TOWARDS AN EXPERT SYSTEM FOR PRESENTING COLOR ALTERNATIVES FOR FACADES (PCAF) AS A "COMPUTER-AIDED ARCHITECTURAL DESIGN (CAAD)" TOOL

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ABSTRACT

Expert Systems applications - as a branch of the Artificial intelligence field -are still one of the hottest topics in the scientific field since it has appeared. In Architecture, there is a need to develop computer applications that would assist architects throughout the different steps of the design process. So, this paper aims at presenting an ideation of an expert system that provides the architect with the correct color alternatives for a facade, and studying the possibilities of establishing it. Such a system could be a good CAAD tool that would facilitate an important part of the architectural design process. To achieve that aim, the research presents an overview of the expert systems concept, components and structure. Then it shows the nature of producing color alternatives for building facades and its requirements, needs and procedures. After that, the research ideates the components and the structure of the expert system for **P**resenting **C**olor **A**lternatives for **F**acades **"PCAF"** in spot of all requirements and needs. The last step is a discussion about the possibility of establishing the expert system PCAF and its different components.

I. INTRODUCTION

Computers have, undoubtedly, become a necessary tool in all science branches. Programmers and software developers have already provided ingenious computer applications in many different fields. But the future would yield other applications that would generally help humanity to improve performance in many aspects of life.
In Architecture, there is a need to develop computer applications that would assist architects throughout the different steps of the design process specially these applications, which are based on the principles of "Expert Systems – (E.S.)" and artificial intelligence in architecture.
Because color is one of the inevitable visual attributes of any material, the color selection of facade components is considered one of the most important steps in the architectural design process. The importance of this step is due to color properties and the role they play in improving the aesthetic aspects of the built environment and, in turn, influencing the human behavior.
An Important question to be discussed: **Why Expert System PCAF?**
The importance of developing PCAF is due to some problems related to selecting the suitable colors of building facades in the architectural design process.
One of the most common problems in the field of architectural design is the negligence of color studies of building facades. It is often considered as the latest step in the design process for many reasons. The first one is that many architects underestimate the importance of color studies in facades, and consider color choice as the simplest step in the design process. Another reason is that the dominance of specific design trends or methods over the architect's way of thinking would inevitably lead to underestimating other ones. This might be due to the creative anxiety of the architect, or due to certain prohibitions being imposed by the society, or perhaps due to limitations in creative ability on the part of the architect.
In addition and in Egypt specifically, there are no regulations that could oblige an architect to present a color scheme for his building to the city councils (municipalities) before getting the final permission for execution. This encourages the underestimation of color studies, and leads to leaving them to the empirical improvisations at site.
The last important problem is the need to consider a large number of color scheme possibilities to choose from by both the client and the architect before arriving at the optimum one. Reviewing such possibilities would require a lot of time, and a hard work to do.
For all the above mentioned reasons, this research seeks answers to a central question:

"Is it possible to develop an expert system that can present the different color alternatives for building facades?"

It can be expected that there is a possibility to develop an expert system PCAF that assists architects in color selecting process through presenting different color alternatives for building facades to decide on the suitable color in a high performance. Such system could be a good "Computer-Aided Architectural Design (CAAD) tool" that would facilitate an important part of the architectural design process.

II. EXPERT SYSTEMS

An Expert System "ES" – also known as knowledge-based system- is one of the artificial intelligence techniques. It is a computer program (system) that uses a representation of human expertise in a specialist domain to perform functions similar to those normally performed by a human expert in that domain. It is not only used to solve a problem like an expert, but can also give the user some confidence about the solution. It can be used either by an expert or by a non expert in system domain. Experts use it as a knowledge source or a knowledgeable assistant. Non experts use it as a tool for solving the specialized problems, where the system is developed for solving it.
Such systems could work better than a single human expert in taking the decisions in a specific domain.

Rule-based programming is one of the most commonly used techniques for developing expert systems. In this programming paradigm, rules are used to represent heuristics, or "rules of thumb," which specify a set of actions to be performed for a given situation. A rule is composed of an IF portion and a "THEN" portion. The "IF" portion of a rule is a series of patterns which specify the facts (or data) which cause the rule to be applicable.

- **Components of an expert system:**

Three essential components represent the skeleton of any expert system. These components are: Knowledge Base, Inference Engine and User Interface:

The Knowledge Base, which contains the domain knowledge, the working memory, which contains the facts about the current problem discovered during the problem-solving session and rules in form IF (condition) THEN (action) ELSE (action).

The Inference Engine that automatically matches facts against patterns and determines which rules are applicable. The "IF" portion of a rule can actually be thought of as the whenever portion of a rule since pattern matching always occurs whenever changes are made to facts.
The "THEN" portion of a rule is a set of actions to be executed when the rule is applicable. The actions of applicable rules are executed when the inference engine is instructed to begin execution. The inference engine selects a rule and then the actions of the selected rule are executed (which may affect the list of applicable rules by adding or removing facts). The inference engine then selects another rule and executes its actions. This process continues until no applicable rules remain.

The User Interface that is the means of communication between the system and the user (architect). He inserts the inputs of the program in order to obtain the essential information which is necessary to the inference engine in order to work. Also and through it, the user receives the results. The user interface may use menus, natural language or any other style of interaction.

An ES may have additional components such as **an explanation facility**, which provides the user with a step by step of how and why such a decision or recommendation was made by the system. This also helps the user gain the problem-solving skills of the domain experts via the expert system (figure1).

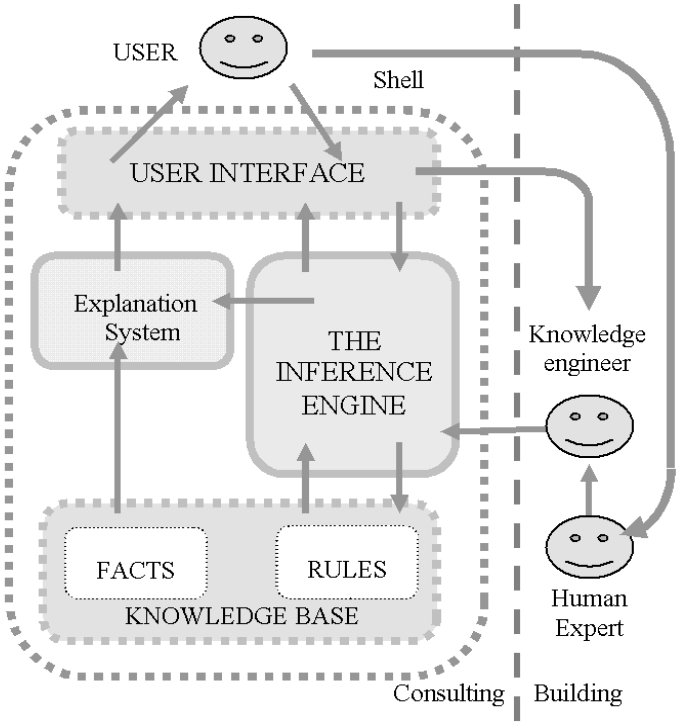

Figure 1. The essential components of an expert system

- **Requirements for building an expert system:**

The first requirement for building an expert system is **The Human Expert** in the system's domain, who possesses the knowledge and skill to solve a specific problem in a manner superior to the others. So he represents not only the knowledge source, but also the source of the methodology of the system work.

The second requirement is **A Knowledge engineer.** He is the builder of the system. He is a knowledge representation expert, who selects the suitable expert system shell (and other tools) for the project, extracts the knowledge from the expert (process of knowledge acquisition), and implements the knowledge in a correct and efficient knowledge base (process of knowledge representation). The knowledge engineer may initially have no knowledge of the application domain.

The third requirement is **an expert system shell**, which is a pre - fabricated expert system without a domain of knowledge. Most commonly expert systems are PC based (approximately 80%) and are built with commercial shells. Other systems are often written in an AI language, such as PROLOG or LISP, while others are written in languages such as C.

A full participation of a domain expert, a knowledgeable engineer, and the user is essential. The user can also help define the interface specifications.

III. PRODUCING COLOR ALTERNATIVES FOR BUILDING FACADES:

In spot of the paper goal, such system emulates the architect method of thinking, and works for getting the color alternatives of a facade. So it is important in this section to show the tools and the methods of thinking and dealing with this matter.

In his work, the architect depends on the studies in the field of color and building facades, which provides him with all the necessary knowledge in this field to take the right decisions. Also he depends on some tools like a color model as a palette, drawing and painting tools. Figure 2 shows architect's method of dealing with produced color alternatives.

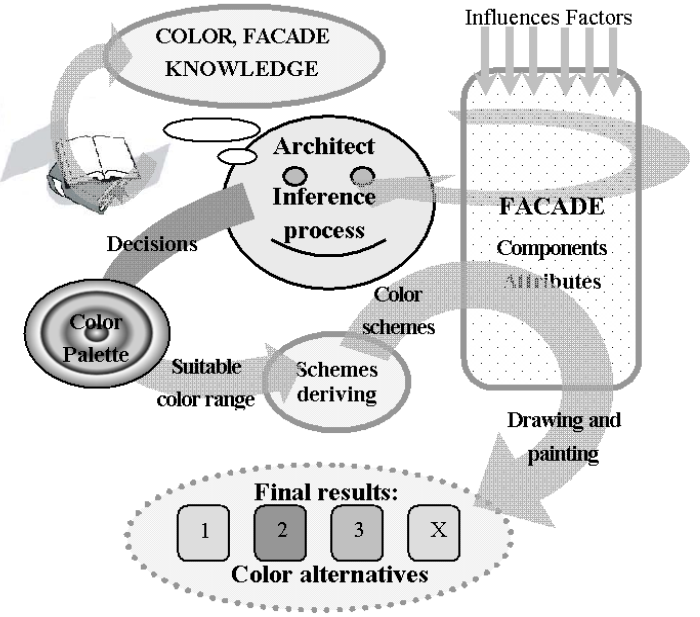

Figure 2. Architect's method of dealing with the process of producing color alternatives

Like all other architectural design steps, architect, in this step, follows some procedures to infer and produce the correct color alternatives of the facade. These procedures are:

1. Analysing facade and its components:
It is important to analyze the facade in order to become acquainted with its components (functional: walls, entrance, exit, windows, voids and solids, decorative: ornaments, cornices, mural paintings, sculptures, floor boxes, colors, texture, patterns, water and green elements, expressive components: symbols, signs, texts, mural paintings, sculptures and superscriptions). Then the architect analyses the different attributes of facade and its components (material attributes: color, texture and pattern, geometric attributes: lines type, areas form and directions, volumes type and directions, forming attributes: proportions, scale, composing relationships, and expressive attributes: calmness, activeness, warmness, coldness, heaviness, lightness, richness, hardness, softness).

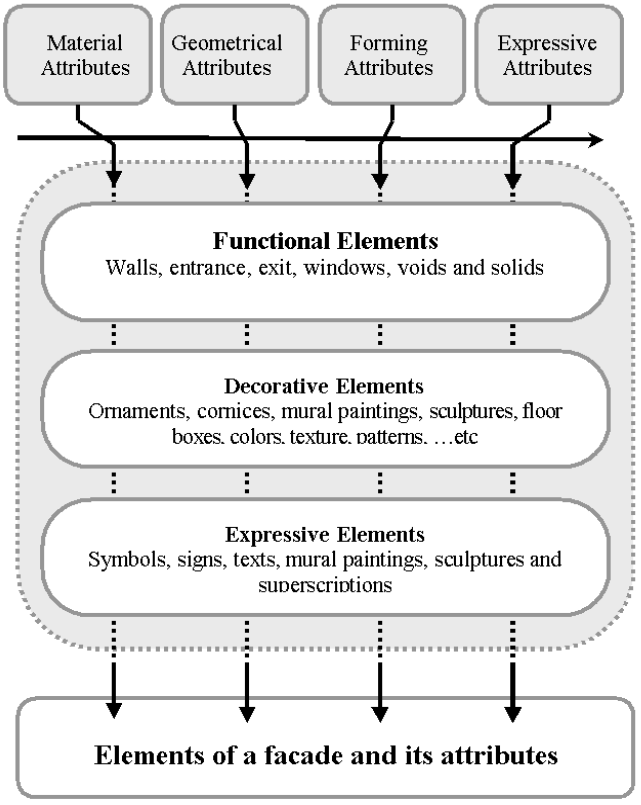

Figure 3. Analyzing facade and its component's attributes

2. Analysing factors, influence the facade:

This step aims at studying the different factors, which affect the color selecting process. These factors are dividing into 3 main groups:

Functional factor, which represents the function of the building and the activities inside it.

Environmental factors, which include climate (temperature, sun brilliance and rain level) situation topographic, pollution level and surrounding colors.

Human factors, which affect the preferences of the members of the architectural work (the architect, the investor and the user of the building). They include economical, social, political, legislative, psychological, cultural, and historical factor.

Aesthetical factors, which include order, harmony, unity and balance. These factors affect the different color schemes used in building facades.

3. Limiting the suitable color range:

In this step, the architect uses his knowledge background or any other knowledge source related to color and facades to find the effect of factors in his color palette (which is a color circle, wheel, model or solid, and traditional or computerized). Every factor has its own color group, which is suitable to it (for example, hot climate requires light and cold colors).

Consequently, with using a suitable color palette, the architect limits the suitable color ranges for all factors, influencing the facade. Then he gets the common color range, which is suitable for all the effecting factors (figure4).

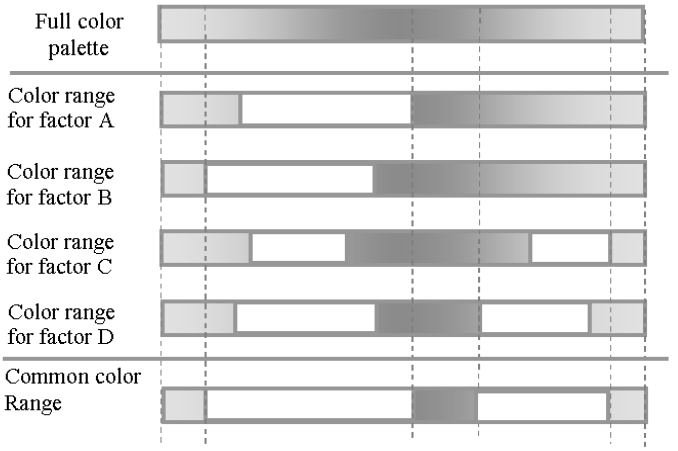

Figure 4. Getting the suitable color range for all factors

4. Deriving the color schemes:

Color scheme is a group of colors, which have a relationship in-between. Specialists in art and color domain extract these relationships from paintings of the famous artists depending on a Chevrul color wheel (12 saturated hues- figure 5).

From the past step, the architect had a color range in his palette, suitable for facade in accordance with the influencing factors. In this step, he begins with one color to derive a color schemes by applying the rules of schemes in this color. The architect repeats this process until no colors remains in the suitable range.

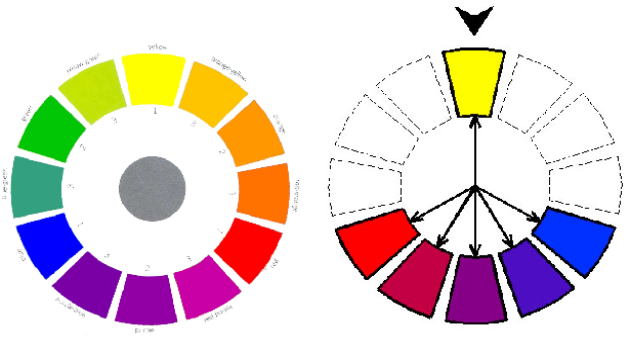

Figure 5. Full color wheel and an example of schemes

5. Applying the color schemes on the facade:

The last step in extracting the color alternatives for a facade is applying the color schemes on a facade for all colors in the suitable color range. It is important to say that one color scheme for a color can give a lot of alternatives. The number of alternatives depends on the number of facade components and the probabilities of color distribution on it. It seems as a tree which can be called "Color Alternatives Tree: CAT – figure 6."

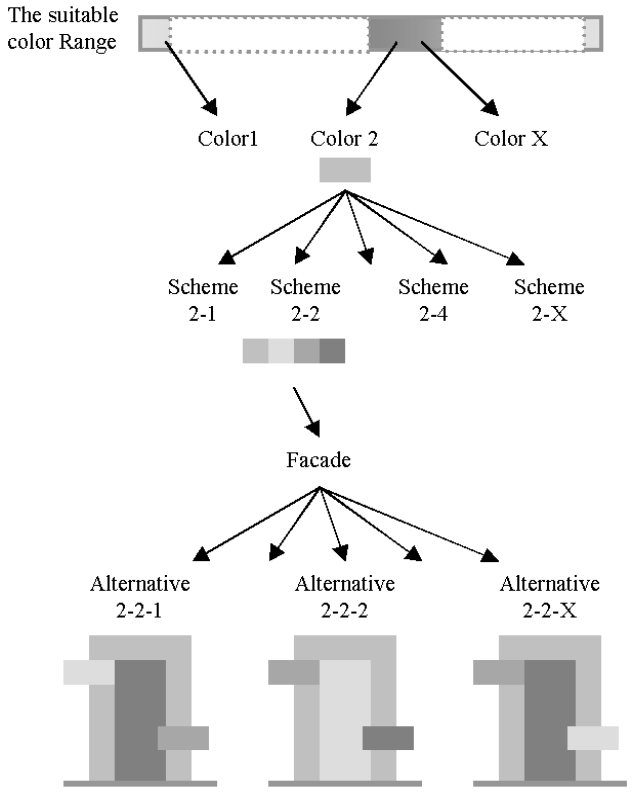

Figure 6. Color Alternatives Tree "CAT"

IV. IDEATION OF THE EXPERT SYSTEM "PCAF":

After showing the nature of producing the color alternatives for a facade and its procedures, this section ideates the working methodology and the components of the expert system "PCAF" in accordance with system domain.

- **Ideation of PCAF working methodology:**

As a method of work, expert system PCAF emulates the methodology and procedures of a work of an expert architect in color domain.

The next steps represent the ideated working method of the system:

1. The system receives, from the architect, the building façade and then begins to analyze it to its components and attributes. Then he encodes these data in a symbolic and digital form. A copy of façade data is saved in a temporary memory to call it later.
2. The system receives the circumstances and the factors influencing the facade and the building design process. After encoding it in a symbolic and digital form, it passes these data to the reasoning part.
3. The system begins to make a reasoning process through searching and calling the rules related to the inserted circumstances and factors. This process leads to the decision that limits the suitable color range for the facade.
4. In this step, the system passes the decision that is derived in the past step through a color model (color palette) to obtain the suitable color range in its natural form and a coded form.
5. After getting the suitable color range from the palette, the system begins to derive the alternatives of color schemes for each color in the suitable range.
6. The system redraws the inserted facade, distributes colors of a scheme onto the facade components and then paints it and saves it as an image. It repeats this process until it finishes extracting all alternatives.
7. The final step is presenting the results represented in images of facade painted with the color alternatives. At the same time, the system presents a report includes all the inserted circumstance, factors, the system decision and its justifications, all data related to colors in many forms.

- **Ideated PCAF components:**

In spot of the ideated work methodology of PCAF, It is presupposed that such expert system can consists of the following components:

1. **The Knowledge base**: That contains a collection of rules related to factors, influencing the suitable color range. Beside rules, it contains the important facts and data in the field of color science like the color attributes: Hue, Lightness and Saturation, color characteristics: hot and cold colors and color scales for Hue, lightness and Saturation. Also it contains the mathematical relationships between the components of color schemes.
2. **The Inference Engine**: that searches the knowledge base for the needed rules, interprets the rules, and uses them to limit the full color palette to get the suitable color range for a rule or to delete the unsuitable colors.
3. **The User Interface** that is a means of communication between the program and the user (architect). Through it, He inserts the necessary inputs of the system like the facade and the influencing factors, and then passes it to the inference engine.
   Through The User Interface, the user receives the color alternatives for a facade and an explanation report that explain inputs, procedures, decisions and its reasons, with all the data related to the color alternative (name of color scheme, colors data and attributes).
4. **The explanation engine:** it receives all processes and their steps, inputs, outputs and procedures from the different components of the system and then concludes all these data into a report and sends it to the user interface parallel to every color alternative.

Beside these essential components, some additional components are required. These components are bounded by the nature of the system domain and they need the user as an architect. The additional components are:

5. **A Facade Analyzer** that can recognize and analyze the facade components and attributes after inserting them into the system as a functional requirement.

6. **The Color Palette** that represents the color source in the system. It also represents a source of the relationships between colors and their characteristics and attributes. The color palette receives the color decisions from the inference engine in order to apply it and get out the suitable color range in a visual form as a color not as a numerical data or symbols. Such color palette can be one of the computer color systems, suitable for the nature of working with color in architecture.
7. **The Schemes Producer that call the mathematical** relationships between the scheme's component from data base and applying it onto all the colors included in the suitable color range, received from the color palette, and produce the schemes alternatives.
8. **The Painter** that is one of the important architectural requirements. It is a program, which is able to call and redraw the inserted facade from the façade analyzer, and to paint it by the color scheme, and then presenting it as an image.

Figure 7 presents the ideated structure of the expert system PCAF, its components and the relationships in-between.

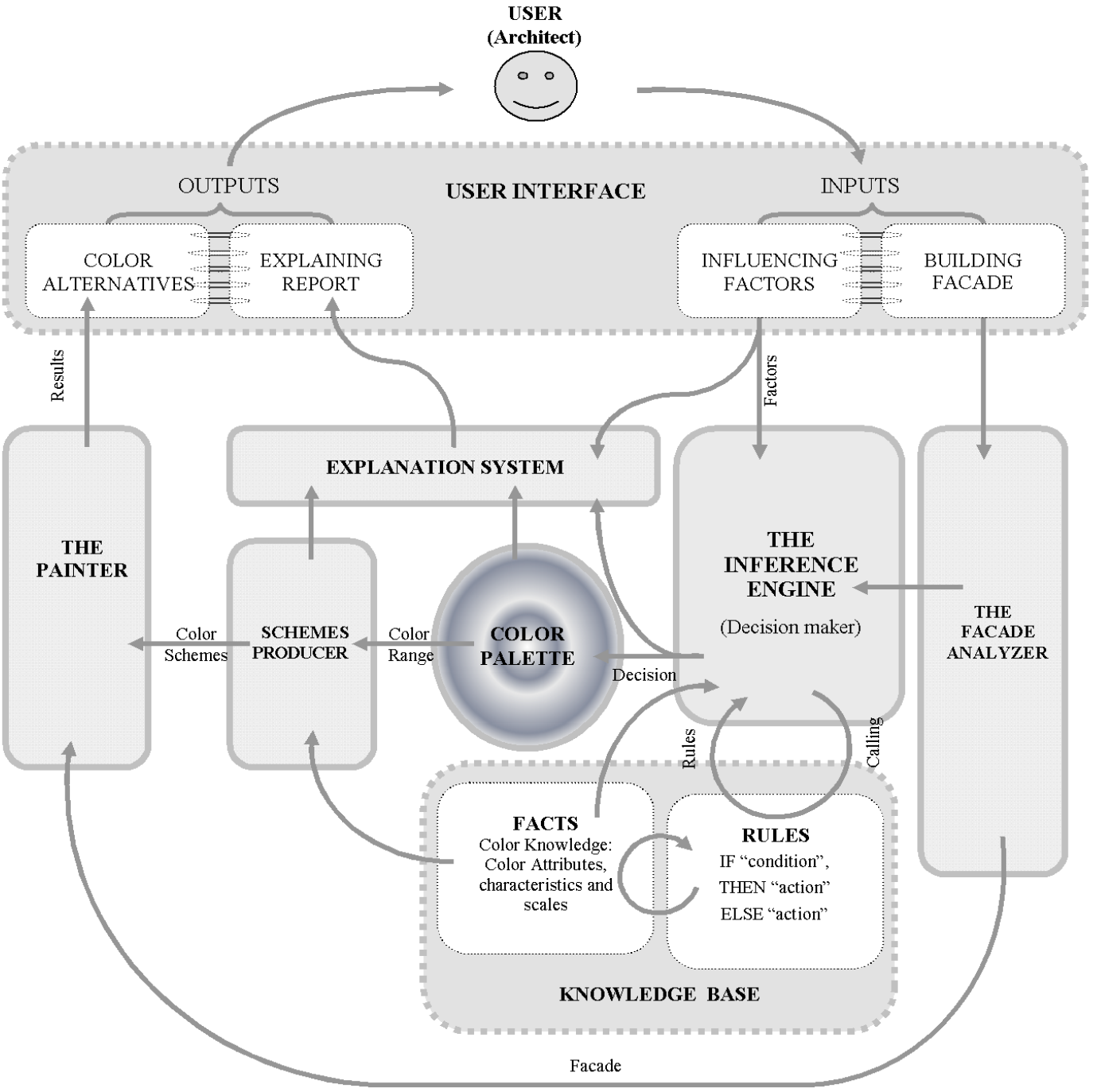

Figure 7. The ideated structure of the expert system PCAF

V. POSSIBILITY OF BUILDING "PCAF":

This section of the study aims at discussing the possibility of building the ideated expert system PCAF. As a rule, if the knowledge used in solving the problem or presenting recommendations have the ability to re-form as rules (IF---THEN---), it is possible to build a Rule-Based expert system. Some systems need addition components that help in realizing height quality emulation of an expert (as in the ideated system in this paper). This leads to that besides studying the possibility of constructing the essential part of the expert system, it is important to study the possibility to construct the additional components of such system.

- **The essential components of PCAF:**

Color knowledge has the ability to re-form in IF --- THEN --- form (rule), for example:

"Hot climate requires light and cold colors"

It is possible to reform this sentence as a rule:

IF .. climate is *hot*, .. **THEN** ..required colors is *light and cold*

Then the knowledge base and the inference engine can build.

User interface can build too.

- **The other components:**

The facade analyzer: It is supposed that a computer program can analyze the inserted façade. There are many techniques can used. One of these techniques is reading the components of a facade drawing file and analyzing it after saving it as Data Exchange File-"DXF". A trial had been produced by the author confirms this possibility (figure 8).

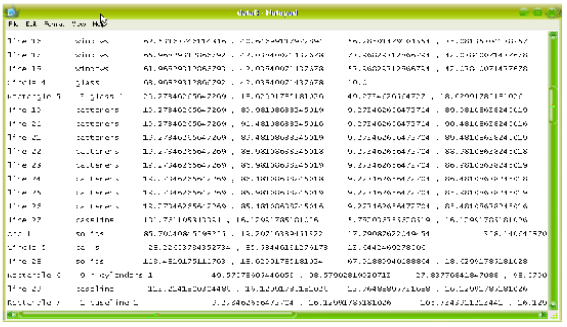

Figure 8. A screen capture of data file shows analyzing for a facade using its DXF file.

The color palette: It is possible to find and use a color model that work as a color palette of the system. Many computerized color models and systems are available such as RGB or HLS system. The important requirement in such palette is enabling the inference engine to read all of its colors and extract the suitable color range from it. A color model which had been created by the author (2003) can be used in such a system (figure 9).

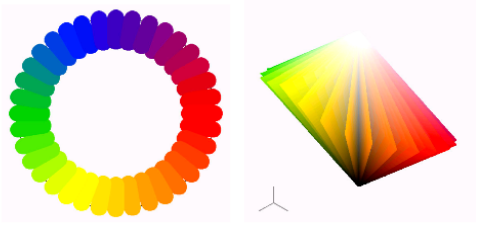

Figure 9. The Pigment Color Model "PCM" as a suitable color palette for the architectural field.

The schemes producer: by applying the mathematical and geometrical relation that organizes the relation between colors in a scheme, it is possible to produce the color scheme.

The author has a published trial to create such a program that can produce the alternatives of color schemes. Figure 10 shows the possible color schemes that are produced for the light green.

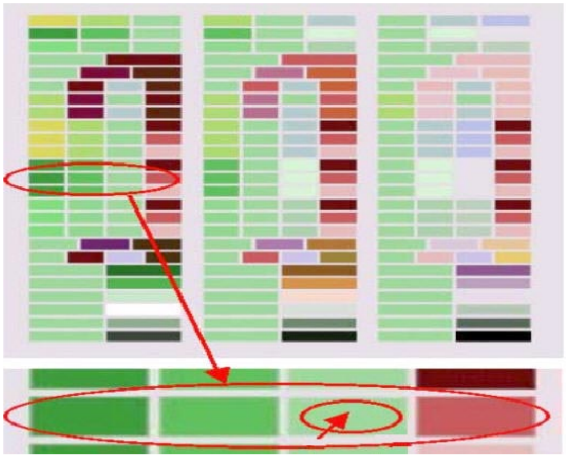

Figure 10. The possible color schemes that produced for a light green by a computer program prepared by the author, 2003

The facade painter: it can build such a program that can read the components of a façade, which saved in the data file by the façade analyzer, and then re-draw, paint and save the façade as an image. A trial program which had been designed by the author confirms this possibility figure 11.

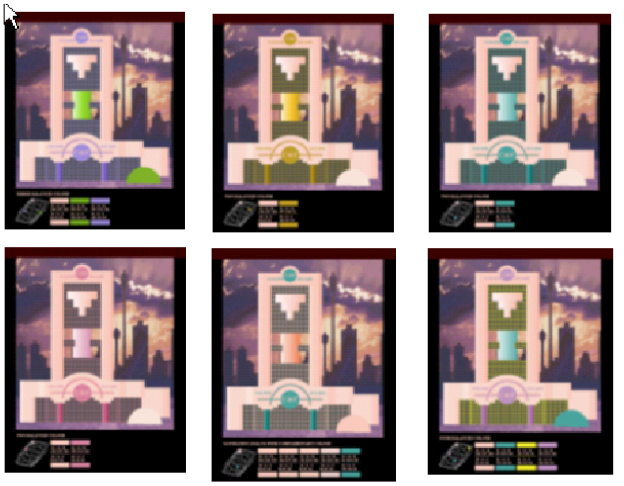

Figure 11. Results of a program, designed by the author, for re-draw and paint the facade with different color schemes

Now, the paper can confirm that it is possible to construct all components for the expert system PCAF, which leads to the possibility to construct the expert system PCAF.

VI. CONCLUSION:

It can be seen from all the points of study in this paper that there is a possibility to construct an expert system as a "Computer-Aided Architectural Design (CAAD) tool" that can provide the architect with the probable color alternatives

for a facade, and facilitate an important part of the architectural design process.

An ideation (a prototype) of the expert system "PCAF" had been presented. This ideation includes the essential components of any expert system beside some addition components related to nature and the function of the system.

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