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in a
NETWORKED
DESIGN WORLD

ADDED VALUE OF COMPUTER AIDED
ARCHITECTURAL DESIGN

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Knowledge Model for Cultural Analogy in Design and Design Education

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Keywords

Abstract

Almost every architect uses analogy while designing. The source of inspiration is nature, technology, geometry, etc., besides the influence of the work of other architects. Analogy in architecture has a close relationship with culture as well. Culture is a dynamic occurrence and evolves by the influence of many aspects such as technological, economical, environmental and social. In the process of design, architects built op knowledge from their own experience and designs, but also from the other designers work. Usually, architects develop this quality and ability during the education, and later by trial and error methodwhile practising the design. This is habitually done based on own conscience, intuition and experience.

The developments in ICKT (Information, Communication and Knowledge Technology) as a part of broader technological developments and the ongoing globalisation, influences the culture as a dynamic process and therefore the architecture.. It is necessary to make these influences explicit for their embedding in architectural design education of young professionals. This can be achieved by transferring the resulting knowledge to a knowledge model by using intelligent modelling techniques. The operational aspects of design analogies to be implemented in education, research and the daily practice of designing architects need attention. This paper discusses the operational aspects of *cultural analogy* in design by using an intelligent computational modelling approach.

Introduction

Simply, the human being learn from the environment where he/she live by contact, by observing nature, happenings, objects and people. In this way, human being get inspiration from the surrounding and other people. This basic observational phenomenon also shows itself in architectural daily practice. The place of the designing architect in the building process is extraordinary and unique, because of the fact that architecture as

a profession deals with *alpha*, *beta,* and *gamma* sciences (Sariyildiz et al., 2002). It is expected from an architect to combine and totally intermingle these three sciences in the ultimate design result, in buildings and the built environment. In this respect, the *alpha* scientist deals with the subjective world of beauty and moral, as expressed by the artistic, intuitive soul. The b*eta* scientist brings in the objective world of facts and logic, represented by the rational mind. The g*amma* scientist considers the interest of the society and culture. The expectation from an architect is to integrate all these sciences in his or her design work and this expectation makes the task of an architect complex, but also unique and challenging.

The well-known and successful architects such as Santiago Calatrava, Frei Otto, Buckminster Fuller have used analogy in various forms (see figure 1). It goes back to Michelangelo who was highly motivated by animal movements and the human skeleton.. In Calatrava's buildings, the inspiration of animals' movements and the skeleton can be seen very clearly in his buildings and structural design, where he even gets the encouragement to built kinetic structures.

Frei Otto, the founder of the Development Centre for Lightweight Construction, used models to define and test complex tensile shapes. Since 1972, Otto has studied biological structures and researched grid shells. As the scale of his projects increased, Otto pioneered a computer-based procedure for determining their shape and behaviour. He often created pavilions composed of primary membrane elements in an additive series. He also developed a convertible roof with a variable geometry.
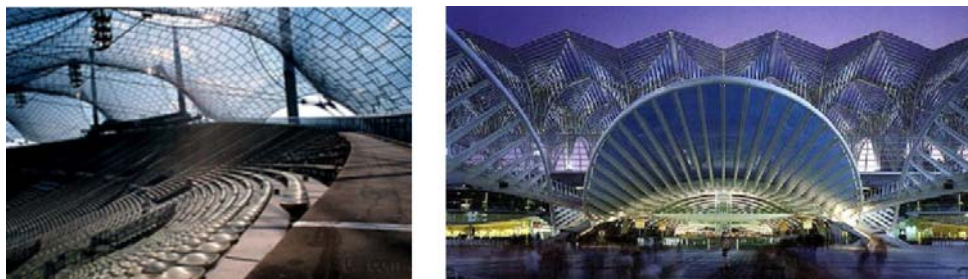

Figure 1. Examples of analogy with nature: Munich Olympic stadium by Frei Otto;
Oriente Station at Lisbon, Portugal by Santiago Calatrava.
http://www.greatbuildings.com/architects/Frei_Otto.html
http://www.calatrava.com/

As mentioned earlier, the source of inspiration of many architects in the design is mostly nature, technology, geometry, and other architects' works besides the, cultural and historical, values which play an important role in design. Before going into *cultural analogy*, first we should analyse what culture is. There are many definitions of culture. Below are a few of these definitions (Mora, 1998):

- The sum total of a way of life of a people; pattern experienced by individuals as normal ways of acting, feeling and being.
- A dynamic system of symbols and meanings that involves an ongoing, dialectic process, where past experience influences meanings, which in turn affects future experience, which in turn affects subsequent meaning, and so on.

- The explicit and implicit patterns of behaviours, symbols and ideas that constitute the distinctive achievements of human groups.
- That complex whole which includes knowledge, belief, art, m o r a l s,   l a w, custom and any other capabilities acquired by humans as members of society.
- Discrete behaviours, traditions, habits or customs that are shared and can be observed.

From our understanding, culture is not something special, extraordinary. It is the complex of everything related to the way of daily life; belief, art, food, shelter, law, moral, custom, knowledge and architecture are all part of a culture.

Many factors influence how cultural values are formed. These can be environmental adaptations, historical factors, social, economic, ecologic and *technological evolution* and *contact with other cultures*. Our focus will be on the *contact with other cultures* from the architectural analogy point of view, which we will point out as *cultural analogy*. We will look at *technological evolutions* and their influence on architectural education and practice.

Contact with other cultures / Cultural analogy

Culture is a dynamic phenomena and evolves by the influence of above-mentioned main aspects. One of the aspects in relation with cultural analogy is the contact with other cultures. The architectural history of Spain is a wonderful example of the cultural influences in buildings and built environment in this country. When the Moorish came into Spain in 711 AC, Cordoba became the capital of Spain and Spain was the most prosperous country of Europe where people from different cultures and religions lived in great harmony together like Jews, Christians and Muslims. In 786 AC , Moorish built the famous mosque of Cordoba as a place of worship while at the same time; this mosque was used as an educational space where each niche was used for different educational subject (see figure 2).
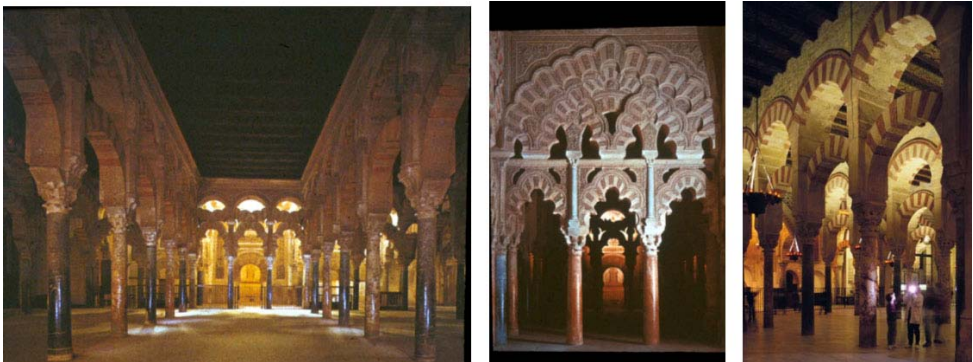

Figure 2. Cordoba mosque, interior arches.

Till the ninth century, before the invention of book print, knowledge exchange found place in the monasteries in Europe, as in the case of Cordoba. The mosque of Cordoba was used as a center for higher education (equivalent to university) and as a prayer hall at the same time. In that period, the Moorish possessed highly developed knowledge on science, culture, art and architecture, in particular on the field of geometry, mathematics,

physics, chemistry, astronomy and building techniques. In present-day terms, the Cordoba Mosque was an international university where students from various European countries came to study.

In his book on the construction of cathedrals, prof.Gout (1990) discusses the origin of technical knowledge in the construction of medieval cathedrals. He mentions that the recent investigations have revealed that this knowledge partly dates back to the Roman Empire, but that it is certain that a significant part of this applied science also comes from the Arab world. Moorish universities in the south of Spain, for instance the university established in the Cordoba Mosque, possessed extensive knowledge on this subject. Students from Western Europe went there regularly to complement their knowledge, sometimes enabled to do so through special student grants. This even occurred so frequently that in the twelfth century the University of Toledo decided to give lectures in Latin, rather than in the original Arabic, especially for visiting students. These foreign students who graduated there, went back to their countries and started to build well-known monumental buildings of the Middle Ages such as the cathedrals of Chartres, Reims and Amiens in France (see figure 3).
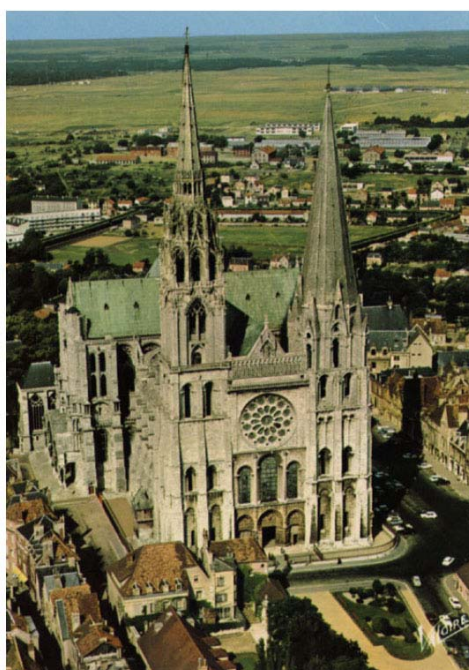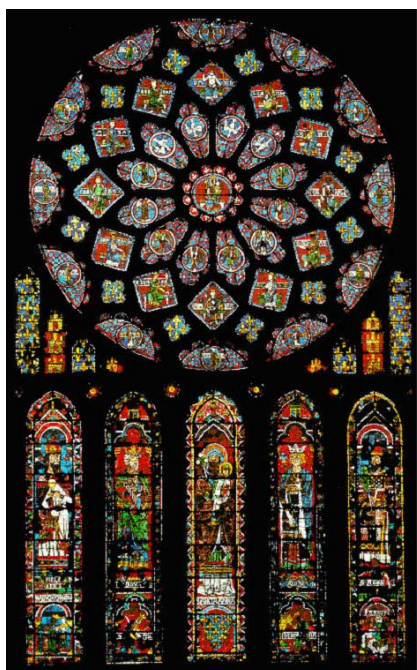

Figure 3. Entrance and rose window of the Cathedral of Chartres, France.
<http://www.cs.princeton.edu/~ken/chartres.jpeg>

During the last decades, as a result of technological developments, the exchange of information and knowledge has highly increased between people worldwide, including scientists and architects. These exchanges are necessary between science and technology, and in order to achieve innovations in our field of science, where the integration of various disciplines is required.

The result of the cultural influences of the Moorish and their exchanges with other

cultures can clearly be seen in Spanish buildings, as well as in urban planning in Spain. The living style of the Moorish which is adopted by Spanish is still very visible in the patio houses, where the interior open space with an orange tree, preserves the feeling of privacy, and the introvert way of daily life of the Moorish culture (some examples can be seen in figure 4). One of the main characteristics of the Islamic cities is the natural growth without planning, in contrast with cities in western cultures with triangular, circular, or radial city planning grids. Therefore, the streets of this natural-growth, non-planned cities in Islamic cultures almost always end up with an astounding building at the end. As a pedestrian, walking through the street arouses one's curiosity to see what will appear at the end of the street; the street is not straight and ends with a small tower or leads you to a new square or courtyard (see example in figure 5).

Figure 4. Moorish Patio houses in Cordoba and in Morocco.
http://www.travelinginspain.com/cordoba.jpg
http://www.ural.ru/gallery/news/countries/europe/spain_cordoba.jpg
http://www.riad-darna.com/*images/*PageAccueil/Porte45.jpg

Figure 5. Narrow medieval streets of Cordoba_Spain and Morocco.
http://*www.personal*.psu.edu/staff/j/x/jxf17/spain2002/Cordobastreet.jpg

Pattern Grammars

Every human society in the history has made use of patterns, from China to South America, from Asia to Europe; various cultures emphasize different aspects. Patterns are used for various purposes, such as in tiling, carpets, window decoration, woodcraft, book covers, etc. Geometrical patterns recur throughout the history of architecture and the arts form its starting point. These patterns have not only been used to decorate buildings, but also to arrange load-bearing structures.

In Islamic cultures, Arabs, Moors and Turks used more complex geometric patterns, because it is not allowed to use sculptures and portraits of human beings and animals in religious buildings.. In these buildings patterns are used mostly as decoration elements and in brickwork. There are few examples where patterns were used as a 3D structural element. The examples of Cordoba Mihrab and the Alhambra palace are the most famous ones (see figure 6).

Figure 6. Corner detail and cupola of Alhambra Palace, Granada, Spain.
Photo's by Dr. H.Umar

The art of designing patterns is clearly very old and well developed, but in contrast, the science of patterns, the study of their mathematical properties, is comparatively recent. (Sariyildiz 1991, Grünbaum and Shephard 1987). In the development of a pattern grammar, patterns are treated as three-dimensional polytopes and polyhedrons so as to use them as an under layer in different phases of the architectural design process.

A cube, for instance, may be defined as a convex body, bounded by six equal planes, each of which is bounded by four equal lines and each line by two points. In each case, three equal lines converge, each of which form the boundary between two equal planes. Irrespective of the length of each line, it unquestionably defines a cube.

The simplest topological forms are the platonic bodies (regular polyhedra: tetrahedrons, cubes or hexahedrons, octahedrons, dodecahedrons and icosahedrons). Archimedean and Catalan bodies result from taking away the angles (flattening) and extending parts (pointing). All these forms can be characterized unequivocally by structural formulas. When a pattern is produced, it has form and structure at the same time (see figure 7).
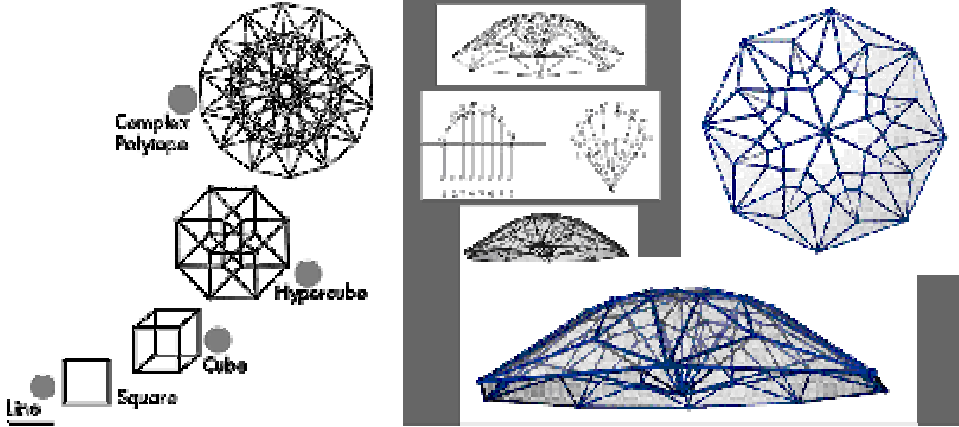

Figure 7. Left: Geometrical transformations of a cube-analogy
<http://www.qaimlyn.com/alaria/4d/analogy.gif>;
Right: Cupola design by means of pattern grammars by Sevil Sariyildiz.

The most recent example of cultural analogy in design by the use of Islamic geometric patterns is the Kuala Lumpur towers designed by Cesar Pelli, in Malaysia (see figure 8). These towers are the highest skyscrapers in the world. Cesar Pelli used patterns to generate the form and structure of the towers, which gives a certain cultural character to the country or city area, while using the cultural elements of Islamic architecture.

Figure 8. Kuala Lumpur tower and ground floor plan derived from Islamic pattern
Source: Cesar Pelli Associates-USA
http://travel.u.nu/pic/my/ petronas.jpg
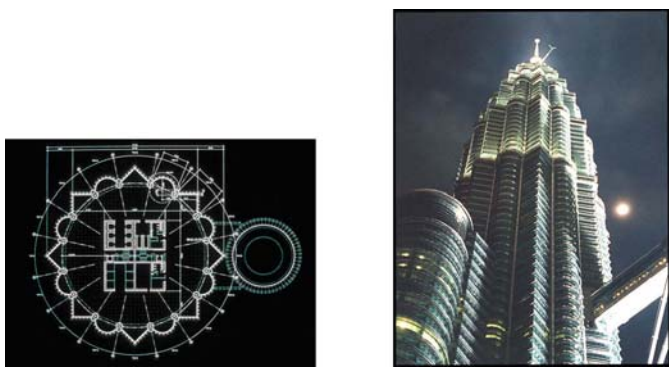
Technological Evolution

During approximately the last 200 years, the technological developments went rapidly compared to the ages before. For example, due to the invention of construction iron and the peoples' lift, it became possible to build high-rise buildings. Inventions in transportation such as car, train and aeroplane made it possible for our cities to become mega-cities or metropolitan areas. Developments in ICKT, together with other technological developments, have influenced the behaviour of human beings, caused changes in our society as a result. Therefore, we are increasingly dealing with globalisation issues and their effects on culture and architecture, which we denote cultural analogy in architecture.

Like in other sectors, the building sector and architecture are influenced by these developments. As an example, the commercialisation of advanced modelling software resulted in creative-digital design in architecture (see figure 9). In the building practice, there are already architects designing and building by using these tools (e.g., Gehry, Novak, Oosterhuis, Spuyboek, Lynn).
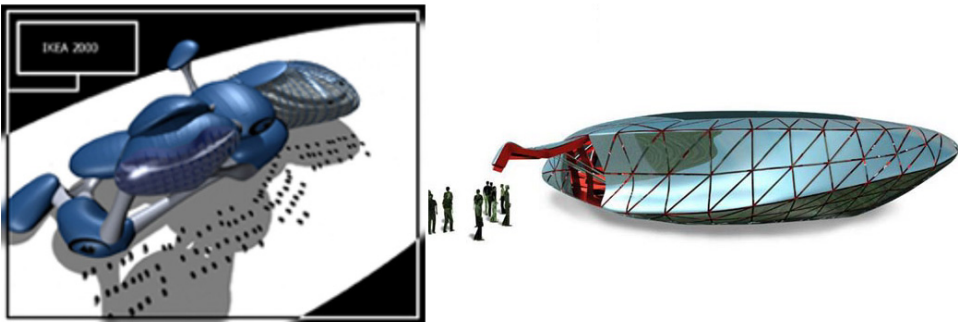

Figure 9. Ikea building (student) design by the late Thomas Dubbink; and Web North Holland by kas Oosterhuis

The objective of science is the well-being and prosperity of mankind as a whole, and it is not restricted to specific target groups. The results of the knowledge developed are universal, and consequently all scientists are responsible to mankind and their function is essential for future generations. We may not confine ourselves to one country alone. Science knows neither frontiers nor nationalism; it did not do so in earlier times, it does not do so today, nor will it do so in the future. Nevertheless, in architectural science, it is necessary to pay attention to the local cultural aspects of architecture, in order not to lose "cultural diversity" in the built environment. Multiculturalism in architecture and the diversity of architecture is an added value in itself. Through the influence of globalisation and as a result of analogy with respect to famous architects, there is a tendency to build the same type of buildings anywhere in the world without considering the cultural values of the location, or a target group of people. The character of a country or region, in terms of cultural architectural values, is being lost. Our buildings and our

cities are all becoming similar and difficult to recognize them if you are in China, Frankfurt, Singapore, New York, . The only recognizable architecture of the cities, which provides character to those cities, is the buildings of famous architects or buildings with a certain character such as the Sydney opera house (demonstrated by figures 10 and 11). We see that in the last decades famous architects are being recognized within a city or a country by their architecture rather than by their use of traditional cultural elements of the location. For example, the city of Bilbao became famous with the Guggenheim museum of architect Frank Gehry. This was also the purpose of the governors of the city, to make the city attractive for tourists.

Figure 10. Kuala Lumpur skyline and Sydney skyline
http://www.enthios.com/runawaytrains/ContactSheet/KualaLumpur
http://www.8ung.at/photomaze/lpics/sydney.jpg

Figure 11. Frankfurt skyline
http://www.mi.informatik.uni-frankfurt.de/images/frankfurt_skyline.jpg

Modelling Cultural Analogy for Education

It is necessary to make explicit to architecture students which they aware of the various social and cultural aspects that play a role in the design process of the product. We are experimenting with a didactic model whose goal is to be a container for *meta-data* that can be used as a design backbone. This model is based on four characteristics that are important with respect to social processes: constructive, objective, relational and subjective characteristics (Kooistra and Hopstaken 2002, Stouffs et al. 2003). The space defined by these characteristics can be said to define a domain, a theme, or a culture. When we apply these characteristics in the context of architecture, we can make architectural analogies about each characteristic. The objective characteristic defines the functionalities or program of a building. The constructive characteristics define the idea or building type. The subjective characteristics define one's reason to go to a building. The relational characteristic defines the energy that is needed to make this building continue to exist. Physical architecture is mostly concerned with the constructive and objective characteristics. However, it is very important for an architecture student to be fully aware of the subjective and relational characteristics.
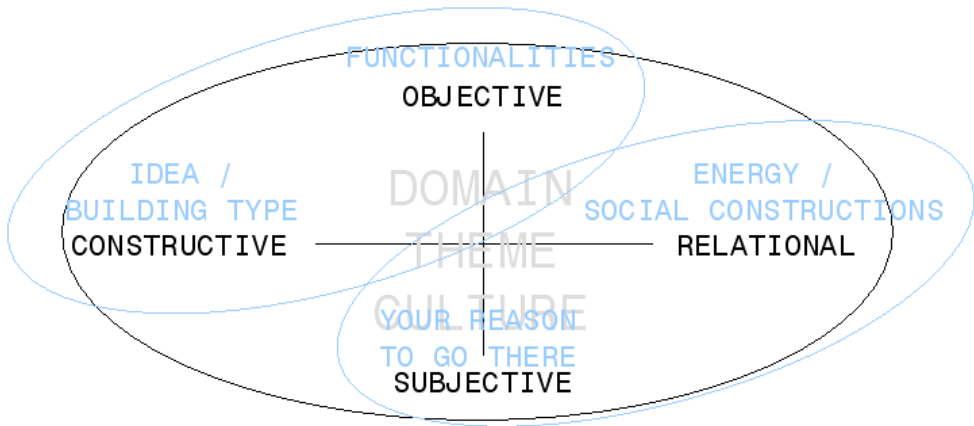

Figure 12. Diagram denoting the space formed by four characteristics of socio-cultural qualities, and their interpretation for architecture.

Intelligent Modelling in Design Education

In a design, cultural influences are rather obviously perceived. However, it is not that obvious if one attempts to make these influences explicit. This is due to the fact that in a design there are a number of design attributes, which are interrelated, in a very complex structure. To unravel this structure is a formidable task, since there are no explicit guidelines for analytical decomposition. The cultural *hallmarks* in an architectural design are perceived essentially by a synergistic consideration rather than by an item-by-item inspection. One can easily recognize the complexity of this design task, simply by realizing the vast number of attributes involved in a design together with their highly

intricate intra-relationships. In this respect, it is most appropriate to invoke Artificial Intelligence (AI) methodologies in which both intelligent-like attitudes and the computational efficiency of advanced computer technology are effectively brought together, as we explain below.

For an analytical approach to the above-mentioned design problem, *first* it is imperative to establish a comprehensive database with all design attributes and with associated cultural design features. Such a database can be formed straightforwardly, however, with some considerable effort, by investigating the existing design examples, most desirably worldwide. As a result of this investigation, a database can be established in any complexity, as design examples are almost infinite for all practical purposes.

Using the database established, *second* a knowledge model should be formed by intelligent technological means. Here, it is important to note that, mathematical logic, which is an integral part of traditional artificial intelligence and deals with symbolic logic, is still of academic interest rather than of practical interest in "machine intelligence". However, in recent years a new concept for machine intelligence is introduced, coined as Computational Intelligence (CI), that is a powerful approach for complex design tasks with regard to the present context. The main machinery of CI includes several "intelligent" techniques, which in broad lines are *neural networks* (Hush and Horn 1993), *fuzzy logic* (Yen 1999, Zadeh 1973) and *genetic algorithms* (Goldberg 1989, Holland 1975). These are collectively referred to as methods of *soft computing* which is a recent area of AI. Neural networks are especially suitable for the knowledge model mentioned above. The formation of this model is illustrated in figure 13.
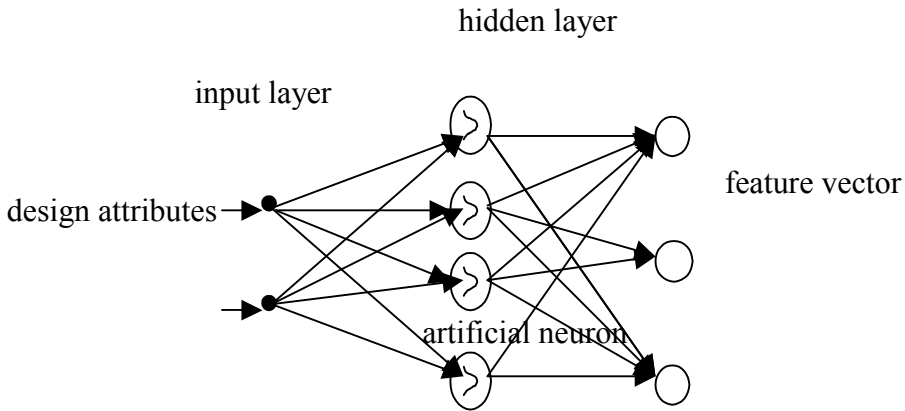

Figure 13. Knowledge model, implemented by a neural network structure.

In the *third* step, a feature vector for a certain design task must be pre-determined. This pre-determination reflects a decision-making process about the design with certain features. The formation of this feature vector is up to the designer and dependent on his or her intention and the designer should complete this formation before starting the design. Once the decision has been made, the necessary design attributes can be identified by a search procedure. This is a search for an appropriate pattern of design attributes at the input of the knowledge model that provides the feature vector at the

output on which the decision has been made. Such a search procedure is reported in another work (Ciftcioglu 2003). For this task, CI is the most efficient and effective approach, due to the size of the complexity of the task in consideration. As the complexity increases, the CI approach becomes more imperative in order to be able to deal with the task with practical qualities. The search can be made in various forms, depending on the subtlety of the design that the designer has in mind. For example, in a very simple way, design attributes can be searched. In a more elaborate form, the design attributes can be computed with regard to some "weighted" features where weights may be goal-orientationally conditioned, meaning that, each feature is weighted according to some design goals. For certain design goals, it may be desirable to impose several criteria to be fulfilled in the feature space. In such a case, searching for an optimal design solution means searching for the most appropriate pattern of design attributes. Such a search is commonly known as a multi-objective optimisation and can be treated most efficiently by genetic algorithms, a powerful combinatorial search algorithm that is inspired by natural genetic evolution (Ciftcioglu 2003, Goldberg 1989). Note that in a multi-objective optimisation we cannot determine a unique solution but we can determine a set of solutions that satisfy the criteria imposed for a set of design conditions. This set of solutions is referred to as *Pareto-optimal front* and is illustrated in figure 14 where f(x1) and f(x2) are the design objectives which are supposed to be minimal and x1and x2 are the attribute vectors. The Pareto-optimal solutions are the optimal design solutions being sought. In figure 14, two hypothetical solutions are connected with a bold line.
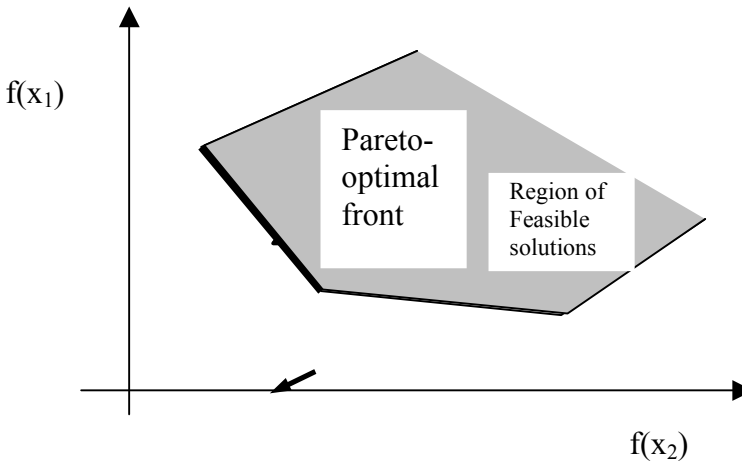

Figure 14. Illustration of pareto-optimal front for multi-objective optimisation.

ADDED VALUE OF COMPUTER AIDED ARCHITECTURAL DESIGN

Conclusions

Analogy in architecture is a well-known field, but not cultural analogy. There is hardly any attention being paid to cultural analogy in architectural education while there is an ongoing globalisation where societies become multi-cultural. We can state that:

- Multiculturalism should be considered as an added value and no longer as a danger; therefore, architectural education must pay attention to the topic.

- It is necessary that the architects build a body of knowledge of cultural values for their use in the design.

- In order to overcome the loss of "cultural diversity" in architecture and to prevent making the world as "unanimous big village" in terms of its architectural character, more attention is needed to cultural aspects in architecture.

- The ongoing developments in the field of ICKT have an important impact in the design of our cities and buildings, therefore it is necessary to educate the future architects on these tools, however, also by considering also the cultural aspects in architecture.

- There is a lack of knowledge in architectural education in Holland on multi-cultural architecture, which should be developed.

- In the future, ICT developments for architecture and the building sector will be in the field of knowledge integration, decision support environments and, finally, the support in the whole design process from initiative until demolition.

- In the future, architects must be able to develop their own *knowledge model* in order to build up their *specific knowledge* in a computer model such that they can use it for their own *support* in their design process.

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