Technical Challenges in the Implementation of a Space Management System (UC1170)

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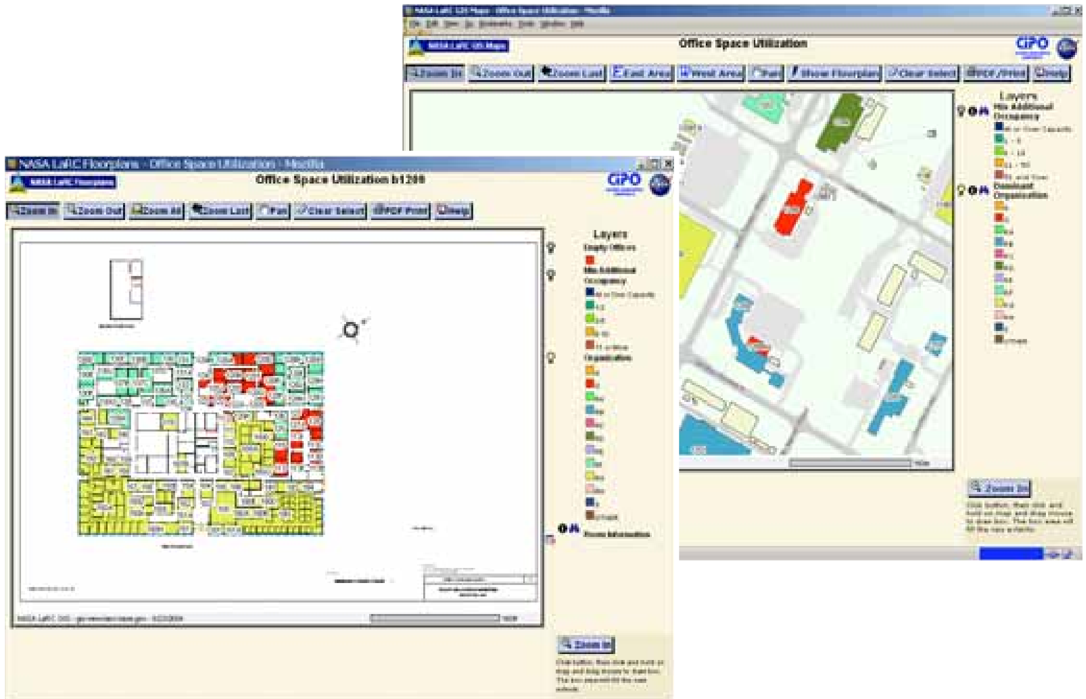
Abstract

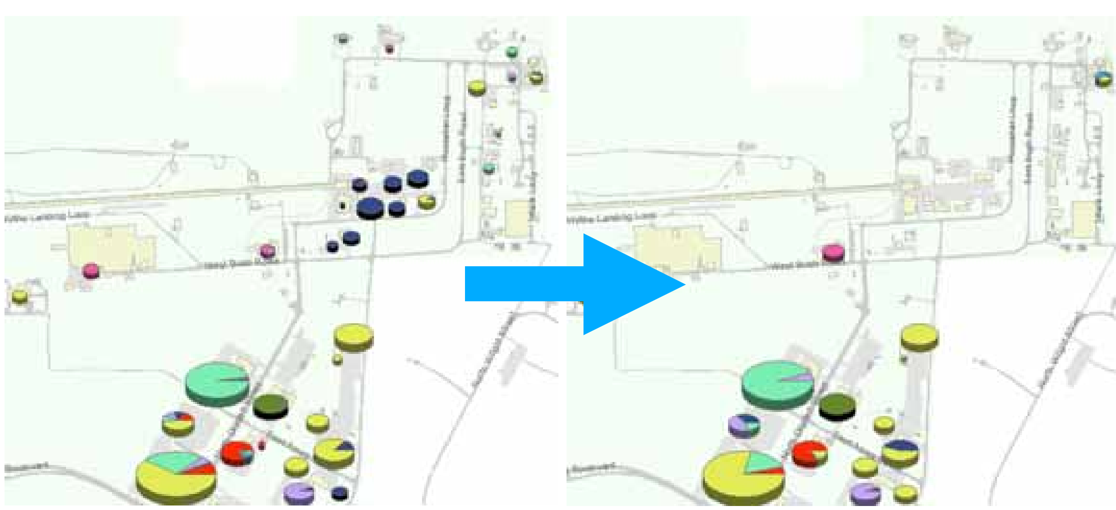
NASA Langley Research Center manages in excess of 300 buildings with more than 4,000 personnel and an average of 1,000 moves required every year to adapt to a dynamic workforce and changing mission objectives. To manage this space effectively, tools and techniques based on ArcGIS, ArcIMS, and Oracle technologies have been developed to assist space utilization managers in this task. This paper will describe the technical issues and challenges in the design, development, and implementation of this system. Topics will include schema design, development of custom layers for visualization and editing of spatially assigned assets, data management and analysis by leveraging Oracle functionality, and implementation of algorithms to optimize space assignment.

Background

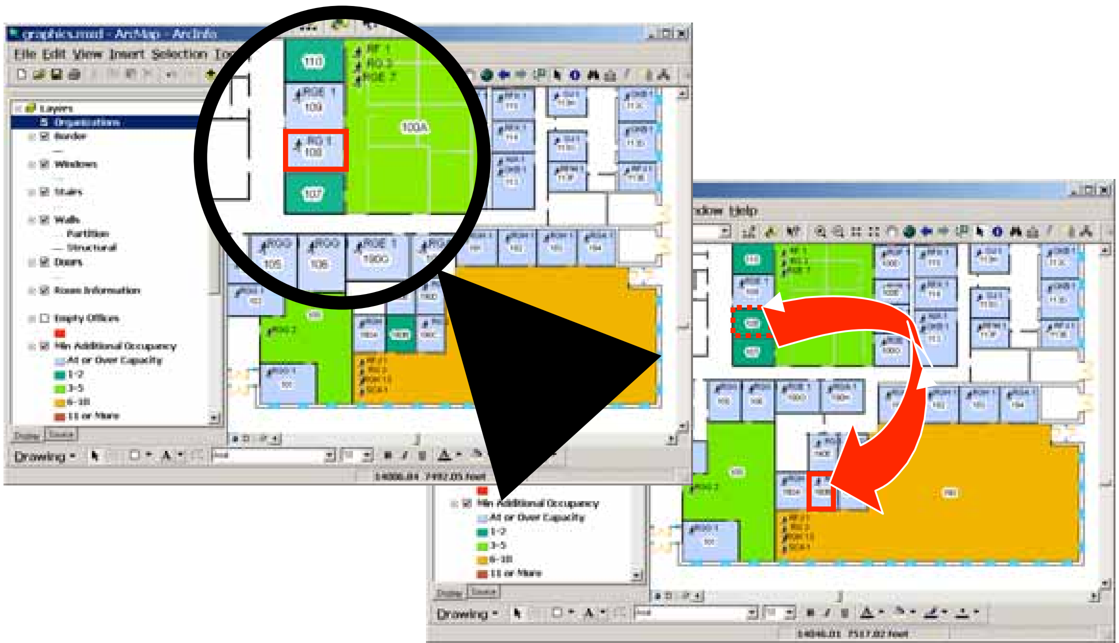
NASA Langley Research Center (LaRC) has developed an extensive GIS capability over the last decade to support management of facilities and infrastructure. This capability includes significant investments in data conversion and collection efforts, off-the-shelf software and custom development, and a team with a broad range of skills from business process, geodetic survey, and remote sensing experience through data management and software development. Relying on this foundation, LaRC has developed a series of applications and tools to better manage the allocation of space. The primary driver for this development has been an immediate need to reduce the operational costs at the center by vacating more costly facilities in favor of more efficient space and achieving a lower average square foot per person.



The application tools developed to support move planning include ArcIMS websites based on a custom template capability that allow viewing of the data aggregated at the center level with a drill down into the floor plan level. The relevant data includes room type, capacity (accounting for circulation space, etc), assigned personnel by organization, accounting information by organization, and available capacity. These tools provide a foundation by allowing the space manager to assess the current state of space allocation including organizational distribution and available space distribution.



A bin-packing algorithm was implemented with assistance from optimization experts at LaRC to evaluate opportunities for relocation to achieve better organizational synergy and vacate buildings with higher operational costs. This algorithm is run within ArcMap and the results are represented using pie charts for each building, scaled by personnel counts, showing the organizational distribution.



An ArcMap extension was developed allowing space planners to establish move scenarios in which people, identified by organizational unit, can be interactively moved within and between buildings. The results are stored as net changes to the underlying personnel data. Additionally planners can propose changes in the type of space (conference, office, etc) and the full cost accounting information. The organizations are displayed using a custom layer that produces point symbol representations showing each unique organization within each room and the associated number of occupants. Summary move information by organization, building, or all changes is available.

Finally an oracle web application allows each organizational manager to make final decisions regarding assignment of allocated space to individual personnel. This can be done in parallel with each manager as his space is allocated.

Data Schema

LaRC's data includes both center-wide geo-referenced data for utilities and surface features and detailed floor plans. Both types of data are managed using the ArcGIS software suite in a versioned ArcSDE/Oracle database. The floor plans provide a convenient multi-level orthogonal view of each structure and are therefore not geo-referenced. The individual drawings are loaded into a grid array to allow queries to be executed across the entire data set. A broad suite of tools assist in managing and using this data including custom feature class extensions, ArcMap extensions for editing and ease of use, an enhanced ArcIMS template, and a nightly processing application that produces a high performance copy of the data with de-normalized schema for faster and easier query and analysis. In addition, the nightly processing performs a transformation of all floor plan drawing features to corresponding geo-referenced feature classes. In this way, all floor plan features call be viewed and analysis performed in the context of other center-wide data.

In addition to spatial data assets, the team's Oracle database manages space utilization, real property, and full cost accounting data associated with every building and room. The database also receives updates for the personnel data on a regular basis from other systems at the center.

The data schema to support move planning scenarios consists of tables to identify unique scenarios and delta tables that store net changes in organizational allocations for each space along with its scenario identification. Additional tables manage proposed changes in space type or accounting information, again with its scenario.

Leveraging Oracle for Data Maintenance and Analysis

To make the move planning scenario data usable by ArcMap, views were developed in Oracle to join all the related space utilization, full cost accounting, and personnel data and apply the appropriate deltas from the move planning scenario tables. In addition this view includes a join with the feature class data to uniquely identify each spatial feature by OBJECTID. This is required because the space utilization data has a two column primary key consisting of building number and room number and a single key is require for joins in ArcMap. The view is then used like any table from within ArcMap and joined to the spatial data for symbolization, labeling, query, etc. Symbolization of additional capacity, for instance, allows space planners to quickly identify and fill space efficiently, because the impact of moves applied in the scenario are immediately apparent. Also note that capacity is calculated for each room using a procedure that evaluates the space classification and accounts for circulation area where needed.

The deltas that were applied in the view are filtered based on the current scenario and this is managed by a session variable within a PL/SQL package. The view references a package function to determine the current scenario. Changing scenarios is performed by a call to a PL/SQL package procedure. Similarly scenario management functions such as creation and deletion are handled by package procedures. In fact, all changes in any data associated with a scenario including moves, space type, etc are performed by PL/SQL procedures. This delegation of responsibility has proven very successful. The PL/SQL code, along with the database constraints, guarantees the integrity of the data, allowing the ArcMap application code to focus on usability issues. All procedure execution is initiated through the appropriate ArcObjects workspace interface.

Custom Layer for Viewing and Managing Spatially Assigned Assets

A custom layer was implemented to allow personnel to be viewed and managed in context of their assigned space. This was accomplished by an extension that can use table data that has a many to one reference to spatial features and render that table data as point symbols within the extents of each spatial feature. While this approach is used here to represent people, it could just as easily represent equipment, furniture, etc. Rendering considers symbol and label extents to provide compact placement and indicates when it cannot render the data for a particular feature, based on scale, with an appropriate alternate symbol.

Custom controls interact with this layer to initiate changes in scenario data through the PL/SQL package.

Space Allocation Optimization

Optimization of space allocation is a complex, multivariate problem. It must balance factors such as synergy, both within and between organizations, affinity to space based on associated technical space requirements for instance, operational costs of available space, allocation of supporting functional areas such as conference and storage, resource requirements such as utilities and networking, compliance with space guidelines and requirements, etc.

The bin-packing algorithm implemented manages to balance many of these considerations, but subsequent work has focused on the application of a genetic algorithm to better balance these diverse considerations. Genetic algorithms have proven performance in similar discrete optimization problems such as scheduling, require only an objective function for evaluation, and support Pareto, or multi-objective, methods.

Acknowledgements

The authors would like to acknowledge the optimization algorithm assistance provided by James Rogers.

This paper describes work that was performed for the Property Management Services Branch, Center Operations Directorate, NASA Langley Research Center under contract number L-70750D.

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