Landscape Information Modeling

Plants as the components for information modelling

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Abstract. *In this paper we report on a recently started PhD project in which we investigate the extension of the concept of "Building Information Model" (BIM) to the domain of landscape design. The potential benefits of BIM in the field of architecture have been reported many times (e.g., Ibrahim et al., 2004; Eastman et al., 2008; Abdelmohsen et al., 2011). However, in landscape design an information model in the way of BIM seems to be missing. Benefits of a Landscape Information Model would be (a) formalisation of knowledge in landscape design; (b) information model to support multiple participants in landscape design; (c) improved information exchange between landscape design, architecture, and urban design. In this paper we set out the basic outline of the research.*
Keywords. *BIM; landscape design; LIM.*

LANDSCAPE INFORMATION MODEL

In this paper we report on a recently started PhD project in which we investigate the extension of the concept of "Building Information Model" (BIM) to the domain of landscape design. The potential benefits of BIM in the field of architecture have been reported many times (e.g., Ibrahim et al., 2004; Eastman et al., 2008; Abdelmohsen et al., 2011). As a technology, various instances of BIM can be found throughout many applications in the Building & Construction Industry. To the best of our knowledge, there is no similar application of the BIM principle for landscape design. In our view, there are three major benefits in the application of BIM principles to landscape design:

- Provision of an information model for the domain of landscape design.
- An information model that would support multiple participants in the landscape design process.

- Integration of landscape design with urban and building designs.

In our research project, creation of an information model for landscape design proceeds in two phases: first, the definition of an ontology of relevant concepts and objects for landscape; and second, the formalisation of this ontology into an information model. This process allows knowledge capture and representation which right now is not available.

Similarly as in architectural and urban design, in landscape design multiple parties are involved (landscape designers, municipality, urban planners, and so on). Reliable exchange of information during the design, realisation, and management phases will increase effectiveness and reduce errors and the risk of (costly) corrections.

Finally, when an information model for landscape would be available, it would allow easier

integration of landscape design with urban and architectural design through exchange of information models. This is important to note, because landscape design is naturally involved in urban structures: parks, green areas, public spaces, and the immediate surroundings of buildings are often subject of landscape design. Therefore a more fluent link through a Landscape Information Model between architecture, urban design, and landscape design would be very beneficial.

CHARACTERISTICS OF LANDSCAPE DESIGN

In our view, a landscape information model consists of two major components: first, the information and knowledge about sites (terrain, ground conditions, weather, micro- and macro-climate, and so forth), and second the information and knowledge about landscape objects ("soft" materials such as vegetation, and "hard" materials of built objects).

Landscape design is a multi-disciplinary field in which areas such as ecology, geography, geology, horticulture, and botany are used. This means that knowledge from quite a lot of areas has to be captured in an information model. Because of the biological nature of landscape design, it is inherently dynamic in time: changes in the terrain, weather, and most of all the "soft" materials have to be taken into account. Therefore the design of a landscape does not just feature a "final" or "fixed" state, but more resembles the design of a process in which the individual development of components and interactions between components have to be balanced.

LANDSCAPE AND NATURAL ELEMENTS IN URBAN CONCEPTS

Landscape design in urban structures serves the following purposes:
- Maintaining and enhancing ecological stability.
- Maintaining and enhancing ecological biodiversity.
- Protection of soil (environment for the realization of natural processes).
- Protection of natural monuments and valuable and threatened species.
- Management of water regime.
- Hygiene environment (in particular attention to air pollution, noise and dust fallout) - transport solution.
- Care for uniqueness, aesthetic and cultural values of landscape identity.

The functions of greenery

The "soft" materials (greenery) have a distinct role in the design of landscapes (Sklenička, 2003):
- Environmental (system of wildlife corridors, insulation - emissions and partly noise, regulation of temperature and air humidity, air flow - acceleration due to temperature differences between greenery and buildings, sanitation - clean air, produce oxygen, ...)
- Recreational, aesthetic, social.
- Water managing.
- Soil-protecting, meliorating.
- Architectural -creation of space - part of the urban image (counterweight to artificial urbanized environment).
- Economic - production.
- Microclimatic.
- Fire-preventing.

We can distinguish between greenery in main function, and in additional function. In the main function, greenery is applied in parks, natural non-forest areas, cemeteries, gardeners, green insulation, botanical gardens, and zoological gardens. In the additional function, greenery is applied in residential areas and private green spaces. Our major focus will be on greenery in main function.

Compositional elements of garden and landscape architecture

The compositional elements of garden and landscape architecture consist of technical elements ("hard") and vegetation elements ("soft").

The technical elements are:
- Terrain.
- Water (water features, irrigation, drainage).
- Solid surfaces, paving.

- Exterior furnishings.

The vegetation elements are:

- High vegetation - tree layer.
- Medium vegetation - shrub layer.
- Low vegetation - ground cover plants, lawn, herbs (perennials, annuals).

Vegetation is a live, volatile and organic component of the composition and it is dependent on the conditions of surrounding environment. When designing the garden/landscape we have to take into account all the conditions that could possibly affect the behaviour of the vegetation elements.

Conditions for inclusion of vegetation elements in the architectural design

Here we have to begin with the introduction and acclimatization of species. In the region of central Europe there are about 80 native species but more than two thousand non-native species can actually grow here.

When some foreign species are introduced we have to let them adapt to local conditions. According to E. Quitt (1971), our region has several climatic regions:

1. VT - very warm, dry (average temperature 9-10°C, annual rainfall 500-600)
2. T1 - warm, dry (a.t. 8-9°C, annual rainfall <500)
3. T2 - warm, light dry (a.t. 8-9°C, annual rainfall 500-600)
4. T3 - warm, light humid (a.t. 7-9°C, annual rainfall 550-700)
5. MT1 - moderate warm, dry (a.t.7-8,5°C, annual rainfall 450-550)
6. MT2 - moderate warm, light dry (a.t.7-8°C, annual rainfall 550-700)
7. MT3 - moderate warm, humid, lowlands (a.t.7-8°C, annual rainfall 700-900)
8. MT4 - moderate warm, humid (a.t. 6-7°C, annual rainfall 650-750)
9. MCh - moderate cold, humid (a.t. 5-6°C, annual rainfall 700-800)
10. Ch - cold, humid (a.t. below 5°C, annual rainfall over 800)

Vegetation is distributed according to their ability of growing in the similar climatic conditions. This is called zoning.

ASPECTS OF TREE VEGETATION CLASSIFICATION

In the following section we provide an overview of generally conceived major properties of tree vegetation that may form a starting point for a general information structure (Michálková, 2011) (Table 1).

The dynamic character of the vegetation elements

As we mentioned previously the vegetation is very dynamic element of the design. We have to predict its changes during the whole life-cycle (size, shape) as well as its seasonal cycle.

- Development/growth: Youth, Period of fertility, Period of death.
- Reshaping: compact design changes in the last stage to the irregular shapes.
- Seasonal cycle - behaviour, requirements, and appearance throughout the aspects of spring, summer, autumn, winter.

OUR APPROACH

The strategy of the research project consists of two parallel tracks: one track is breadth-first and top-down, in which we aim to comprehensively describe the domain of landscape design; the second track is depth-first and bottom-up, in which we aim to develop specific information models for representative components of landscape.

The top-down approach provides the general framework for the landscape information model, and ensures that we do not oversee relevant aspects. The bottom-up approach ensures that we can define realistic and applicable information models.

BUILDING INFORMATION MODEL

Although Building Information Modeling (BIM) has its roots in the mid 1980s, its popularity within the Architectural, Engineering and Construction industries has risen only recently- that is reason why in-

Composition type

- Basic, skeletal trees - long-living they stay on the spot throughout the parks lifetime - oak, linden, maple, elm.
- Additional trees.
- Filling, temporary - fast-growing species.
- Under-layer (middle and lower floors).
- Ground covering species.

Visual characteristics

- Size.
- Habitus (shape variable within species).
- Structure.
- Texture - the period of dormancy.
- Color - foliage, flowers, fruits.

Size of tree

- Small 5-10 m fruit trees, ornamental cultivars.
- Medium 10 (15)-20M hornbeam, birch, rowan, birch, spruce, pine, fir.
- Large 20-30 (40) m to 40m: Buba, lime, ash, poplar, elm, maple.

Branching structure

- Branching dense, sparse.
- Direct branches, gnarled.

formation modeling is still being developed for the buildings mainly - the construction management and facility operations.

That may explain that in our investigation we did not find any indication of existence of a survey or a research in our direction. Firstly we needed to get a deeper knowledge of the term "BIM" and also the software that supports this system of work.

What we found about BIM could be generalised to this: Building Information Modeling covers more than geometry- it extends the traditional approach to the building design (two-dimensional drawings as plans, elevations, sections, etc.) beyond 3-D to time as the fourth and cost as the fifth dimension, and sixth dimension is the life cycle management. It also covers spatial relationships, light analysis, geographic information, quantities and properties of building components (for example manufacturers' details).

There are two major BIM software developing companies Graphisoft (ArchiCAD) and Autodesk (Revit) that bring their products to our market. Additionally there are also Nemetschek (Allpan Architecture) and Bentley (Microstation V8i).

LANDSCAPE MODELLING SOFTWARE

We have found several smart "CAD based" programs, but all of them are used for 2D design (the traditional way). One case is for example ArborCAD, which is special purpose CAD software for the needs of arborists. It is based on the landscape software LAND-WorksCAD. It has a lot of features specially aimed at information about plants, trees, and their properties.

Additionally there are also some applications that work with plants as dynamic objects:

- NatFX is a plug-in (for Alias|Wavefront's Maya) designed for modeling and animating 3D plants (age, season, and scale). Animation is possible either as a realistic effect (with botanical constraints) or as a cartoon effect (by-

Foliage texture
- Texture fine (small leaves)
- Coarse texture (large-leaved trees - maples, horse chestnut, sycamore)
- Airy texture (platane).

Growth and growing characteristics
- Age.
- Growth rate.
- Environmental requirements.

Lifetime
- Short-living (about 80 years ,willows, poplars, alder, birch), fast-growing.
- Average, (200-300 years, maple, hornbeam, rowan, spruce, pine), survivor type.
- Long-living (600-800 years, oak, linden, beech, yew).

Environmental requirements
- Temperature: thermophilic (oak, beech, maple), cryophilous (spruce), no particular requirements-pine, birch, sycamore.
- Moisture: Xerophilic (rowan tree), Mezophilic (ash tree), Hydrophilic (willow).
- Light: Heliophile (larch, pine, birch), Average, Heliophobic (yew, hornbeam).
- Nutrients: most of the plants have average demand for nutrients, but some may demand alkaline soils - Addition of Ca or acidic that requires addition of peat. Some species tolerates salinity - that ones are suitable for street alleys (acacia).

passing the constraints), using natFX's built-in plant skeletons. All natFX trees and plants are fully textured, based on scans of actual leaves, stems, and bark. NatFX is currently available as a plug-in.

- EASYnat by Bionatics is an add-in that can be used within AutoCAD or 3Dmax. Currently the trees are parametrically generated from the input data (height, width, age and season) (Figures 1 and 2).

3rd   5th   7th   10th   15th   20th   50th year
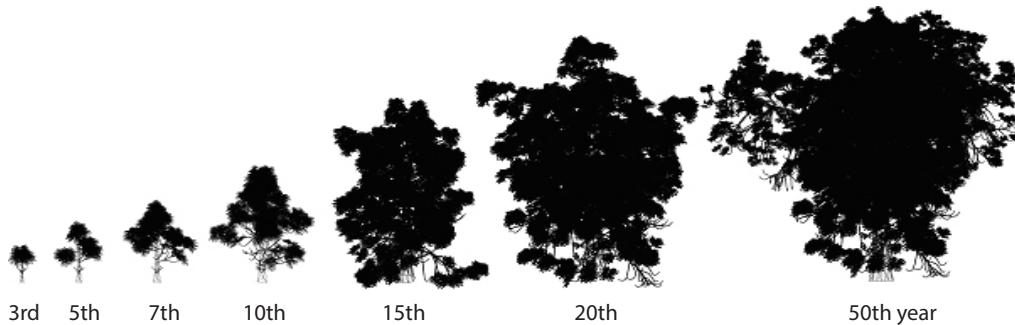
EASYnat could be suitable for our further research - for implementation into object orientated software like Revit or ArchiCAD and development of their attributes and actions. The plants should have more attributes and while simulating the grow process, they should react and interact with its surroundings.

UNIFIED MODELLING LANGUAGE

BIM involves representing a design as combinations of 'objects' that carry their geometry, relations and attributes. Such objects and relations can be described by UML (Unified Modelling Language). UML is a standardized general-purpose modeling language in the field of object-oriented software engineering. It is a tool for defining the structure of a system through several types of diagrams. UML enables to model an application specifically and independently of a target platform (Fowler and Scott, 2000; Blaha and Rumbaugh, 2004).

UML diagrams represent two different views of a system model: static (structural) and dynamic (behavioral) diagrams (Schmuller, 2001). There are more than ten different types of UML diagrams. In our inquiry we are interested in class diagrams, object diagrams and activity diagrams (Figure 3).

In our research we aim to advance the information model of the vegetation to be comprehensive. This means that we not only model the general attributes of vegetation (for example for trees family, genus, species, cultivar, decicious/evergreen, season), but also the time dynamic attributes (for example for trees height, canopy perimeter, trunk perimeter), surrounding reaction (for example for trees soil requirements, geographic location, moisture), and interaction (for example for trees spread, ecologically close trees, and antagonistic plants).
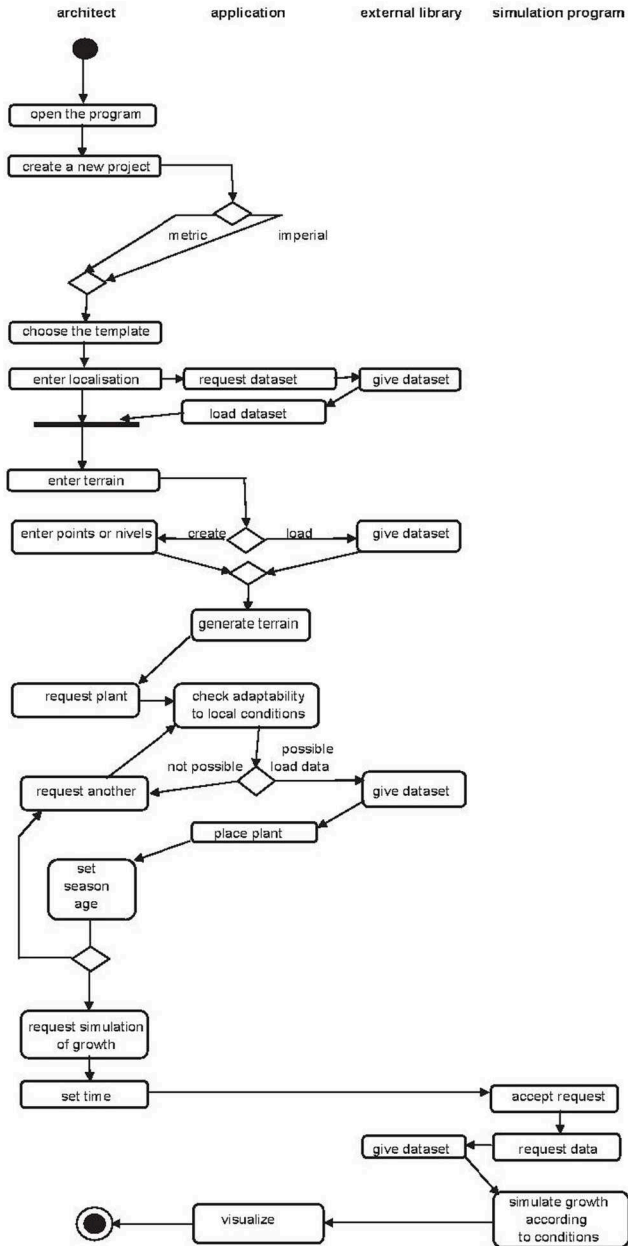
In real life coding examples, the difference between inheritance and aggregation can be confusing. If you have an aggregation relationship, the aggregate (the whole) can access only the PUBLIC functions of the part class. On the other hand, inheritance allows the inheriting class to access both the PUBLIC and PROTECTED functions of the superclass.

DESCRIPTION OF POTENTIAL APPLICATION OF UML DIAGRAMS

We have applied the class diagrams to our study case: we needed to state the classes and all the atributes that our classes should have. Then we have created one instance of that class and the relations (Figure 4).

These diagrams we use to map the classes that appear in our application study. While describing the plants as object for BIM you have to take in account all their properties and attributes -such as height, perimeter of canopy, perimeter of a trunk, classification in the meaning of family- genus- species- cultivar, to state if the plant is decidious or evergreen, the aspect of season (mainly to state the existence and color of the leaves), the age of the plant and its habitus an finally for most efficient work with the objects the detailing and the way of graphic appearance.
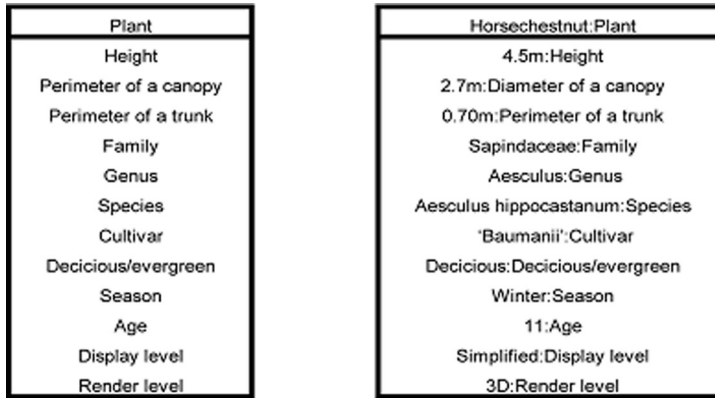
Figure 3
Activity diagram.

Plant
Height
Perimeter of a canopy
Perimeter of a trunk
Family
Genus
Species
Cultivar
Decicious/evergreen
Season
Age
Display level
Render level

Horsechestnut:Plant
4.5m:Height
2.7m:Diameter of a canopy
0.70m:Perimeter of a trunk
Sapindaceae:Family
Aesculus:Genus
Aesculus hippocastanum:Species
'Baumanii':Cultivar
Decicious:Decicious/evergreen
Winter:Season
11:Age
Simplified:Display level
3D:Render level

Figure 4
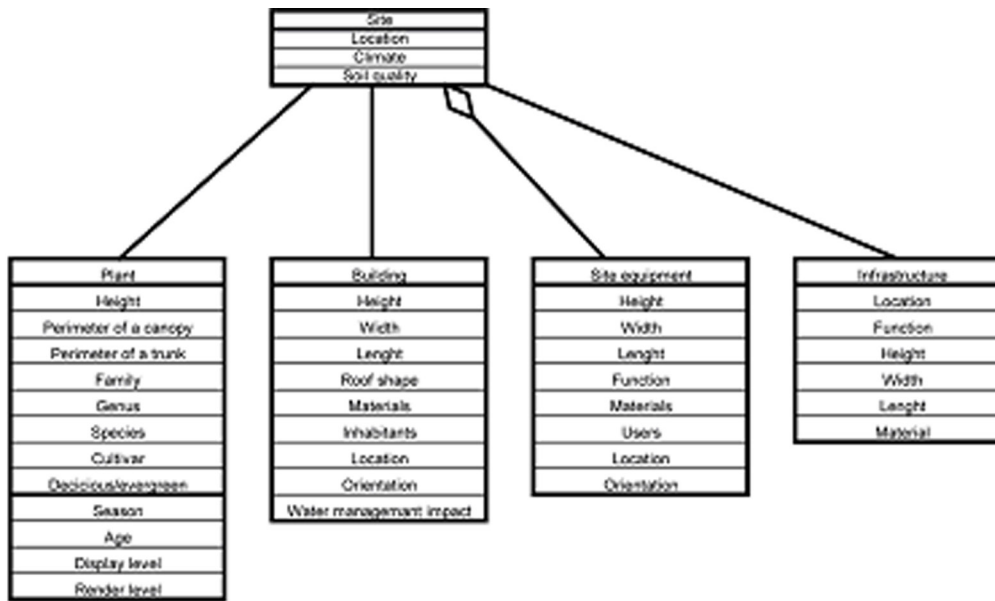*Class and instance diagrams.*

Figure 5
Diagram of relations between classes.

The same (properties and attributes) we should state for the other objects that we would like to involve in our application.

In this preliminary diagram (Figure 5) you can see buildings (can cover the minor architectural works in the countryside), site equipment (such as benches, trash cans, lightning, equipment for cyclists-parking places) and infrastructure objects.

DISCUSSION

In the paper we have presented our first findings towards a Landscape Information Model. The work is still in a very preliminary phase, but we hope to have laid some foundations. As trees are dominant visual

elements in landscape design, we have started with more concrete knowledge capture of trees. In the next steps we aim to implement a parametric data model of trees in Revit.

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