Evaluation of Final Product Integrated with Intelligent Systems in Architectural Education Studios

H. Derya ARSLAN

Asst. Prof. Dr. Necmettin Erbakan University, Architecture Department, Meram, Konya, Turkey.
deryaarslan@konya.edu.tr (Corresponding Author)

Gonca ÖZER

Research Asst. Selcuk University, Architecture Department, Selcuklu, Konya, Turkey.
gonca.ozer@hotmail.com

Ahmet ÖZKIŞ

Research Asst. Selcuk University, Computer Engineering Department, Selcuklu, Konya, Turkey.
ahmetozkis@selcuk.edu.tr

ABSTRACT

Intelligent systems and artificial intelligence are used in many areas today. In this study, it was investigated how smart systems could be successful in evaluating the projects presented as final products within the scope of studio lesson in architectural education process. In line with this aim, the study was arranged with the educational design projects designed by the students within the scope of the architectural design studio, which is the most important basic unit of architectural education. Firstly, the projects prepared during the training process were assessed and graded by the jury. After that, 51 architects (architecture fourth graders) were asked to evaluate the educational structure projects obtained at the end of the training process over the delivered products. Five different criteria have been used in evaluations such as form, function, aesthetics, flexibility and authenticity. The assessments made by the architects and the jury members were paired and the data set was created. The numerical values obtained were trained and tested using intelligent system methods used to solve different problems in the literature. At the end of the study, evaluation scores and estimation percentages of intelligent systems were found. Intelligent systems seemed to come very close to the assessments that the jury made. The use of intelligent systems for the final product evaluation in architectural studios has been recommended.

Keywords: Architectural education, Building designing, Project evaluation, intelligent systems

1. INTRODUCTION

Design emerges as a common product of reason and experience. The design, which is an intuitive and creative process, also includes irrational, mystical and unconscious features. Osborn (1957) ; Gordon (1961); Gergory (1966) and Lobell (1975) argues that design knowledge is subjective, not objective. However, Alexander (1964); Jones (1970) and Archer (1963) stated that design can be expressed in the form of a number of techniques and formulas, and that design is a strategic activity that provides an optimum solution.

Architecture is in a multi-faceted relationship with other sciences during the stages of analysis, programming, modelling, material selection, construction system and marketing. Working in partnership with different disciplines at each stage ensures that the relevant stage is terminated economically and practically. Especially with the end of the 20th century, the rapid development of computer technology has triggered the relationship between technology and architecture. As a result, modern architectural approaches have emerged today.

In the design or project studios where the foundations of the architectural profession are laid, project design principles are explained to students in terms of contemporary architectural approaches and basic architectural criteria (Dinç; 2007). The evaluation of the students' work in the studio over a period of time and the examination of the mistakes made are a separate tutorial dimension of the lesson. However, during the evaluation of the final product resulting from the studio lesson, there are also differences in the judiciary due to the subjective opinion differentiation among evaluator jury members.

In this study on the objectivation of the subjective judgments, it was researched whether an evaluation method integrated with intelligent systems could be used in architectural project evaluation. The intelligent system application that forms the motivation for this work takes place in many design and evaluation processes involving technological inputs from 3D digital modelling technologies that transfer design to drawing to intelligent structures where automation systems dominate. Intelligent system techniques used in architectural science are mainly concentrated on image processing applications, artificial neural networks (ANN, hereafter) and some other hybrid methods. Especially in the restoration and rebuilding of historical buildings, in obtaining three-dimensional images of buildings and in some other building-facade works, digital image processing methods are used (Hua and Weiyu, 2004; Zischinsky et al., 2000; Karslı et al., 2009; Turan, 2004; Crespo et al., 2010; Luhmann and Tecklenburg, 1997; Duran et a., 2002; Patias

et al., 2008; Hemmleb et al., 1997; Batista et al., 2010) . In addition to this, spatial heat comfort, heat loss, brightness value and outer insulation layer have been determined in the studies using ANN (Tosun and Dinçer, 2011; Tosun and Dinçer, 2011; Kazansmaz and Günaydın, 2009; Keleşoğlu and Akarsu, 2008). In a study (Arslan and Ceylan, 2012) using image processing and ANN together, researchers have developed a new approach to detect the ideal classroom location in primary schools. In another study (Palabıyık and Çolakoğlu, 2012) a fuzzy multi-criteria decision model was developed to help evaluate product-based architectural design alternatives.

Although the examples given above are used in the literature, intelligent systems used in architecture discipline are not as many as those used in the solution of complex engineering problems and in engineering designs. The main reason for this is the fact that individual feelings and thoughts are at the forefront as well as technical criteria, especially during architectural design. In other words, the impact of human dimension on design distinguishes architectural science from other disciplines.

In this study, it has been tested how intelligent systems can be successful in evaluating the final product in architectural design. In line with this aim, the educational building projects whose models and drawings were designed by students were evaluated in the direction of basic design principles determined within the scope of architectural design studio course which is the most important part of architectural education in terms of time and effect. The 16 different educational building projects designed by the students were evaluated by 51 architects (architecture fourth graders). Five different criteria have been taken into consideration. The evaluations of the projects based on basic concepts such as form, function, aesthetics, flexibility and authenticity were carried out by using different intelligent system methods such as ANN, Artificial Bee Colony (ABC) and Regression Analysis (RA). The results of these methods have been tested for prediction success.

2. BASIC PRINCIPLES IN BUILDING DESIGN

Architecture including many different disciplines which can be defined as science and art of designing and implementing structures and physical environment is realized primarily by the contributions of the architect from design to production stages. In the process of designing a building that is completed with an architect's aesthetic, functional and technical concerns, some of the features of the product can create an exit-a starting point for design. According to Marcus Vitruvius, these three principles are Firmitas (strength), Utilitas (functionality), Venustas (beauty). This classification was defined as Comodita (Usability), Perpetuita (Continuity) and Ballezza (Beauty) by Alberti and Palladio in the Renaissance period. Although ranking in principles or differences in terms

changed, it basically maintained its features until today without losing its essence. With today's terminology, the architectural possesses features like form, function, aesthetic, constructions etc. with pragmatic (benefit), syntactic (organization) and semantic (meaning) dimensions.

2.1. Basic Principles of Form-Based Building Design

In building design, the product feature which the designer independently decides on is considered to be the form. The aesthetic effect of the form that forms the semantic dimension of the product requires a philosophical interpretation while at the same time creating the artistic direction of the building design phenomenon. Different forms and their arrangement on different surfaces cause the individual to have a different perception of the building. "*Rectangular forms create balanced and dynamic effect, narrow angled forms unbalanced and uncomfortable effect, circular forms create relaxing and soothing effect. Curves or diagonal directions are perceived as energetic and dynamic in terms of visual impact*" (Ertürk, 1991). The fact that the form that makes up this structure is geometric or has a free form plays an important role in visual perception.

2.2. Construction-Based Building Design Principles

The basic feature of the construction is rational thinking. The main purpose of the construction is to realize the necessary and sufficient space with minimum labour and material, that is, minimum cost. Construction is used to mean "*building, constructing, making, installing, arranging procedure*". Until the industrial revolution, bearer and carried elements of a building which constituted the building as constituents were the same which resulted in the direct formation of the functional partitioning of the building and the form of the universal form. Stonage, arch, vault, dome architects are typical examples of this. In the industrial revolution and afterwards, the construction left its unique structure in itself. In this case, the changing methods and materials of the construction would be able to direct formal arrangements. However, the exhibition or concealment of the construction elements also appears to be a fundamental decision in building design.

2.3. Function-Based Building Design Principles

The design theme is an important criterion for the "function" which is the pragmatic purpose of the building. The interrelated spaces of buildings, the horizontal and vertical circulation flows form the functional structure of the building or in other words the network of relations. The fact that this functional network is solved by some mathematical tools provides data related to the holistic form of the building (Broadbent;

1973). These numerical values obtained are the primary data in forming the "*Formal Embryo of the Building*", which is called "*Stain*", "*Schema*", "*Editing*".

2.4. Aesthetics-Based Building Design Principles

Architecture has often used proportional systems and geometry throughout history to create certain forms or to limit the forms created. The purpose of using such a system is to have a harmony between the elements of the structure and to create a feeling of integrity throughout the structure with this "principle which makes beauty beautiful". "*It is the measure that will provide or guarantee the beauty, the formality it brings*" (Timuçin, 1993).

It is extremely important that the architectural project created alongside these four items has a unique (original-private) structure. According to Türkan and Erdem (2016), architectural education is an application area equipped with conceptual network and acceptance that nurture, justify and direct the "creator author" figure especially through the studio environment, the production of authenticity. The contradictions and potentials that this area holds in this sense continue to offer valuable insights (Türkan ve Erdem, 2016).

3. PROJECT EVALUATION IN ARCHITECTURAL EDUCATION

Architectural Design (project) courses are the backbone of architectural education. Architectural Design courses cover all the knowledge and skills gained by the student during the architectural education process such as the creation of space, the solving of architectural problems, the creation and development of three-dimensional composition. The first of the architectural project courses is Basic Design course which is the preparation for the architectural design. In this course, students make 2D and 3D Basic Design studies which are the preparation for design education. Then they create a project where they will meet the structure in a way that they will use the basic design knowledge and skill they gained till then. They are expected to develop and present their projects in the direction of criticism of the executives. In other Architectural Design courses besides Basic Design, students are expected to carry out project studies on topics determined by students. The final (year-end) evaluation of project studios in architectural education is usually done by the jury which consists of the relevant architectural project executives. The differentiation of jury members' specializations or a further examination of the positive or negative aspect of the project affects the evaluation score. It is obvious, however, that the product that students create over a period of time (about fourteen weeks) should be evaluated according to many parameters (Concept / Fiction, Functional solutions, Structural solutions, Architectural expression). In other words, the development process must be considered as well as the result achieved in the project.

4. CREATION OF DATA SET IN LINE WITH DESIGNED PROJECTS

4.1. Sample Projects

In the study, 16 different elementary education buildings made by Selçuk University Architecture Department 2nd Grade students in the 4th semester were evaluated. At the end of the semester, the students handed in presentation papers that they prepared as A_1 to best describe their project. An exemplary presentation sheet is given in Figure 1. In addition, all the assessments made by students are given in Table 1. In Table 1, the grades of the boys and girls and the grades given by the jury members at the end of the semester are shown.

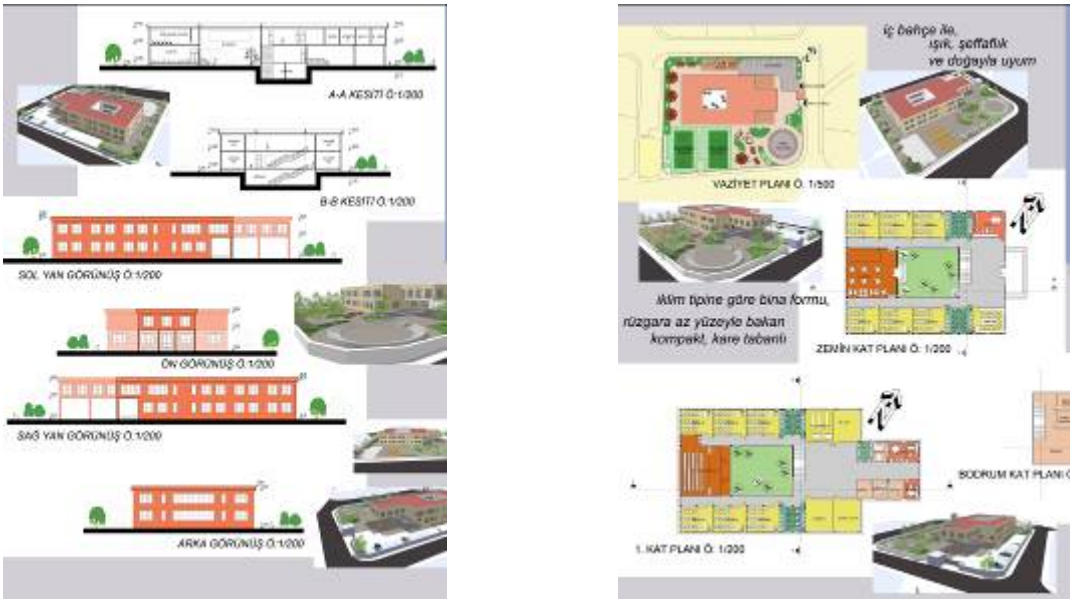

Figure 1. *Sample Presentation Sheet*

4.1. Participations

Selçuk University Department of Architecture, 4th Grade 8th Semester students evaluated the projects in the study. The reason for the selection of senior students is that these students will soon get the title of architect. 39 were female and 12 were male of 51 participants. In the study, students were also asked to make an assessment on the sheet presentation in addition to five basic criteria such as form, function, aesthetics, flexibility and authenticity. Likert scale was used in the study, with the ratings grading from 1 to 5 grades ranging from very poor to very good. The students made the evaluations of the sheets on the computer. The score of each project was determined by taking the averages of the evaluations of 51 students in different criteria. Table 1 shows the score of each project.

5. ANAYSING DATABASE

5.1. Soft Computing Methods Used in Analyses

In this work, it is aimed to predict truly expected results in the Table 1 by using an advanced method. In literature, there are different methods such as ANN, optimization algorithms and regression analysis to solve the prediction problem (Çelik et al., 2016).

5.1.1. ANN Application

ANNs are intelligent systems that are successfully used to solve complicated problems in many different applications such as pattern recognition, identification, classification, speech, vision and control systems (Hasni et al., 2012). ANN structure is based on our understanding of biological nervous system (Lippmann, 1987). Neurons are the basic structural unit of nervous system and receive inputs from other sources, combine them in some way, perform a generally nonlinear operation on the result, and then output the final result (Kung, 1998). In the study, first of all ANN based intelligent system has been used, however the results show that for the datasets ANNs is not a suit method because of lack of sample size. All of three datasets have 16 samples and it is not enough to train ANNs.

5.1.2. ABC Application

In the literature there are several types of optimization algorithms namely genetic algorithm, particle swarm optimization and bees algorithms. There are also new and interesting approaches, which is a member of the swarm intelligence family of algorithms. Artificial Bee Colony (ABC) algorithm (Karaboga, 2005) is one of the most successful optimization algorithm in optimization literature. So, ABC algorithm is used to fit the proposed model. The results of ABC algorithm for this study shows that ABC stuck into local minima and has a poor performance when search space is very large (lower bound: -10^10, upper bound: 10^10 is taken).

Table 1. *Architectural Projects and Scores*

									
	Female	**Male**	**Jury**	**Female**	**Male**	**Jury**	**Female**	**Male**	**Jury**
Score	55.48	68.33	66.00	86.66	90.00	75.00	77.94	73.33	75.00
									
	Female	**Male**	**Jury**	**Female**	**Male**	**Jury**	**Female**	**Male**	**Jury**
Score	69.23	67.33	85.00	69.84	68.00	95.00	71.89	66.00	70.00
									
	Female	**Male**	**Jury**	**Female**	**Male**	**Jury**	**Female**	**Male**	**Jury**
Score	84.71	77.00	75.00	53.12	65.66	72.00	74.97	87	70.00
									
	Female	**Male**	**Jury**	**Female**	**Male**	**Jury**	**Female**	**Male**	**Jury**
Score	50.46	60.00	65.00	76.10	79.33	75.00	82.76	82.33	80.00
									
	Female	**Male**	**Jury**	**Female**	**Male**	**Jury**	**Female**	**Male**	**Jury**

Score	51.89	48.33	50.00	47.89	61.67	50.00	71.69	73.00	75.00

	Female	**Male**	**Jury**
Score	94.56	95.67	90.00

5.1.3. Regression Application

Regression is a type of analysis that predicts continuous output variables from several independent input variables. Given a number of samples, each one of which is characterized by certain input and output variables, regression analysis aims to approximate their functional relationship. The estimated functional relationship can then be used to predict the value of output variable for new enquiry samples. Generally, regression analysis can be useful under two circumstances (L. Yang et al., 2016);

(1) When the process of interest is a black-box, i.e. there is limited knowledge of the underlying mechanism of the system. In this case, regression analysis can accurately predict the output variables from the relevant input variables without requiring details of the however complicated inner mechanism.

(2) When the detailed simulation model relating input variables to output variables, usually via some other intermediate variables, is known, yet is too complex and expensive to be evaluated comprehensively in feasible computational time.

The statistical analysis presented in this paper was performed using SPSS for Windows software. Fitting model is shown in Eq.1

$$y = a_1*\sin(b_1*V_1+c_1) + a_2*\sin(b_2*V_2+c_2) + a_3*\sin(b_3*V_3+c_3) + a_4*\sin(b_4*V_4+c_4) + a_5*\sin(b_5*V_5+ c_5) + a_6 \quad \text{(Eq.1)}$$

In the equation, y is predicted presentation value, V_1 is Form, V_2 is Function, V_3 is Flexibility, V_4 is Esthetic, and V_5 is Originality. After obtaining fitting models, generated new models for male, female and mix are shown in Eq.2, Eq.3 and Eq.4 , respectively. In the Table 2, parameters constant values are given for each group. Regression Analysis results belong to three models are shown in Table 3.

$$y = 18.385*\sin(5.116*V_1-13.163) - 8575.514*\sin(0.077*V_2+1.358) + 1466.041*\sin(-$$

$0.336*V_3+5.722) - 43.496*\sin(2.83*V_4-5.903) – 47.895*\sin(2.773*V_5-3.142) + 10089.303$ (Eq.2)

$y = 628.823*\sin(0.341*V_1-2.663) + 14.007*\sin(10.058*V_2-27.908) + 1015.117*\sin(0.174*V_3+1.012) + 25.542*\sin(3.623*V_4-8.078) + 17.584*\sin(7.701*V_5-18.148) - 315.505$ (Eq.3)

$y = 26.111*\sin(3.777*V_1-13.672) + 80.782*\sin(1.641*V_2-3.432) + 28998.305*\sin(-0.083*V_3+4.941) - 48.56*\sin(2.934*V_4-4.029) + 20.134*\sin(2.674*V_5-3.576) - 28989.954$ (Eq.4)

Table 2. *Parameters constant values on estimating scores*

	Male	**Female**	**Mix**
Form	5.116	0.341	3.777
Function	0.077	10.058	1.641
Flexibility	-0.336	0.174	-0.083
Esthetic	2.83	3.623	2.934
Originality	2.773	7.701	2.674

Table 3. *Multivariable Nonlinear Regression Model Results*

Exp. No	**Expected Results**	**Male Results**	**Female Results**	**Mix Results**
1	66	72.29	65.61	65.65
2	75	75.34	75.67	75.24
3	75	73.38	74.31	75.02
4	85	91.20	83.15	85.89
5	95	87.99	98.08	94.47
6	70	68.59	68.18	70.66
7	75	74.69	74.03	74.30
8	72	69.46	68.1	71.47
9	70	68.34	70.57	71.59
10	65	58.06	61.47	65.42
11	75	78.84	77.01	72.71
12	80	79.78	80.09	80.89
13	50	51.30	55.39	49.98
14	50	58.06	51.9	50.07
15	75	71.20	74.54	74.78
16	90	89.47	89.9	89.86

R-square (R^2) and RMSE values are also shown in Table 4. In the analysis, obtained R-square values shows that model of mix data has the best fitting and R-square value. The Equation 5 and Equation 6 are calculation method of R-square (R^2) and RMSE values, respectively. Where X_t is output values, $X_t^{'}$ is target values and n is the sample size.

$$R^2 = 1 - \frac{\sum_{t=1}^{n}\left(X_t - X_t^{'}\right)^2}{\sum_{t=1}^{n}\left(X_t^{'}\right)^2} \quad \text{(Eq.5)}$$

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}\left(X_t - X_t^{'}\right)^2}{n}} \quad \text{(Eq.6)}$$

Table 4. *R-square (R^2) and RMSE values*

	Male	**Female**	**Mix**
R-square (R^2)	0.8689	0.9618	0.9948
RMSE	4.2225	2.2799	0.8394

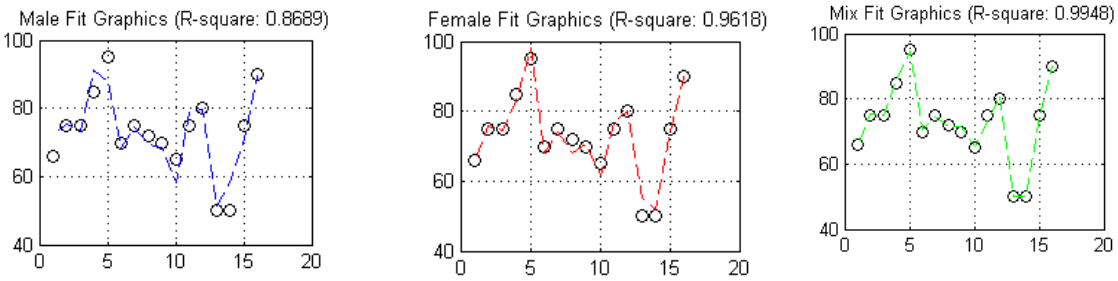

Figure 2. *R-square (R^2) values for the each participant groups*

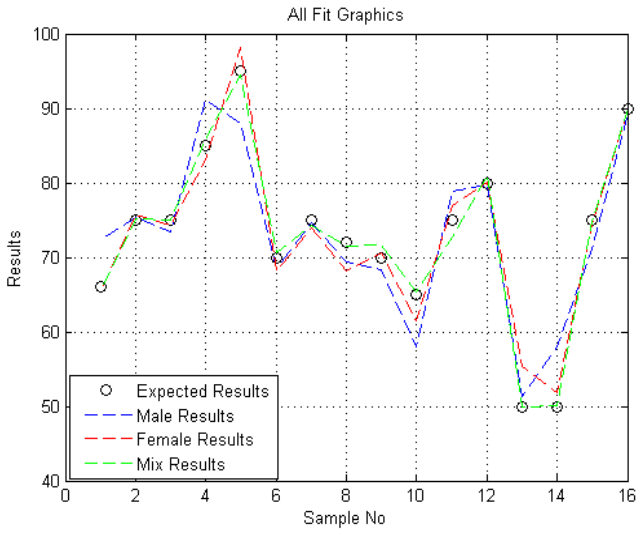

Figure 3. *R-square (R^2) values for the all participants*

6. CONCLUSIONS

In this study, the architectural projects designed by the students in architectural education were first evaluated and graded by the jury members. Later on, 51 architects (architecture fourth graders) evaluated the products delivered. The evaluations were based on five basic criteria such as form, function, aesthetics, flexibility and authenticity, and presentations made by students. The numerical evaluations obtained according to the relevant parameters are turned into a matrix format and some intelligent systems used in the literature were desired to estimate the scores. The findings from the study are as follows;

1. Intelligent systems are not all successful in solving the foreseen problems. For example, in this study, while ANN and ABC algorithms failed to show sufficient success, RA largely predicted the results of students and jury members. 16 projects and 51 architects used in the study limited the success of ANN and ABC algorithms.
2. The study suggests that female students are more likely to do correct project evaluations than male students. There are numerous social studies in the literature where male / female gender differences are discussed. It can be said that female students' evaluation sensitivity is higher than male students. Moreover, the fact that the number of subjects is unequal is also a factor in the difference between the results of the two groups in this context.
3. Especially during the evaluation of the final product which is the result of studio lesson, the use of intelligent systems as decision makers is important for objective evaluation due to the differentiation of subjective opinion among evaluator jury members and the differentiation in the evaluations.
4. Evaluations are made considering the development process as well as the final product in the projects. It is not possible to predict this evolution of intelligent systems. Intelligent systems can only be used as a tool to evaluate the final product.

In this study, it was seen that the intelligent systems used, even in limited numbers, were very close to the evaluations that the jury had made. This study indicates that intelligent systems, which are thought to be very unusable in project evaluation stages, can be used if they are developed in the coming years, and that experts developed by artificial intelligence and intelligent systems can substitute people as decision makers in the long run.

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