Material Characteristics Representation: Requirements, Definition and Implementation

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Abstract – **This paper describes the problem of reusability of materials in computer simulation and visualization in architecture. Architectural and functional requirements for software implementation are discussed, along with the description of the software tool for creating, storing and manipulating material description files.**

Keywords – **Material Characteristics, Material Explorer, Xmat**

I. INTRODUCTION

In the early phases of the architectural design a "project of building" is imprecise and incomplete [1], because it is just a sketch and details are not yet defined. On the other hand, validation of the technical qualities of buildings by experts with sophisticated techniques is preformed in the detailed design phase. These quantitative mathematical methods use precise and complete data that are available only at the end of the design.

For the question of luminous ambiences, at the beginning of the design (sketch phase), the architects' approach is rather intuitive. Towards the end of the design, when everything is well defined, it is possible to perform simulations to verify if the ambience in a given project is close enough to architectural intentions and if norms and recommendations are respected. However, in that phase it is too late to advise on possible modifications of the buildings morphology. On the contrary, materials (their surface appearance) may generally be changed at any stage of the design.

To bring the resulting ambience closer to intentions, architects may use several different computer programs to help them in the process of design and representation of ambiences of architectural project. These programs allow them to simulate imaginary buildings, and to verify their intentions, preferences and respect of norms. On the other hand, programs follow strictly defined geometrical and physical laws, which give quantitative accuracy to the project.

For modeling and simulation in architecture there is a great number of different computer programs available on the market, such as AutoCAD, ArchiCAD, 3Dstudio Max, Radiance, etc. All these programs offer similar possibilities for modeling different geometrical primitives, but their capability to simulate luminous ambiance of the building is different. Definition of luminous ambiance involves description of artificial light sources (luminaries characteristics and position), natural light sources (sun, sky), building position and environment, and description of materials used for building interior and exterior.

Although every architectural project has its original structure and shape, the number of available materials is limited to the number of existing materials. So it is not unusual to use materials, which are already used in some other projects.

In this paper we consider the reusability problem of materials in computer simulation and visualization, and offer software tool for creating, storing and manipulating with material description files. The paper is organized as follows. In next section, architects concept of material description is faced with computer simulation approach. Sections III and IV describe architectural and functional requirements, which software should follow. The last section contains the description of software implementation and application.

II. MATERIAL REUSABILITY

According to previous discusion it is recomendable to have reusable material descriptions. From architect point of view this would enable easy search and use of materials in project. Also, using of “existing“ materials, gives certanity to architect's choice of appropriate materials. On the other hand, from the programmers point of view, this reusability, means the definition of a universal format for storing description of material characteristics, which should be easy to search using different criteria.

It should be taken into consideration that existing formats, enable precise and accurate definition of materials in terms such as: color component values (red, green, blue); reflection and transmission coeficients; specular, diffuse and ambient component; pattern or texture used etc. Architects use more qualitative and subjective descriptions of ambient and materials, such as: calm, dark, dynamic [2]. During the design many architects look for these keywords to symbolize an ambiance they wish to create. This adds one more requirement for material file format: it should include description of both physical (optical, thermal, etc.) and subjective characteristics of materials. This indicate an important requirement for such format - it should be easily extendable.

The final aim is to enable architect to search through large number of materials, to examine their characteristics, and to use some of them for further work in various simulation

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programs. It is also desirable to have some images which represent material examples.

III. ARCHITECTURAL REQUIREMENTS

Previous section gives us guidelines that should be followed in definition of a format for storing material characteristics. Main attributes of this format are enumerated in next list:

- It should be easy to semantically search files in this format, using different searching criteria.
- Appending of new characteristics to existing material description files should be easy and it should not violate the logical structure of a file, which means that format should be extendable.
- Format should be easy to interpret and preview to a user.
- It is desirable do define a format that is program independent, and that is easily converted to other textual formats. This would enable material reusability in different simulating programs.

Following this requests we defined Xmat file format. This format, as described in [3], is based on XML. It inherits all XML advantages described in [4], which offers additional advantages to this format: legibility, logical structure, and possibility of semantic validation of files contents through concept of XMLSchemas. Appropriate XMLSchema, which contains description of all possible entities in Xmat documents, is also defined in [3]. Every material definition in Xmat format contains physical, quantitative and descriptive, qualitative information about material. Section of Xmat document that contains physical data is based on Radiance material definition.

Radiance is open-source, Unix based, software for accurate lighting simulation and visualization based on ray-tracing algorithm [5]. Its input files are composed of textual description of geometric primitives and materials they are made of. These files can be entered manually or imported from other simulation programs such as AutoCAD, 3DStudio etc. The imported files contain only description of geometric primitives, and appropriate materials are assigned to them afterwards.

The main reason why we selected Radiance is its format for material definition. While other programs use parameters like specular, ambient and diffuse components for defining material characteristics, radiance use more intuitive concept of *material types.* Each material type in Radiance, describe one kind of material behaviour [6]. For example: a *plastic* surface has a color associated with diffusely reflected radiation, but the specular component is uncolored; for *metal* surfaces the specular component is modified by the material color [7]. This description of materials is analogous to their real behavior. To define different *plastic* materials, user simply varies basic material parameters: red, green, and blue color components, reflection secularity fraction and material roughness.

Code samples 1. and 2. give material description in Radiance and Xmat format.

```
void metal gold
0
0
5 0.6 0.8 0.4 0.7 0
```

Code sample 1.

Example of material description in Xmat format includes some additional information: architect and project name.

```
<Material>
 <Metal>
    <ModifierName>void</ModifierName>
    <Identifier>gold</Identifier>
    <Color>
       <Red>0.6</Red>
       <Green>0.8</Green>
       <Blue>0.4</Blue>
    </Color>
    <Specularity>0.7</Specularity>
    <Roughness>0</Roughness>
 </Metal>
 <Architect>Clément Vergely</Architect>
 <Project>Wurth Foundation</Project>
</Material>
```

Code sample 2.

Material definitions in Xmat format are stored in a *material base*. Each base entity, stored in Xmat file, contains one material description. Special textual files are defined for material base search and manipulation..

IV. FUNCTIONAL REQUIREMENTS

All requests previously described can be organized in a few basic features that should be implemented in the software. In Figure 1. these features are represented in a form of Use Cases, following Rational Rose unified notation. From the sake of simplicity, some rather complex features are represented as one use case. All features should be implemented respecting to architectural requirements defined in Section III.

Use Case diagram contains only one actor – *User*, who represents user of the software.

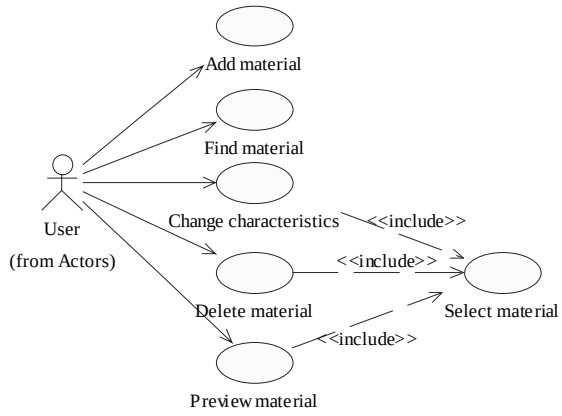

Figure 1. Use Case diagram

Each use case in the diagram represents one specific feature:

Add material use case enables user to add a new material to Material base. A material could be added from different sources: it can be imported from some existing Radiance file, or it can be added from a scratch. Initial material file is analysed and stored in Xmat file, which is then appended to the material base.

- Material base can contain great number of materials, and program should provide some kind of mechanism for searching through it. Feature *Find material* should enable user to find material in material base, based on different criteria.
- *Change material* – once material is stored in base it can be changed in few different ways: existing characteristics can change their values, or some new characteristics can be added to material. Characteristics for each material can be, as described earlier, different: radiance material definition, optical, thermal, subjective etc.
- *Delete material* – possibility to delete selected material from Material Base
- When user select material it is important to *preview material* characteristics. Characteristics can be in text and/or image format.
- Feature *Select material* is simple use case included from other more complex use cases. Its functionality is to enable material selection for further actions.

V. Material Explorer

Following all defined requirements software tool Material Explorer is created. Material Explorer was developed in QtDesigner, in Linux operating system.

Material Explorer main window is shown on Figure 2. Main widow can be divided on two areas: area for setting search filters, and area for preview of material characteristics.

To find material(s) with certain characteristics user should define query for searching. Query is easily defined using filters drop down boxes. Every filter contains one characteristic and a corresponding value. For example, if user sets a filter to have characteristic ”Project” and value ”Project1” that means that he wants to find all materials in material base which were used in project “Project1”. Up to four filters can be set, and relations between them can be *and* or *or*, which provides definition of complex filters. Final query value is previewed in the bottom of the window.

List of available characteristics and their values is composed from database contents, e.g. list of characteristics contains all characteristics that exist in material base. When user choose come characteristic in drop down box, corresponding value drop down box is filled with all possible values for that characteristic.

Each time filters contents are changed material list, in left part of the main window, is updated. Material list contains all materials from material base, which have values equal to filter values.

When a material in the list is selected its data, from Xmat file, and image, if exists, are previewed in the right bottom part of a window. Selected material can be changed or deleted.

Toolbar contains all features defined in previous sections. User interface for these features is simple and descriptive, so even the non-professional users can use Material Explorer.

The common applications of Material Explorer are described as follows. In the process of the design an architect develops a project in AutoCAD or some other simulation program. Defined scene can be imported to Radiance. Imported objects, as mentioned in Section III, do not contain appropriate material definitions, and the architect should manually define materials, and assign them to the objects. Further Radiance simulation is beyond this discussion. The material definitions, since described using Radiance syntax, contain only material optical characteristics, and they are not appropriate for storing and searching for further projects.

To preserve materials used in some project, the best way is to store them in some kind of base or library, and to attach them some additional data, which would simplify their future use. Utilization of Material Explorer is a good mean for this task. Materials defined in Radiance can be easily attached to Xmat material base. Afterwards user can add some additional data for each material file, such as: architect name, project name, material manufacturers name, material type (brick, concrete, wood), some qualitative expressions that describe material behaviour or architects subjective impressions. For architects, the character of some space is determined by its luminous ambiance. Since the objects made of different materials compose the ambiance, subjective impressions of the ambiance are closely linked to those materials. *Change material* feature would also enable adaptation of an existing material for some new purposes.

On the other side, engineer or any other expert who gives advice to an architect, could use Material Explorer to define some technical characteristics of materials, such as thermal characteristics, material weight and durability, fire resistance etc. In the process of consulting or design an engineer can search the material base in order to find most appropriate material for some purpose. His approach is rather quantitative and based on the physical principles.

All these additional data are used in Material Explorer as keywords, which enable user easy and semantic search of the material base. Search criterion can be complex, due to existence of four filters. User can also attach an image to the material, which would simplify selection of an appropriate material for some purpose.

True benefits of this software, in the process of material selection and manipulation, become visible when material base contains hundreds of materials collected from different projects.

VI. Conclusion

This paper describes dual nature of architectural project, represented through disparity of objective and subjective approach. It focuses on problem of materials reusability in computer simulation and visualization in architecture. In addition software tool for creating, storing and manipulating with material description files, has been realized. This will

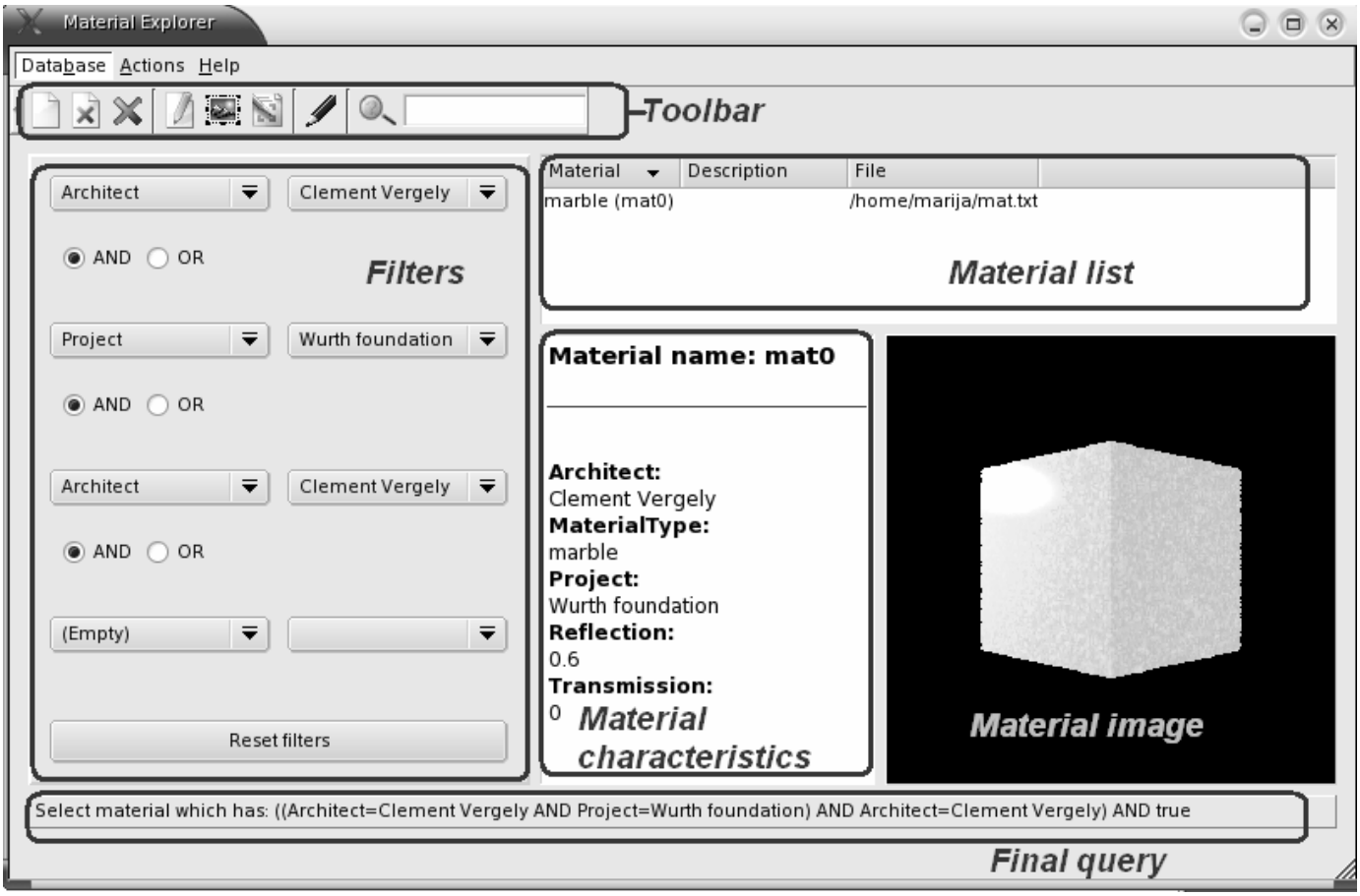

Figure 2 – Material Explorer main window

help designers to manipulate, preview, choose through a larger number of materials (several thousands) using both technical (physical) and architectural (qualitative) characteristics.

The final goal is to regroup a very large number of materials and their characteristics for various technical areas (thermal, acoustics, cost, sustainability, visual aspect, etc.). This will make these materials ready for simulation in all these areas; hence improve the speed of validation of buildings behavior.

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