Investigating Patterns of Contemporary Architecture using Data Mining Techniques

Rabee M. Reffat
Architecture Department, King Fahd University of Petroleum and Minerals, Dhahran, 31261, Saudi Arabia
http://faculty.kfupm.edu.sa/arch/rabee
rabee@kfupm.edu.sa

Abstract. *This paper addresses the utilization of Data Mining as an advanced technique of information technologies to investigate and identify the patterns of architectural features of contemporary architecture in Saudi Arabia in two suggested building types: houses and commercial office buildings. Such patterns will help in developing a model of patterns of architectural features that can be utilized to augment the architectural context of Saudi Arabia. The paper presents a constructed framework that provides a comprehensive analysis of recognition criteria for identifying each architectural feature of the nominated set of nine features. These architectural features include: spatial relationships, space allocation, circulation, building form, façade treatment, building structure, external finishes, environmental aspects, and cultural features. The recognition criteria for these architectural features are expressed in the attribute-value format. Such criteria are extracted for houses and commercial office buildings specifically within the context of Saudi contemporary architecture based on extensive case analysis that represents the diversity of architectural designs of houses and commercial office buildings. The paper also, introduces a process model of applying Data Mining for investigating patterns of contemporary architecture.*
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Introduction

The construction industry has adapted information technology in its processes in terms of computer aided design and drafting, construction documentation and maintenance. The data generated within the construction industry has become increasingly overwhelming. Furthermore, past experience often plays an important role in future buildings. Therefore, applying data analytic techniques to efficiently deal with information of existing buildings has the potential to improve the architectural context of new buildings specifically and the environment within which these buildings will be constructed and used. Traditional methods of data analysis such as spreadsheets and ad-hoc queries are not adequate

since they can only create informative reports from data, but cannot analyze the contents of these reports. Hence, there is a significant need for a new generation of techniques and tools with the ability to automatically assist humans in analyzing a large amount of data to provide useful knowledge within the architecture and construction industry. This research aims to utilize Data Mining as an advanced technique of information technology to investigate and identify the patterns of architectural features of Saudi contemporary architecture.

The role of patterns in architecture

Every place is given its character by certain patterns of events that are not necessarily human events. For instance, the sunshine shining on the windowsill, the wind blowing in the grass are events that affect the users just as much as social events. Therefore, a building or a town is given its character, essentially by those events which keep on happening there most often. The standard patterns of events vary very much from building to building, and from culture to culture. But each town, each neighborhood, each building has a particular set of these patterns of events. Hence, the world has a structure in which certain patterns of events (both human and nonhuman) keep repeating and are always anchored in the space. Certainly, a culture always defines its patterns of events by referring to the names of the physical elements of space which are standard in that culture. These patterns of events are always interlocked with certain geometric patterns in the space. Each building and each town is ultimately made out of these patterns in the space; they are the atoms and molecules from which a building or a town is made. On the geometrical level, certain physical elements are repeated endlessly and combined in an almost endless variety of combinations.

A building is made of elements (including walls, windows, doors, rooms, ceilings, nooks, stairs, terraces, etc.), that are repeated over and over again. Further, it might be puzzling to realize that these elements which constitute the building blocks of a building keep varying and are different every time that they occur. If these elements are different every time that they occur, then it can not be the elements themselves which are repeating in a building. Therefore, these elements can not be the atomic constituents of space. One needs to look more carefully at the structure of the space from which a building is made to find out what is really repeating there. Beyond its elements each building is defined by certain patterns of relationships among the elements. Evidently, a large part of the structure of a building consists of patterns of relationships. Initially it seems that these patterns of relationships are separate from the elements but in fact the elements themselves are patterns of relationships to an extent that the things which seem like elements dissolve and leave a fabric of relationships behind which are the constituents that gives the characters to a building, town or a country. Hence, each pattern of relationships in a space or a building is congruent with some specific pattern of events. For instance, an expensive restaurant gets its structure and character from its patterns. Similarly, the city of London gets its life and structure from its patterns too. It is important to note that the repetition of patterns is quite a different thing from the repetition of parts (Alexander et al, 1979).

Each pattern is a three-part rule, which expresses a relation between a certain context, a problem, and a solution. As an element in the world, each pattern is a relationship between a certain context, a certain system of forces which occurs repeatedly in that context, and a certain spatial configuration which allows these forces to resolve themselves. Patterns offer a technique for capturing design and architecture, presenting and communicating architectural knowledge at all levels of a system, allowing experience to be understood and distilled. Patterns allow developers to work on and understand designs, and are not a basis for automation of design; frameworks and libraries present code-level reuse often built on common patterns.

Data Mining and identification of patterns

Data Mining is a process that uses a variety of data analysis tools to discover patterns and relationships in data that may be used to make valid predictions. Data Mining finds patterns and relationships in data by using sophisticated techniques to build models and abstract representations of reality. Data Mining (DM) techniques are tools that allow identification of valid, useful, and previously unknown patterns so that one can use to analyze a substantial set of projects. These technologies combine techniques from machine learning, artificial intelligence, pattern recognition, statistics, databases, and visualization; and can help to automatically extract concepts, interrelationships, and patterns of interest from large data set (Witten and Frank, 2000; Han and Kamber, 2001).

Data Mining (also known as Knowledge Discovery, KD), has been defined as "the nontrivial extraction of implicit, previously unknown, and potentially useful information from data" (Frawley et al, 1992). It uses machine learning, statistical and visualization techniques to discover and present knowledge in a form that is easily comprehensible to humans. Mining data enable humans to understand how systems that were once thought to be completely chaotic actually have predictable patterns. Through KD, the patterns and causal relationships behind can be found in AEC (Architecture, Engineering and Construction) projects data. By applying KD to identify novel patterns, designers will be able to build knowledge models that may be used for the recurrent activities of on-going design projects, as well as for future project activities, and avoid unanticipated consequences (Soibelman and Kim, 2002). It presents a significant potential for addressing the problem of transforming knowledge implicit in data into explicit knowledge for decision makers.

Data Mining techniques have been employed for extracting additional information from hypermedia cases and incorporating the knowledge into the case-based model of structural designs wherein knowledge discovery techniques were integrated in the learning loop (Maher and Simoff, 1998). Reffat et al (2004 a and b) have utilized Data Mining in improving the maintenance and management of buildings during their life cycle. Applying Data Mining of building maintenance has helped to discover: procedures that reduce future failures; repairs or maintenance operations that are being done improperly; ways to improve repairs that reduces subsequent down time; undocumented methods being used by experienced personnel that result in reduced down time; and advance notice of likely failures before failures occur. Such discoveries can be used to modify building maintenance and repair procedures thereby reducing downtime, increasing uptime, and significantly reducing the costs of maintenance and repair.

In contrast to traditional methods of statistical data analysis, Data Mining (DM) is an automated process that discovers new trends and patterns without the need for human intervention. DM takes input variables whose relevance may not be obvious to a designer but which becomes evident as result of this process. In addition, DM makes no prior assumption about the probability distribution of the input variables (Gaussian, Poisson, etc.), as is required in statistics, and is therefore more robust and general. However, like other methods, the process of transforming the data to be in a format suitable for knowledge discovery is not automated and has a large impact on the results obtained. In this research, the utilization of Data Mining aims to analyze the Saudi contemporary architecture through investigating the patterns within and between a set of identified architectural features.

Contemporary architecture in Saudi Arabia

Traditional architecture of Saudi Arabia has been thoroughly investigated. On the other hands, the contemporary architecture in the Arab states generally and Saudi Arabia specifically has never been investigated at any comprehensive level (Kultermann,

1999). In the last 40 years, development has been rapid and sensational. Kultermann (1999) has made an attempt to gather material on the contemporary architecture in the Arab states in order to create a basis for later evaluation. Since 1960s and as result of the building frenzy, buildings and cities, office and commercial buildings, university campuses and housing estates are continually under construction. Fascinating environments with new sets of solutions have been created in Saudi contemporary architecture. Investigating patterns of architectural features is essential since they form the elements of architectural composition and character.

Saudi Arabia encompasses a greater variety of architectural styles than any other country in the Arabian Peninsula. The buildings of the coastal, mountain and plains regions are entirely distinctive and local in their character. King (1998) described the characteristic features of the vernacular style for the towns and villages of each region - the Red Sea coast, the northern inland oases, the southwestern mountains, the central plains of Najd and the eastern Gulf Coast - and how buildings were used. Furthermore, King (1998) has provided a detailed description of building materials, construction techniques and technology in the use of coral, plaster, mud brick and stone. In Saudi Arabia, modernism in planning and architecture was adopted in the 1950s. In the late 1970s a postmodern trend emerged – it introduced new and distinguished typologies of urban and architectural works, some of which became landmarks. The result is the radical heterogeneity of the contemporary Saudi city. Though contemporary architecture is not rooted in tradition, it has certain essential qualities that are not peculiar to the time when the buildings were constructed. Perhaps their most significant quality is their scale and accommodation of new emerging functions (Eben Saleh, 2001). The architectural contemporary thinking in Saudi Arabia has been studied by Al-Harbi (2002), especially in El-Hegaz in three time periods: a period before oil, a period after oil and a period of entering into globalization era. That study has attempted to understand the direction of contemporary architecture in El-Hegaz in particular, and in Saudi Arabia in general. This has been looked at through new revolutionary directions of buildings in Saudi Arabia taking into account the laws of building in Saudi Arabia, design thinking of Saudi architecture, and the way of producing that thinking in architectural designs.

Contemporary architecture in Saudi Arabia seems to be oriented toward the assimilation of emerging technological aspects rather than human aspects. It has emphasized on the role of technology to remedy the fault of architects in solving environmental issues. The adaptable architectural form need to be designed to respond to environmental conditions and considerations. Unfortunately, the practice of customizing individual physical identity in designs, in which an appropriate atmosphere of determinant forces can not be found, has made it difficult to sustain Saudi traditions in the contemporary architecture. A rapidly changing lifestyle has led to modifications in the built form and its environment. The influence of the modernism ideal was expressed in the planning and design of Saudi's post traditional era in the1950s. The imprints of successive phases of urban development and their planning principles are still evident in the morphology of newly built neighborhoods (Eben Saleh, 2002). Furthermore, modernity has become one of the inseparable components of Arab cities including Saudi Arabia to the extent that we can no longer talk about an imported modernity and an authentic heritage. Arab architectural modernity is present today before our eyes and we do not need to invent it or create it anew. It is present with all of its richness and problems, its beauty and ugliness, and its liveliness and contradictions. As in most of the world, modernity in Arab cities has the good and the less good, the beautiful and the ugly. What is important is that modernity has now become a part of our architectural heritage (Thabet, 1998). Therefore, the contemporary architecture should be thoroughly investigated and dominant architectural featured should be identified.

Features of contemporary architecture in Saudi Arabia

While a major part of architectural design and inquiry into understanding design vocabulary concerns itself with aesthetics, feelings, visual, mental and sensual dimension, many other set of aspects relate to physical dimensions of building. The ultimate aim of this research is to develop a model of patterns of architectural features that might be utilized to augment the architectural context of Saudi Arabia. This will be supported by: (a) identifying the pattern of architectural features in the Saudi contemporary architecture and determining the occurrence rates of these patterns, and (b) identifying the interrelationships between these patterns and various contexts within which they occur.

It is important to note that there are not only patterns within a certain architectural style but there are also patterns of changes in the architectural styles (Meinecke, 1996). Such changes can be captured by the occurrence rate of patterns over a period of time. In this research, we have selected two building types (houses and commercial office buildings) to be analyzed from the Saudi contemporary architecture. The primary reason for this selection is their dominance within the Saudi contemporary architecture. A set of nine architectural features have been identified to investigate their patterns and interrelationship between these patterns in the suggested building types. The nominated set of nine architectural features includes: spatial relationships, space allocation, circulation, building form, façade treatment, building structure, external finishes, environmental aspects, and cultural features. An extensive literature review was conducted on these architectural features and how they were expressed (developing a set of attributes and values), in building designs generally and in houses and commercial office buildings specifically within the context of Saudi contemporary architecture. In this analysis, extensive literature review has coincided with exploratory site visits to the selected three cities to guide and support the appropriateness of such analysis. This analysis was essential in developing selection criteria of a rich set of buildings that represent the diversity of architectural designs of houses and commercial office buildings in Saudi contemporary architecture.

Identification of recognition criteria for nominated set of architectural features

As a result of the above process, the recognition criteria for each architectural feature of the nominated set of nine features have been identified for detached houses, complex apartments, and office buildings. An example of the recognition criteria for detached houses is shown in Table 1.

Process model of applying Data Mining for investigating patterns of contemporary architecture

Data Mining techniques will used to perform the Data Mining functions, including summarization, association, classification, prediction and clustering. The results obtained from applying various Data Mining techniques will be thoroughly evaluated. Patterns of architectural features in the Saudi contemporary architecture of houses and commercial office buildings will be investigated; the occurrence rates of these patterns of architectural features will be determined. Furthermore, the interrelationships between these patterns of architectural features and various contexts (city and national levels) within which they occur will be discovered using Data Mining techniques. The discovered and learned knowledge using Data Mining will be presented in the form of patterns, rules and relations as illustrated in the process model shown in Figure 1. The process model includes the following elements:

- Establishing the Mining Goals: This involves the identification of patterns of architectural features and relationships among them as recognized in the data sets.
- Selection of Data: This step identifies a subset of variables or data samples, on which mining can be performed. There will be many tables in the

Features	Attribute	Values
1. Spatial relationship	Functional Requirement	Visiting, living, cooking, playing, sleeping
2. Space allocation for each house space	Functional Relationship	Strong / Medium / Weak
	Allocated space	Minimum / Medium / Maximum
3. Circulation	Horizontal circulation	Type (linear, radial, clusters, grid, hierarchical, distributed, etc)
		Percentage of circulation space to total built area
	Vertical circulation	Type and number (staircases, elevators)
		Percentage of circulation space to total built area
	Disabled access	Type (ramps, elevators)
4. Building Form	Organization	Centralized / Linear / Radial / Cluster / Grid
	Orientation	N / NE / E / W / NW / S / SE / SW
	Height	One floor / Two Floors / More than 2 floors
5. Facade Treatment	Main Entry Façade direction	N / NE / E / W / NW / S / SE / SW
	Fenestration pattern	Regular / Asymmetry / Symmetry / Irregular
	Façade Style	Heritage / Modern / Post-Modern / Minimalism
6. Building structure	Single- family detached houses	
	Semi-detached	
	Terraced-house or row house	
	Concrete	Precast concrete forms, removable concrete forms, concrete masonry, Autoclaved Aerated concrete, insulating concrete forms
	Post and beam structure	
	Load bearing wall structure	
7. External Finishes		Thermal behavior / Climatic compatibility / Environmental Impact
	Marble	
	Paint	
	Masonry	
	Granite	
	Stone	
	Others	
8. Environmental Aspects	Building Envelope	Adaptability, Affordability, Energy efficiency, Durability, Degree of interaction, (Intelligence), Health/comfort
	Shading devices	
	Thermal Insulation	
	Glazing	
	Lighting	
	HVAC	
	Indoor quality	
9. Cultural Features	Psychological factors	Satisfaction, dissatisfaction
	Social factors	Privacy (Separation between men & women)
	Contextual factors	Government regulations (set-back, design specifications, built-up area of land coverage)
	Geographical factors	Environment and climate (humidity, temperature, wind speed

Table 1
Identified recognition criteria for each architectural feature of the nominated set of nine features for detached housing.

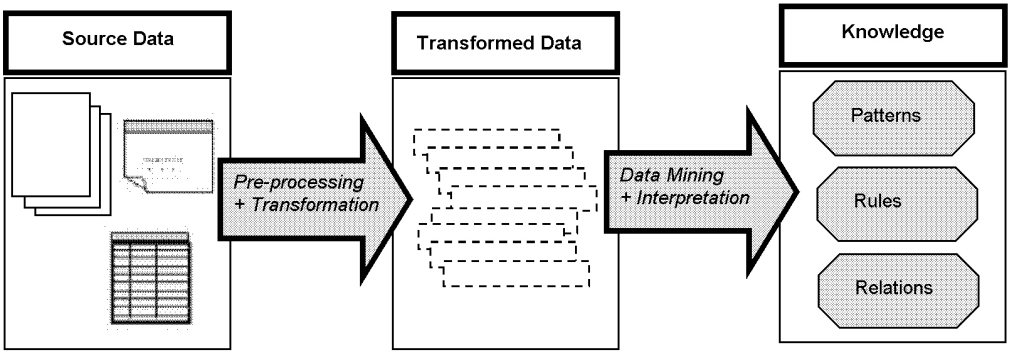

Figure 1
Forms of knowledge discovered from the transformed data set using Data Mining techniques.

database but not all of them are suitable for mining since some might not be sufficiently rich.

Extensive and through data collection has been undertaken of houses and commercial office buildings' related design information from city councils and municipalities, architectural offices in the three selected cities of Riyadh, Jeddah and Dammam. This collection is based on the selection criteria that include: (a) collecting the samples of the dataset from districts that best represent the diversity of contemporary architecture at each of the three selected cities; (b) selecting buildings that are built from the 1960s to present; (c) priority of the selection is assigned to buildings with award-winning, and/or designed by world renowned architects, and/or presenting a distinctive school of thought in architecture; and (d) housing samples cover single detached villas and multi-story apartments buildings. The total collected data size is 585 buildings while the target was 150 building.

- Data Pre-processing: This step aims to remove the noisy, erroneous and incomplete data. The presence of too many different categories of data makes visualization of the displayed information very difficult.
- Data Transformation: The data stored in the various tables are required to be in a specified format. Sometimes, it is useful to transform the data into a new format in order to mine additional information.
- Data Warehousing: Data warehousing is the process of visioning, planning, building, using, managing, maintaining and enhancing databases. The data will be stored in WEKA's data warehouse. WEKA (Witten and Frank, 2000) is a collection of machine learning algorithms for solving real-world Data Mining problems. The algorithms can either be applied directly to a dataset or called from your own Java code. WEKA not only contains tools for data pre-processing, classification, regression, clustering, association rules, and visualization, but is also suitable for developing new machine learning schemes. In this research both WEKA and IBM Intelligent Miners will be utilized in mining the data.

Conclusion

Studies on Saudi contemporary architecture have been quite limited especially from the perspective of identifying the patterns of architectural features and emerging architectural styles in the contemporary buildings in Saudi Arabia. Such study is crucial to construct the contemporary architectural image of Saudi Arabia and to guide future building developments of the most dominant patterns that can be utilized to form the character of Saudi contemporary Architecture. Without the identification of such patterns for the Saudi contemporary architecture, new buildings will be designed and constructed with old,

present or new architectural concepts that might distort the charter of Saudi architecture rather than enforcing or enriching the current architectural character if these sets of architectural patterns were identified and used to conceive the design development of new buildings.

This paper introduced the utilization of Data Mining as an advanced technique of information technologies to investigate and identify the patterns of architectural features of contemporary architecture in Saudi Arabia that will help in developing a model of patterns of architectural features that can be utilized to augment the architectural context of Saudi Arabia. A framework that provides a comprehensive analysis of recognition criteria for identifying each architectural feature of the nominated set of nine features has been conducted. Furthermore, a process model of applying Data Mining for investigating patterns of contemporary architecture has been introduced.

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