A Graph-Based Generative Method for Supporting Bridge Design

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Abstract. This paper deals with a CAD tool supporting the conceptual phase of the bridge design process. Design drawings are created on the monitor screen by arranging elements of a visual language. It is possible to define visual design patterns, which are added to the visual language vocabulary. Both design drawings and the visual patterns are represented by graph-based data structures which are obtained automatically. The graph rules, which make it possible to replace subgraphs corresponding to visual patterns by subgraphs representing other patterns, are defined. By substituting selected subgraphs in the internal graph representations of drawings by other subgraphs in the possible way, the proposed system generates graph structures representing innovative bridge designs.

1. Introduction

Nowadays CAD systems facilitate an integration of various phases and aspects of engineering processes (Pahl & Beitz, 1996). CAD software is widely used to support the process of generating design drawings and product models. However CAD systems still lack generative methods to easily generate classes of similar design variants. For example models of bridges often have similar structures but differ in sizes or fitting to varying environmental conditions (Chung & Wang, 2014; Pipinato, 2015). For many years structures of design objects have been represented and generated using graphs and graph transformations (Rozenberg, 1999; Vilgertshofer & Borrmann, 2016).

This paper deals with the problem of the conceptual phase of bridge design in the unified graphical environment delivered by the system called *GraphTool*, which supports graph transformations (Ryszka & Grabska, 2013). This new software provides graphical editors for defining different types of graphs and graph transformation rules. Graph structures, which can be transformed using graph rules, are used as internal representations of bridge designs.

The designer generates drawings of bridges by arranging elements of the visual language. The vocabulary of this language is composed of visual primitives and visual relations between them. Bridge drawing parts can be considered as visual design patterns (Alexander, 1977), which are generated with basic elements of the language vocabulary, and added to this vocabulary. Then, elements of the extended vocabulary can be used to create design drawings.

One of the challenges of CAD systems is to automatically transform design drawings on the monitor screen into appropriate graph-based date structures (Strug et al., 2016). In the presented approach both topological structures and semantic properties (geometrical parameters, materials, environment aspects) of bridges are represented by composition graphs (CP-graphs) and their attributes, respectively (Borkowski & Grabska, 1995). A CP-graph is a labelled and attributed graph, where nodes represent components of artefacts and are labelled by names of components they represent. To each node a number of bonds expressing potential connections between components is assigned. Bonds are connected by edges representing relations between components and labelled by the relation names. Moreover nodes have attributes specifying properties of components assigned to them. Both whole design drawings generated by the designer and the visual patterns are automatically transformed into the corresponding CP-graphs. Nodes of these graphs represent visual primitives corresponding to