DESIGN PATTERNS IN GENERATION OF ARTEFACTS IN REQUIRED STYLES ***(paper)***

Topic: Design

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Abstract
Art and architecture are considered to be creative activities of humans. Yet all of the artistic artefacts are build of a number of basic elements or patterns. The idea of design patterns was introduced by Christopher Alexander in the domain of architecture and has been later adapted for the use in many other disciplines, including computer science [1]. In his concept a pattern reflects the design decisions taken by many designers in different situations over the span of many years in order to solve a given problem. The use or the lack of particular patterns can be linked to the quality of a given design. In order to use patterns in design generation there is a need for a formal representation of the design knowledge, which usually requires the ability to capture geometric, structural and numerical information. On the basis of such knowledge representation the processing of the designs can be performed.
This paper deals with a tool supporting the conceptual phase of the design process. Using this tool the designer generates drawings of artefacts by arranging elements of the visual language. The vocabulary of this language is composed of visual primitives and visual relations between them, which are defined on the basis of the specified ontology [2]. Design requirements related to styles are turned into visual design patterns, which are added to the language vocabulary. Design drawings generated by the designer are automatically transformed into the corresponding graph-based data structures. Nodes of the graphs represent visual primitives of the visual language, while edges allow for expressing relations between them. Nodes and edges of graphs are attributed by visual properties representing characteristic features of primitives and relations. The considered internal representation of drawings provides the basis for analysis of artefacts which can give the feedback to the designer.
The discussed tool automatically assesses preliminary design drawings on the basis of the specified style requirements. The style of the considered artefact depends on the type of the patterns used, their structural, topological and numerical features. Visual design patterns representing style requirements are mapped by the proposed ontological interpretation to graph structures. Reasoning about compatibility of drawings with the specified design criteria is performed by searching for graphs corresponding to visual patterns in the internal graph representations of drawings. The system supports the designer by prompting him/her which style requirements are not fullfiled. The approach is illustrated by examples of designing gardens in the Japanese style.

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Design Patterns in Generation of Artefacts in Required Styles

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Abstract
This paper deals with a tool supporting the conceptual phase of the design process. Design drawings are created on the monitor screen by arranging elements of a visual language. Design requirements related to styles are turned into visual design patterns, which are added to the visual language vocabulary. Both design drawings and the visual patterns expressing style features are represented by graph-based data structures which are obtained automatically. Reasoning about compatibility of drawings with the specified design criteria is then performed by searching for graphs corresponding to visual patterns in the internal graph representations of drawings. The approach is illustrated by examples of designing gardens in the Japanese style.

1. Introduction

Art and architecture are considered to be creative activities of humans. Yet all of the artistic artefacts are build of a number of basic elements or patterns. The idea of design patterns was introduced by Christopher Alexander in the domain of architecture and has been later adapted for the use in many other disciplines, including computer science [1]. In his concept a pattern reflects the design decisions taken by many designers in different situations over the span of many years in order to solve a given problem. The use or the lack of particular patterns can be linked to the quality of a given design. In order to use pattern generation in computer aided design there is a need for a formal representation of the design knowledge, which usually requires the ability to capture geometric, structural and numerical information. On the basis of such knowledge representation the processing of the designs can be performed.

This paper deals with a tool supporting the conceptual phase of the design process. Using this tool the designer generates drawings of artefacts by arranging elements of the visual language. The vocabulary of this language is composed of visual primitives and visual relations between them, which are defined on the basis of the specified ontology [2]. A visual language allows us to create design styles in two stages. First, visual patterns are generated with elements of the language vocabulary, which are formed and expressed in a particular manner according to pattern design requirements. The visual patterns generated in the first stage are added to the language vocabulary. Then, elements of the extended vocabulary are combined and expressed in a particular (often unique) and consistent manner according to design requirements related to the style of the whole design.

One of the challenges of CAD systems is to automatically transform design drawings on the monitor screen into appropriate graph-based date structures. The framework of ontology

proposed in this paper allows us to define the correspondence between the drawings and their graphs. Design drawings generated by the designer are automatically transformed into the corresponding graph-based data structures. Nodes of the graphs represent visual primitives of the visual language, while edges allow for expressing relations between them. Nodes and edges of graphs are attributed by visual properties representing characteristic features of primitives and relations. The considered internal representation of drawings provides the basis for analysis of artefacts which can give the feedback to the designer.
The discussed tool automatically assesses preliminary design drawings on the basis of the specified style requirements. The style of the considered artefact depends on the type of the patterns used, their structural, topological and numerical features. Visual design patterns representing style requirements are mapped by the proposed ontological interpretation to graph structures. Reasoning about compatibility of drawings with the specified design criteria is performed by searching for graphs corresponding to visual patterns in the internal graph representations of drawings. The system supports the designer by prompting him/her which style requirements are not fulfilled. The approach is illustrated by examples of designing gardens in the Japanese style.

2. Visual design patterns

This section explains how visual design patterns can be used to discover design ideas during conceptual designing. Conceptualization is one of the most challenging aspects of designing because it forces designers to consider many disparate factors. There exists the need to keep in mind objects, concepts, and other entities that are assumed to exist in the considered design domain of discourse, and the relationships that hold among them. The conceptual stage of design is illustrated by creating stylish gardens.
In the framework of computational ontology during the conceptual design phase the designer determines a set of *concepts*, which can constitute elements of design problem solutions, and a set of *relations*, which can take place among the concepts. Design concepts are partially ordered according to a given generalization/specification hierarchy. On the basis of this ontology elements of a visual language are specified.
Apart from a vocabulary of a visual language being a finite set of visual primitives, a finite set of rules specifying possible configurations of these primitives in space is defined. Primitives of a visual language and their spatial relationships correspond to concepts and relations defined by the ontology for a given design domain. Using these elements the designer creates design drawings, which represent general ideas about design solutions, by means of a system editor. Each specialized design domain has its own visual language related to concepts of this domain [3].
Let us assume that the application domain concerns designing gardens. A set of concepts contains *tree, flower, shrub, path, brook, pond* and *garden object*. The concept *garden object* contains concepts such as *bench*, *fountain, stone, footbridge* and *table with chairs*. Two relations between concepts are considered. The first relation represents adjacency between elements representing concepts, while the second one represents the facts that elements representing subconcepts of the concept *garden object* are placed above the other ones.
A vocabulary of the visual language used in the garden design system is composed of visual primitives representing various types of trees, flowers and shrubs and ponds There are also primitives representing fragments of paths and brooks, benches, fountains, tables with chairs, footbridges and stones. Visual primitives representing flowers, shrubs, fragments of paths, table with chairs and a footbridge are depicted in Fig.1. Design drawings representing

garden projects are composed of the above mentioned visual primitives arbitrary placed by the designer on the plane corresponding to the garden space. Two visual relations, namely *near* and *on*, which externalize the relations *adjacency* and *being above*, between garden elements are considered.

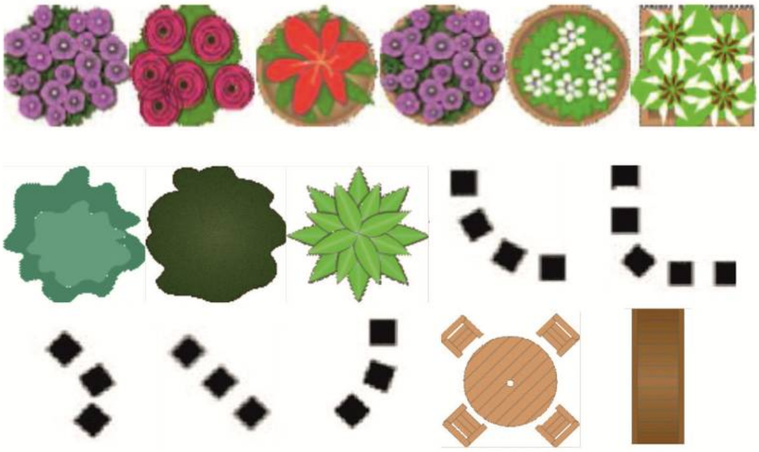

Fig.1. Some primitives of the considered visual language

When the designed artefact ought to have features of a given style, style requirements should be considered. Ontological approach to design allows us to express style-related knowledge using ontological concepts and visual language elements corresponding to them. Style requirements can be illustrated by visual design patterns composed of visual primitives. Let us assume that the designer wants his garden to be in the Japanese style. The arrangement of the elements in such a garden must be compatible with the art of feng shui. In Japanese gardens stones, water, trees and flowers should be present. Moreover, paths should be winding and a footbridge should be placed over the water. The last two requirements are fulfilled if in the garden drawings all paths are composed of visual design patterns containing curve path fragments, which are shown in Fig.2a and 2b, and the drawing contains at least one visual design pattern shown in Fig.2c, representing a footbridge over a brook.

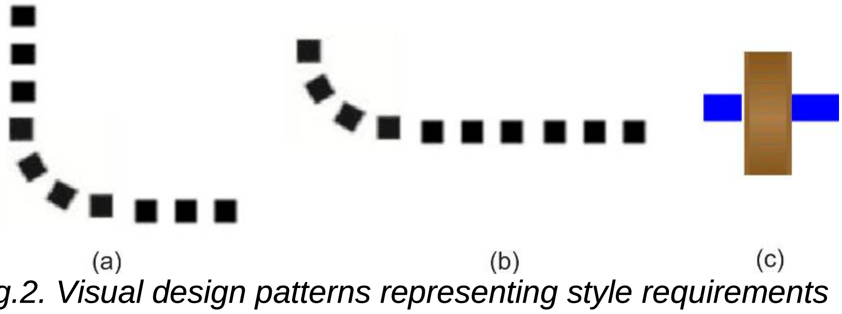

Fig.2. Visual design patterns representing style requirements

An example of a Japanese style garden drawing created by the designer is presented in Fig. 3. It contains visual primitives representing eight trees, seven flower clumps, a group of three stones, a winding path and a brook with a footbridge over it. Two visual patterns from Fig. 2a, one from Fig. 2b and one from Fig. 2c are present.

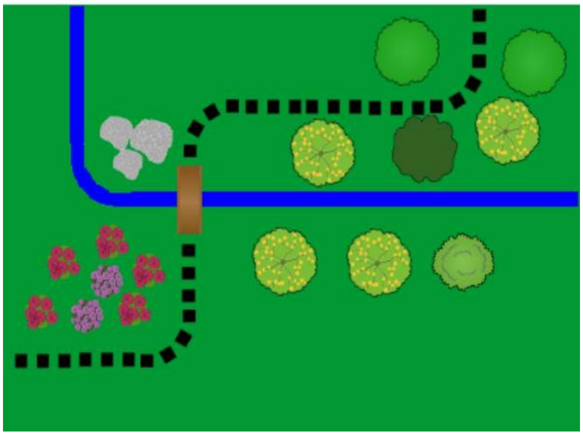

Fig.3. An example of a garden design

3. Graph-based representation of drawings

In design aided by a computer system the knowledge extracted during the conceptual design phase should be expressed in a formal machine readable format. In other words we need to make knowledge representation accessible electronically, structured and understandable by computers, interoperable and transparent. Graphs can be combined with the most popular logic-based knowledge representation technique, where knowledge is represented explicitly by symbolic terms and reasoning is the manipulation of these terms. This knowledge provides a starting point for design refinement. There exist many types of graphs useful for specification and modelling of design knowledge during CAD processes.

In this paper directed labelled graphs are used to reflect the design knowledge extracted from design drawings on the monitor screen. They can be automatically processes by the design system and used for reasoning about design features. Graph nodes represent primitives of the visual language vocabulary, while edges express relations between them. Nodes are labelled by names of primitives and edges are labelled by names of relations between visual primitives. The edges representing the adjacency relation are undirected and labelled *near*, while edges representing the being above relation are directed and labeled *on*.

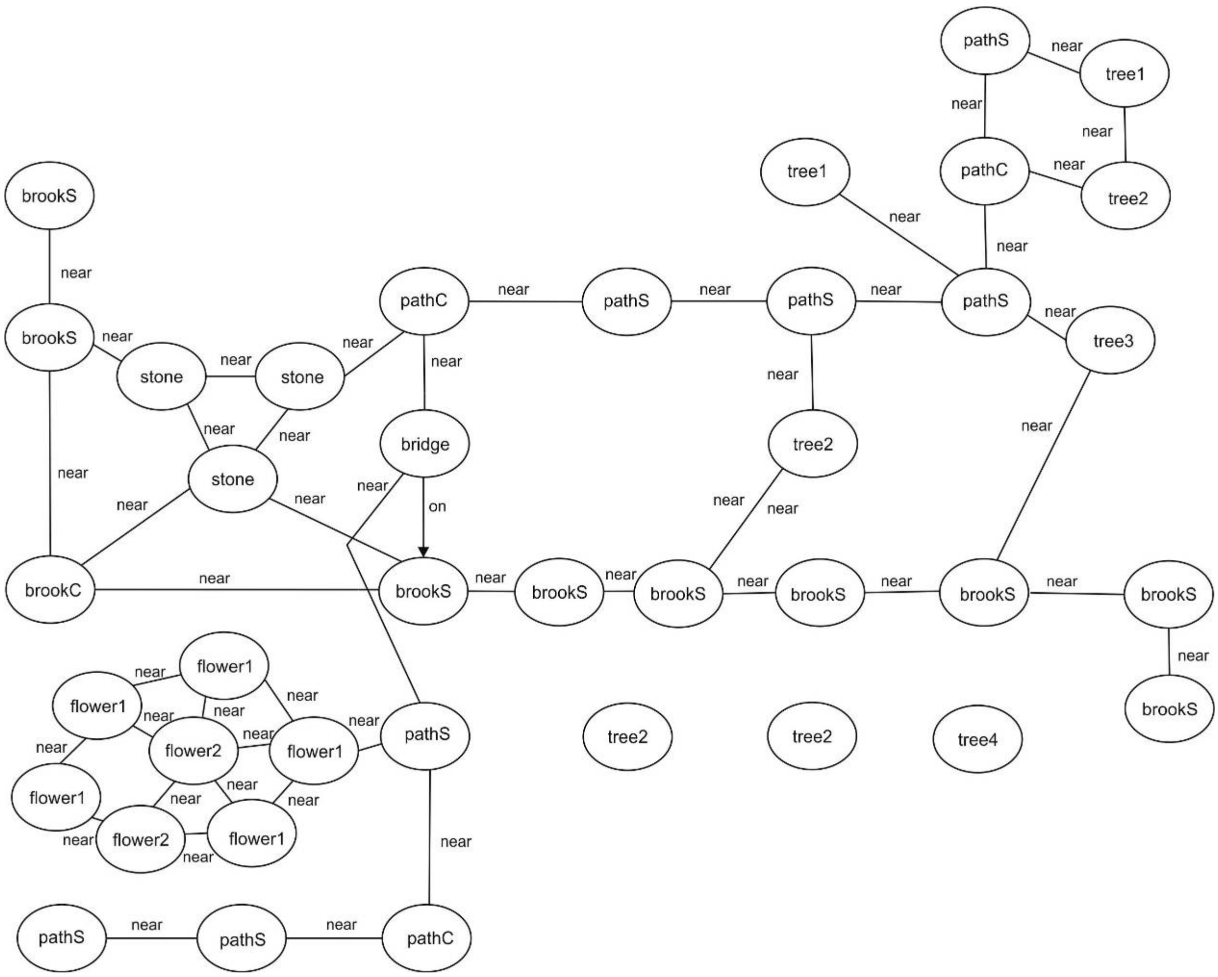

Fig.4. A graph representation of the garden drawing presented in Fig.3

A graph corresponding to the garden design presented in Fig.3 is shown in Fig.4. It contains 39 nodes and 49 edges. Eight nodes, labelled *tree1*, *tree2*, *tree3* and *tree4* represent four kinds of trees. Five nodes, labelled *flower1* and *flower2* represent five flower clumps composed of two kinds of flowers. Three nodes labelled *stone* represent a group of three stones. Nodes labeled *pathS, pathC, brookS, brookC*, and *bridge* represent straight and winding fragments of the path, straight and winding fragments of the brook, and the footbridge. There are 48 edges (labelled *near*) representing the adjacency relation between garden components, and one edge (labelled *on*) representing the fact the footbridge is above the brook.
The visual patterns representing style requirements are mapped by the ontological interpretation to graph structures. This interpretation assigns graph nodes to visual primitives representing concepts and graph edges to relations between them. Three graphs representing visual design patterns shown in Fig.2 are presented in Fig.5.

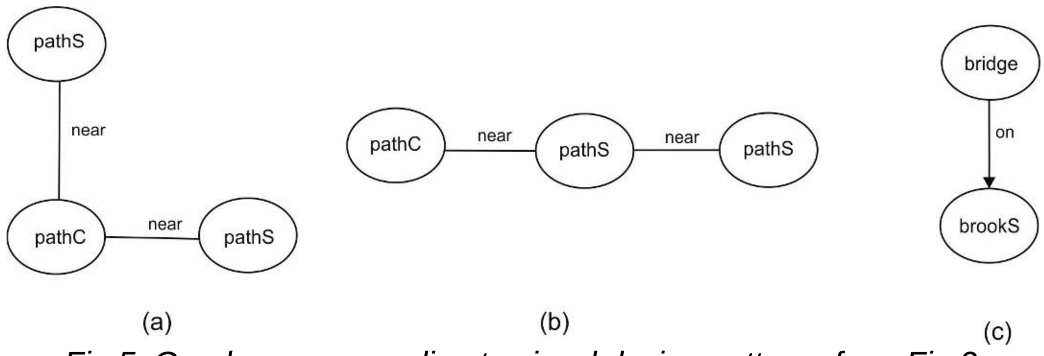

Fig.5. Graphs corresponding to visual design patterns from Fig.2

4. Reasoning about design style

The ontological approach presented here facilitates the development of reasoning modules of a CAD-system which are based on a graph data structure.

The system which supports the conceptual design phase assists the designer by reasoning about drawings on the basis of their graph-based internal representations. It can check the compatibility of the solution with the specified requirements and suggest the needed modifications.

The reasoning process consists in searching for graphs representing visual design patterns corresponding to style requirements in the graph-based representations of design drawings. Each design requirement can be represented by one or more graphs corresponding to visual patterns. For example there exists a winding path in the designed garden if the drawing contains either the visual pattern shown in Fig.2a or the pattern from Fig.2b. One of the graphs representing each style requirement should be present at least one time in the internal representation of the considered drawing. In the case when such a graph is missing, the system displays the message telling the designer which style requirement is not fulfilled.

An example garden design which was to be in the Japanese style is shown in Fig.6. Checking style requirements the system found that in the graph representation of this design there is no subgraph isomorphic with either the graph from Fig.2a or the graph from Fig.2b. Therefore it displays on the screen the information that the requirement '*winding path*' is not fulfilled.

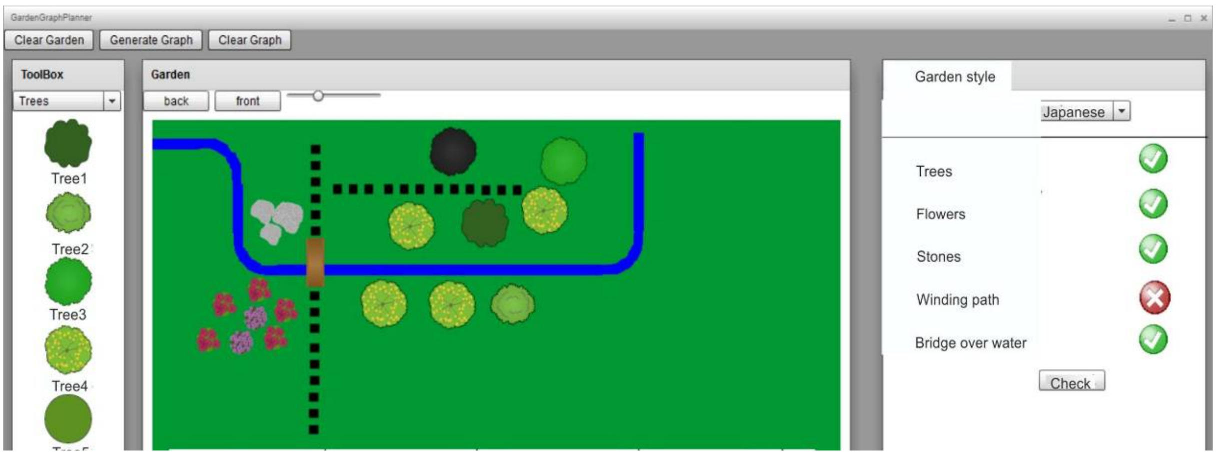

Fig.6. Garden design with no winding path

3. Conclusion

This paper deals with supporting the conceptual phase of designing using the visual design system. The ontological approach allows us to define a visual language and visual design patterns corresponding to style requirements. Moreover, this approach makes it possible to define the correspondence between design drawings and their graph representations. Design drawings created by means of the system editor are automatically transformed into the internal representations in the form graphs. Then design requirements are mapped into graphs by the ontological interpretation. The design system reasons about the style of designed objects by checking the existence of specified graphs in the internal representations of design drawings. The process of visual design is supported by the feedback from the computer system. Thanks to this feedback a dialogue between the designer and the computer system can be improved.

In the future the system will be extended by the possibility of generating 3D visualizations of designs.

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