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Design Pattern Detection by Sub Graph Isomorphism Technique

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Abstract: ***Design Patterns are proven solution to common recurring design problems. Design Pattern Detection is most important activity that may support a lot to re-engineering process and thus gives significant information to the designer. Knowledge of design pattern exists in the system design improves the program understanding and software maintenance. Therefore, an automatic and reliable design pattern discovery is required. Graph theoretic approaches have been used for design pattern detection in past. Here we are applying an algorithm for graph matching which is based on the sub graph isomorphism. The same algorithm we are here using for design pattern detection from the system design.***

Keywords: design pattern, UML, matching, sub graph isomorphism**.**

1. Introduction

Graph based approached have been used in many software engineering problems. Design Patterns are proven solutions for common recurring software design problems. The design patterns have been extensively used by software industry to reuse the design knowledge [1]. During maintenance of a software system the necessary tasks are to understand and modify it. It would be helpful to discover pattern instances in it, if any. Many algorithms have been proposed for design patterns detection like [2, 3, 4, 5]. Similar works on design pattern detection have been discussed in section 2.

This paper presents a design pattern detection technique by sub graph isomorphic. Here, the graphs are corresponding to the relationship graphs which exist in the UML diagrams of system design (model graph or system under study) as well as in UML diagrams of design patterns. In the classic concept of exact graph matching, the aim is to determine whether two graphs are the same or whether a subgraph of one exists in the other.

The algorithm is based on graph isomorphism technique. Two graph are said to be isomorphic when there is a bijective relation. The outline of this paper is as follows. In section II related works are discussed. Section 3 explains the representation of model graph and design patterns in terms of relationship graphs is explained. The graph matching algorithm is described in section 4. In section 5 the design pattern detection is described using some examples. Lastly we concluded in section 6.

2. Related Workout

The first attempt for automatically detecting design pattern was by Brown [6]. In this work, Smalltalk code was reverse-engineered to facilitate the detection of four well-known patterns from the catalog by Gamma et al. [1]. Antoniol et al. [5] developed a technique to identify structural patterns in a system to observe how useful a design pattern recovery tool could be in program understanding and maintenance. Nikolaos Tsantalis [2] proposed a methodology for design pattern detection using similarity scoring. However, the limitation of similarity algorithm is that it only calculates the similarity between two vertices, not the similarity between two graphs. Jing Dong [3] gave another approach called template matching, which calculates the similarity between sub graphs of two graphs instead of vertices, to solve the above limitation. S. Wenzel [4] purposed a difference calculation method works on UML models. The advantage of difference calculation method on other design pattern detecting technique is that it detects the incomplete pattern instances also. Bergenti and Poggi [7] developed a method that examines UML diagrams and proposes the software architect modifications to the design that lead to design patterns. . Kim et al. Champin et al. [8] proposed a new method to recover the GoF1 patterns using software measurement skills. They developed a design pattern CASE tool to facilitate the easy application of their method. DPR method used three kinds of product metrics, and the measurement plan was established on the basis of the GQM paradigm. Many other tools have been developed for design pattern detection. But there is no standard tool for it that can be used to solve the maintainer's problem. Stencel and

Wegrzynowicz, [9] proposed a method for automatic design pattern detection that is able to detect many nonstandard implementation variants of design pattern. Their method was customizable because a new pattern retrieval query can be introduced along with modifying an existing one and then repeat the detection using the results of earlier source code analysis stored in a relational database. Drawback was that the method was not general enough to identify all design patterns. Further the translation of first order logic formulae as SQL queries is very laborious and error-prone.

In earlier work, klenberg approach was used for vertices scoring and fuzzy graph algorithms for design pattern detection. But the drawback of these two methods is they are only concerned about node similarity not the whole graph. Graph matching detection approach was used that overcomes this drawback [11]. We have used these and other approaches for design pattern detection in GIS application [12]. To reduce complexity of design pattern detecting algorithm we used the graph decomposition technique [13]. The order of complexity of this decomposition algorithm is O(n3), where n is the number of nodes present in the graph. This algorithm works for only those design patterns having similar relationships among at most three classes in its UML class diagram. However this condition may not hold for only few of the design patterns. Thus this approach can be applied for almost all of the design patterns. In another work we find out whether design pattern matches to any subgraph of system design by using decision tree [14]. A decision tree is developed with the help of row-column elements, and then it is traversed to identify patterns. By applying the decision tree approach, the complexity is reduced. We proposed a new approach 'DNIT' (Depth-Node-Input Table) [15]. It is based on the concept of depths from the randomly chosen initial node (also called root node which has depth zero) in directed graph. In another work we applied state space representation of graph matching algorithm to detect design patterns [16]. State space representation easily describes the graph matching process. The advantage of this method used for design pattern detection was that the memory requirement was quite lower than from other similar algorithms. Another advantage is that it detects variants as well as any occurrence of each design patterns. Inexact graph matching [17, 18] was also used for design pattern detection. We showed that normalized cross correlation can also be used for this [19].

3. Relationship Graph Representations

The system under study or the system for which we have the source code is taken first, the corresponding the class diagram of UML of that code (object oriented system) is drawn. After that the relationship graphs (that exists in UML diagram) is extracted. We have taken the UML Diagram of system designs shown in Figure 1. There are three relationships (i.e. generalization, direct association and aggregation), the corresponding relationship graphs (i.e. directed graph) are shown in Figure 2. Generalization relationship graph has relationship between only four of the nodes, Direct Association relationship graph (i.e. fig 3) has relationship between three of the nodes and Dependency relationship between two of the nodes.

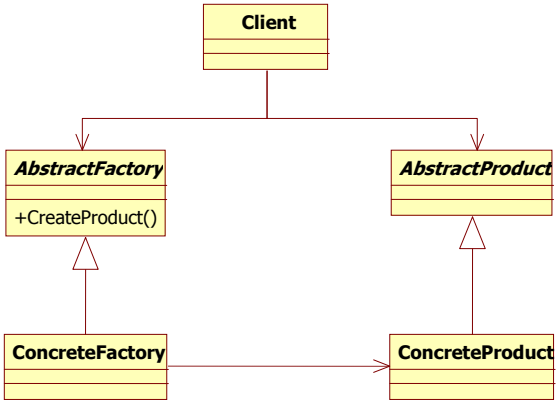


Figure 1: UML Diagram of system design [11]

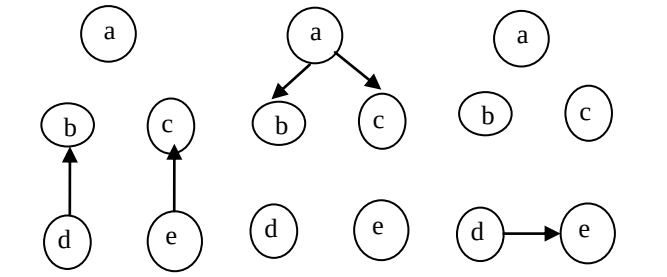


Figure 2: Corresponding Graphs for UML diagram shown in Figure 1

4. Graph Matching Algorithm

Let us consider a directed graph G (V, E), where V is a set of vertices (nodes) and E is a set of edges.

Consider two graphs, G_1 (V_1, $E1$) and G_2 (V_2, $E2$), and a matrix representing the correspondences between V_1 and V_2. Here $V_1$and V_2 denote sets of vertices, in graph G_1 and G2 respectively, similarly E_1 and E_2 are the set of edges in graph G_1 and G2 respectively.

The graph G1 and G2 are said to be subgraph isomorphic if there exist a subgraph S in G1 such that S is isomorphic to G2, i.e. There is bijective relation in S and G2.

The relationship graph of model graph and design pattern graph can be represented by using matrix, in which the (i,j)th entry of matrix can be represented by 1 if there is a relationship between node i and j, otherwise 0. One of the characteristics of such type of matrix is that we can interchange the columns.

Next we see whether the design pattern graph matrix exist in the model graph matrix or not. If all the rows and columns are completely exist then is fully matched. If some of the rows or columns exist the partially matching and if none of the columns or rows exist then no matching.

5. Design Pattern Detection Using Graph-Matching Algorithm

There are 23 GoF (Gang of Four) [1] design patterns. UML diagrams can be drawn for each of the corresponding design patterns. Here we are considering some of them. After checking

sub isomorphism between the relationships graphs of a design pattern and the model graph, there may be three cases:
i) Relationship graph of a design pattern is (sub) isomorphic to the model graph.
ii) Relationship graph of a design pattern is partially (sub) isomorphic to the model graph.
iii) Relationship graph of a design pattern is not (sub) isomorphic to the model graph.
In the case i) design pattern exist in model graph.
In the case ii) design pattern partially exists in the model graph.
In the case iii) design pattern does not exist in the model graph.
All these cases are described in detail by using examples.

5.1 Design Pattern Detection as Strategy Design Pattern: Exact Matching

Firstly, we are considering. Factory Design Pattern, the UML diagram and corresponding relationship graph (DPG) is shown in Fig. 3 and Fig. 4 respectively. In this case we find at least one minimum error (without having q) bijective matching such that for all matched nodes there corresponding edges are same.

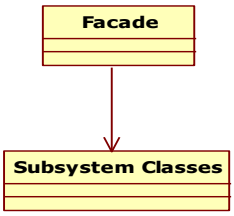


Figure 3: Factory Design Pattern

Figure 4: Direct Association Graph of Figure 3

Table 1: Direct association matrix for model graph of figure 2

	a	b	c	d	e
a	**0**	**1**	1	0	0
b	**0**	**0**	0	0	0
c	0	0	0	0	0
d	0	0	0	0	0
e	0	0	0	0	0

Table 2: Direct association matrix for Design pattern graph of fig 4

	1	2
1	**0**	1
2	**0**	**0**

Here the matrix shown in table 2 is fully matched with the matrix shown in the table 1. It is exact matching.

5.2. Design Pattern Detection as Command Design Pattern: Partial Matching

In some cases it is also possible that a particular design pattern partially exist in the system design pattern (case ii discussed in section 4). For example consider the Mediator Design pattern, the UML diagram and corresponding relationship graph (DPG) is shown in Fig. 7 and Fig. 8 respectively. In this case we will not find the fully matching, i.e. all the relationship graph are not fully matched. Some of the relationship matched and some of the not mtched.

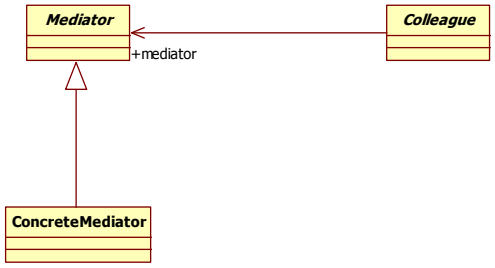
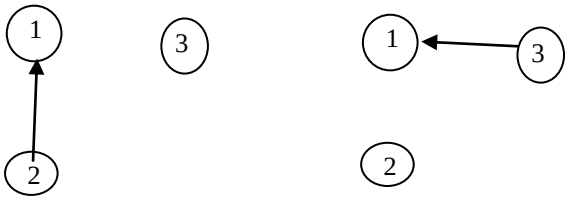


Figure 5: Mediator Design Pattern



Generalization graph Direct Association Graph

Figure 6: Corresponding Graphs for UML diagram shown in Figure 5

Table 3: Generalization matrix for model graph of fig 2

	a	b	c	d	e
a	**0**	**0**	0	0	0
b	**0**	**0**	0	0	0
c	0	0	0	0	0
d	0	1	0	0	0
e	0	0	1	0	0

Table 4: Generalization matrix for Design pattern graph figure 6

	1	2	3
1	0	0	0
2	1	0	0
3	0	0	0

Table 5. Direct Association matrix for design pattern graph figure 6

	1	2	3
1	0	0	0
2	0	0	0
3	1	0	0

In the mediator design pattern there are two relationship graph there i.e. generalization and direct association and corresponding matrices are shown in table 4 and Table 5 respectively. If we interchange the columns of the generalization matrix (Table 3) of model graph, then the generalization matrix (Table 4) of design pattern graph matched, but the direct association matrix (Table 5) of design pattern graph does not match with the direct association matrix (Table 1) of model graph. Here out of two relationship one matched, but one not. So there is a partial matching between System design and design pattern.

5.3 Particular design pattern may not exist

Above we have seen the examples of design pattern existence (complete or partially) but it can be possible that a particular design pattern does not exist in the model graph. In this case we will not find any matching between relationship matrices. For example if we take singleton design pattern (Fig. 7), there is only one relationship: direct association on itself node. Corresponding DPG is shown in Fig. 8 and its matrix is shown in Table 6. Here there is no matching in the direct association matrix (Table 6) of design pattern and direct association matrix (Table 1) of system design.

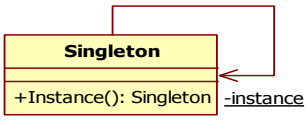


Figure7 : Singleton Design pattern

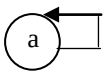


Figure.8: graph for figure 7

Table 6: Direct Association matrix for figure 8

	a
a	1

6. Conclusion

This paper presents an approach for design pattern detection using subgraph isomorphism technique. We took the relationship graphs of the model graph (MG) and a design pattern (DPG), after that the corresponding relationship graph, matrices are created and then the sub graph isomorphism is applied on both of the graphs and tried to find out the bijective mapping. If for this bijective matching, the matched nodes have the corresponding edges, we say that the design pattern exist in the model graph. If for the matched node no corresponding edges are found, design pattern does not exist in the model graph, and if for the matched nodes some of the corresponding edges are found and some are not found, we say that design pattern partially exists in the model graph.

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