Campus Landscape Information Modeling: Intermediate Scale Model that Embeds Information and Multidisciplinary Knowledge for Landscape Planning

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Abstract

Building Information Modeling (BIM) and Geographic Information Systems (GIS), as their names imply, are models of information at different scales that usually appear segregated. Our proposal is to integrate both scales of information in a Campus Information Model (CIM). This paper focuses on the description of this integration in terms of information and knowledge models, from the point of view of landscape design. We emphasize on the description of CLIM, an interactive tabletop we have developed to support collaboration and planning of landscape, which is constructed using models of information and knowledge to perform assessments, including quantitative aspects of effectiveness, efficiency and satisfaction of certain features of the Georgia Tech Campus.

Keywords: Campus Information Modeling; Landscape Modeling; Landscape Planning; Knowledge-based Design; Interactive Tabletop.

Introduction

The activity of design and planning of a university campus brings together a variety of experts in different areas that need to negotiate their goals, priorities, constraints, and budgets in a short period of time. During the design process, it is necessary to do several assessments that will have an impact on every decision throughout the process to, after several weeks, convey in a unique plan. In these types of scenarios, supporting collaboration among experts is essential to interchange views and bring all the variables up to a common design space. To convey the different perspectives on a single platform, and evaluate alternative scenarios and projects in near real time, we propose the use of a Campus Landscape Information Modeling (CLIM) Tool (Figure1).

While BIM supports detailed modeling and evaluation at the building scale, GIS supports planning and evaluation at the urban scale. On the one hand, BIM is an integrated model that is capable of storing geometric information about buildings, their attributes, and their relations to one another. BIM provides integration of such information by mapping non-spatial information into the model and allowing one to run a series of analyses, such as cost, energy, lighting, etc. (Eastman et al., 2011). On the other hand, GIS store spatial information about features, providing integration and analysis of spatially referenced data. GIS is an integrated system that allows capturing, storing, retrieval, checking, integrating, manipulating, and analyzing spatial data (Star and Estes, 1990).

Campus Information Modeling (CIM) integrates both, BIM and GIS scales, into a campus scale model (de Laat, 2011). CIM takes some aspects from each modeling systems according to their information features types, information models behind the systems, and operations for evaluations. CIM stores information about spatial as well as non-spatial features, comprehensively analyzes spatial and non-spatial data, such as cost and goals, to finally integrate the spatiotemporal-referenced information, by scenario structure, displaying it as a spatial and temporal representations.

Our university's CIM is composed of building and landscape information combined into one design space. However, as this paper focuses on CIM from a landscape design and planning perspective, we restrict our description to landscape data types, and landscape information and evaluation models. We will start by describing the development of our CLIM tool.
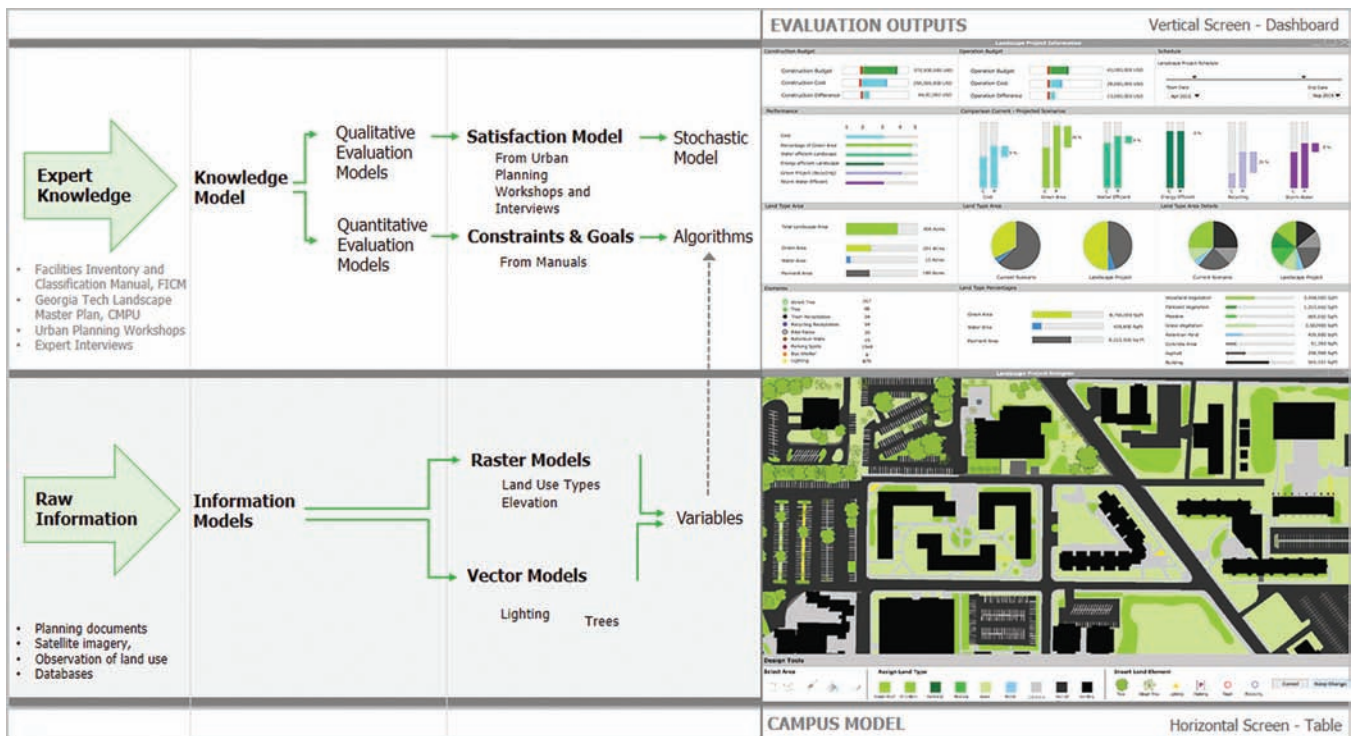
Figure 1: CLIM tool is based on two types of models: Information Models and Knowledge Model, which converge on the CLIM's screens as a model visualization and user interface.

Interactive Tabletop for Landscape Planning

To support the collaborative planning activity described above, we have designed a Campus Landscape Information Modeling tool (Swarts, Gomez, Soza, Shaw, MacDaniel, and Moore, 2013). The CLIM supports collaboration due to its physical features in conjunction with its user interface (figure 2). The physical features, such as a horizontal multi-touch tabletop, which uses a 55" screen to display real-time visualization of campus top view, allow direct interaction with the landscape information model –the top view of the campus. The user interface of the horizontal screen renders a top view of the campus at the resolution of 1sqft per 10 pixel units. This is approximately a 1:200 scale. In the lower border, and accessible from the large edge of the screen, it displays icons that allow access to design and planning commands, such as 'assign land type', 'select land type', 'select tree', 'delete tree', etc.

The CLIM tool also has a vertical 55" screen component, which presents a dashboard that displays real-time updates on objects – such as the number of trees or parking spots; attributes –such as the percentages of trees types and areas types; and project information –such as the overall number of trees, total percentage of green areas, and comparison among alternative projects; and real-time assessments of some aspects of the model –whether percentages of land types meet the goals in terms of green areas, tree canopy, water efficiency, energy efficiency and cost. All of this information is graphically presented in the vertical dashboard as bar and pie graphs to more easily understand the constraints, assessments, and goal achievements.

Information and Knowledge Models

Campus Landscape Information Models allows direct collaboration among different disciplines by accessing real time information and evaluations on the screens, allowing for storage and retrieval of alternative designs as projects or sets of projects –or scenarios. CLIM was built specifically for our university campus, therefore the specific information about our university was used to construct the two fundamental models in which CLIM is founded: Information model and knowledge model (see figure 1). The information model was constructed directly from raw quantitative data, such as land use and tree inventory, while the Knowledge models were constructed from both expert and user knowledge, extracted from manuals, interviews, and surveys.

Figure 2: CLIM Tool. Multi-touch table and dashboard screen.

Table 1: Taxonomy of knowledge type proposed by Krathwohl (2002) in "A revision of Bloom's taxonomy," and knowledge strategies related to the source of the knowledge, the elements and examples for landscape design.

Knowledge Type	Knowledge Strategies	Example	Elements	Knowledge Source
Factual knowledge	Terminology and Specifications of Details	Tree Types, Land Types	Modified Information Colors Elements representation	FICM Manual CMPU Manual
Conceptual knowledge	Categories, Models, and Structures	Layers Zones Projects Scenarios	Layers Categories Structure Groups of Categories Timeline	FCIM Manual Case Study
Procedural knowledge	Algorithms and Procedures	Remove Tree Change Land type Percentage of Green Area on Budget Parametric sections Evaluations	Commands Variables Parameters Constraints Evaluations Assessments Design Guidelines	FICM Manual CMPU Manual Interviews Case Study
Meta-cognitive knowledge	Design strategies Context and Conditions	Information Models Time representation Scenario Representation Goals Strategies	UML Structure Layout UI Design	Case Study Interviews CMPU Manual

CLIM's two fundamental models, an information model and a knowledge model, differentiate themselves by the complexity of their construction (see figure 1). While the information model refers to the integration of geometric representation of objects and their attributes, the knowledge model refers to the variables, constraints, goals, operations, and their relationships to construct quantitative and qualitative evaluations, in order to specify semantic meanings. These two models organize frameworks for data and knowledge, for exploration and understanding of decisions, and for comparison across systems. The top-view of the campus, which is displayed on the tabletop, is constructed on top of two types of information model views: A raster model representation and a vector representation (see figure 3).

Raster models represent land use types, while vector models represent land elements such as trees. Assessment results, which are visualized on the dashboard, integrate literal information and the expert knowledge from sources: Landscape Master Plan (CMPU, 2010), Postsecondary Education Facilities Inventory and Classification Manual (FICM, Cyros and Korb, 2006), interviews, and a case Study (Full description in Swarts et al., 2013), to convey the relationships, dependencies, and conditionals for decision-making. The user interface features –such as the layout, icons, and commands– are constructed on top of the aforementioned information models and knowledge model. In the following section, we will describe in details the information models and the knowledge model on which our CLIM is built.

Information Models

CLIM imports raw information about land types (i.e. grass, meadow) and landscape elements (i.e. trees, lighting) from planning documents, satellite imagery, observation of land use, and databases (such as tree inventory). Both models mentioned above, rater and vectors, are visually rendered onto an aerial view of the campus (see figure 3). Direct touch interaction with the visual model allows users to access information about the 29 land use types defined for our campus, its areas, and attributes such as water permeability, density of vegetation, etc. Interaction with the model also provides users with access to raw information about specific elements and their attributes –such as tree location, height, canopy radius, age, species and condition.

By integrating both information models from BIM and GIS but at the campus scale, CIM allows planners to dialogue within a richer scenario, in which roads, pedestrian paths, green areas, water collection, and buildings and their information interact to quantitatively evaluate the capacity, occupancy, and efficiency of the projects or systems, and the effectiveness and user satisfaction of some aspects of projects and systems.
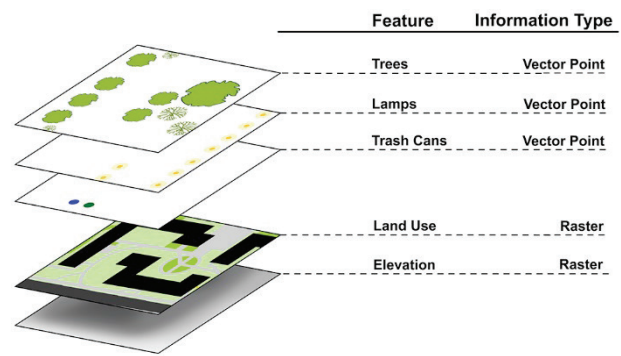
Figure 3: Two raster layers: Land use and elevation; and several Vector layers: Tree, lamps, trashcans, etc.

Knowledge Model

Knowledge models are essentially constructed from expert knowledge, however they connect with information models. We translated documents and interviews –such as Facilities Inventory and Classification Manual (FICM), Landscape Master Plan document (CMPU), city planning workshops, and interviews with landscape planners- into expert knowledge format (Swarts et al., 2013). We used Bloom's knowledge taxonomy–Factual, conceptual, procedural, and Meta-cognitive knowledge (Krathwohl, 2002) – to construct the structure of our Knowledge-based model, using 4 strategies respectively: Specifications of Details; Categories, models, and structures; Algorithms and procedures; and strategies. Please refer to table 1 for a better understanding of knowledge taxonomy.

Specification of details

Specifying graphics, such as colors and graphic representation of elements, implicates the incorporation of knowledge modified information, which emerges from the combination of information and experts' knowledge. For example, although the raster model is based on land use information extracted from pure data, it is classified into 29 land use types that are defined in the FICM manual. Also, the colors used to visually represent land-use types, are colors proposed on the CMPU manual. Mapping of the information from the tree database, such as tree location or tree canopy, to vector-point information is a literal visual representation from data to icons, but the specific species of trees used for our campus's visual identity are defined by the CMPU manual.

Categories, models, and structures

Layers to organize the data came from the FCIM manual, which, for example, provides categories for all space types for university campuses, information that is not only categorical, but also related to budget estimates for specific design proposals. From the case study, a main structure for the campus intermediate scale model emerged: Projects, collection of projects –or scenarios– and alternative projects or scenarios to compare simultaneously, all scheduled in a timeline, to define which alternative responds better to a set of constraints and material and immaterial goals, such as budget and satisfaction respectively.

Algorithms and procedures

Evaluations are processed under several criterions such as economic, capacities (number of parking spots), areas (green areas by zone, total green areas), among other criterion that impact landscape decision-making. The evaluation outputs are visualized on the dashboard display, as informative bar graphs and pie charts that update in real-time, to give feedback to users for each decision. Furthermore, we translated knowledge from the manuals into the global goals of a campus through evaluational algorithms, which calculate specific outputs from the model, such as, to "increase the woodland area to a minimum of 22% of

campus", which is based on the "criteria for determining when to use appropriate procedures" (Krathwohl, 2002).

Additionally, by incorporating experts' understanding of problems from city planning workshops, we defined and incorporated some software commands, such as new measurement for distances –minutes' walk, or the concept of parametric street sections, which maintain the through-width, modifying the median and sidewalk, but maintaining entities. For example,

a. Sidewalk | buffer (tree) | bike | thru | thru | median | turn lane || *
b. Sidewalk | buffer | bike | thru-street car | thru | thru/ median || *
c. Sidewalk | buffer | bike-bus | thru | thru | median || *
d. Sidewalk | buffer | bike | ** | thru | thru | median || *

   * Symmetry
   ** Parking / Bus Pull Off / Right Turn

Design strategies

A set of design guidelines and expert best practices are compiled in the CMPU document, which has the goal of achieving a "livable, sustainable and beautiful campus." (CMPU). For our campus, there are 3 main sets of guidelines. One refers to earthwork and water and includes landform and grading, stormwater management, water courses, etc. Another is vegetation, which contains guidelines for tree protection, tree replacement, plant selection, irrigation, etc. The last are guidelines for hardscape, which provides rules for circulation, pavements, facilities, stops, furniture and lighting among others.

Within vegetation guidelines, for example, one design recommendation is for the conditions under which a tree should be replaced. As an example "*if* the tree circumference at 4.5' above the ground *is* less than 37" (or the diameter is less than 6"), *then* plant one 3" caliper tree, or two 2" caliper tree, or ten 1" caliper trees." In our CLIM, this condition has been implemented in the form of conditional statements within the algorithms. The command for tree replacement is displayed in a context menu, which adapts based on this condition, suggesting the option for the replacement of a tree whose circumference is less than 37 feet.

UML structure

The object class structure of each landscape project is designed in a Unified Modeling Language (UML) format to manage all the classes and objects. The UML model helped us to more clearly identify the elements and structure of categories that are used in a Landscape Planning project. Fundamentally, CLIM has two major *project classes*: Building and non-Building projects. Within landscape projects, there are 4 actions that represent the decision making of landscape design: 'Create New Project', 'Demolition', 'Replacement', and 'Renovation'. These actions are the *project types*, and one –or all of them– compose a project.

Additionally, to organize the information in a way that is understood by experts, projects are classified by space type. Landscape projects are classified using 4 (of the 9) space types suggested by CMPU: Green Areas, Athletics, Parking, and Green Roof. Through this classification we create the project instance and scenario structure. All landscape projects are sub-classes of the non-building project class, and they are attributed with a set of space types. Additionally, each space type has surface materials and element types associated with it, such as grass, meadow, green roof, water pond, concrete, asphalt, trash cans, lighting, signage, among others. The above list was described previously in the Specification of Details section.

Layout and UI design

Hardware and software layout is designed to support collaborative design as described previously in the Interactive Tabletop section. The organization of the scale and orientation of the physical hardware responds to the collaboration and interaction among experts (as observed in the case study meetings), allowing up to 10 experts to interact simultaneously, using the 40 touch inputs points that the sensor allows.

User interface design is separated into two physical parts, an interactive tabletop with the model, and a dashboard for information. The tabletop receives all the interaction and visually represents, in near real–time, the project output. Close to 90% of the tabletop is used to represent the model, while the other 10%, the menu in context (see figure 2). The menu is located along the longest screen edge facing out nearest the users, with icons that are designed to be accessible independent of the visual orientation. The context menu also changes depending on the most recently performed actions. This context menu helps us to reduce the screen area utilized by the command icons.

Discussion

Several tools have been developed to support collaboration and interaction among experts in a landscape design scenario. Some examples are LANDSVIEW (Birt and Coulson, 2009), SELES (Fall, Daust, and Morgan, 2001), and Smart Plan (Sasaki). Also, there are efforts in interaction in large screen maps (MacEachren, Cai, and Chen, 2006), negotiation of stakeholders using virtual reality (Ball, Capanni, and Watt, 2005), and physical interaction for terrain manipulation (Pipper, Ratti, and Ishii, 2002).

However, independent of the technological improvements, our main goal is to go one step further from information to knowledge and propose a framework to capture specific expert knowledge from landscape designers and include it into the process of design and implementation of the CLIM tool. The main objective of this framework is to construct a taxonomy of aspects of knowledge that can be computationally captured, and suggest strategies to deconstruct it, and implement it by parts (see table 1).

This project is a work in progress, whose next steps are the inclusion of qualitative aspects for landscape evaluation, such as the satisfaction of campus users (students, faculty, administrator, alumni, visitors). These types of qualitative aspects are not directly measured from raw information or knowledge models, but collected through surveys, and translated into information to support decision-making.

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