other improvements include the addition of robust methods for accessing geometric data of MIT buildings, scalable data structures, more intelligent path finding algorithms, and an improved web application that visualizes a route in 3D from beginning to end.

References

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