A COMPUTER PROGRAM FOR LIMITING THE SUITABLE COLOR RANGE FOR FACADES

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Abstract. Limiting the suitable color range is considered as one of the important steps in the process of choosing color for facades. This paper aims at developing and presenting a rule based program that its main function is **L**imiting the **S**uitable **C**olor **R**ange (**LSCR**) for building facade. So, the paper presents the steps of color limitation process, its requirements and classification of different factors that influence color decision such as functional, climatic, environmental, social, commercial and political factors…etc. After this step, the paper presents a description of the supposed program, its components (the user interface, the knowledge base, the inference engine and the color palette) and the relationships in-between. Then the paper presents the running sequence of LSCR and a practical example for using it to limits suitable color range for a facade due to its circumstances.

1. Introduction

Computer became a necessary tool in all science branches including architecture. During the last years, it began to exist in all aspects of architecture. But there is a need to develop more applications that would assist architects throughout the different steps of design process.

Because color is one of inevitable visual properties of any material, the color selection of facade components is considered as one of the important stages in architectural design process. One of the particular steps in this stage is limiting the suitable color range depending on the factors that influence the building and the color decision.

In the past, architects used traditional color circles, solids and models as a color palette to choose the suitable colors through it. But with the recent possibility of computer to compose a large amount of colors (about

16.77 million), specification of the suitable color range became not easy with traditional methods. This fact leads to a question about the role, which computer can play in this step in order to avoid neglecting of any suitable colors for facade.

This paper presupposes that computer can plays a role in assisting in limiting the suitable color range for building facades depending on a knowledge base for all factors that influence selecting color. So the paper aims at presenting a rule based program for **L**imiting the **S**uitable **C**olor **R**ange for building facades "**LSCR**" in accordance with all circumstances and factors, influencing the building and the color solution.

2. COLOR LIMITATION PROCESS

It is important that becoming acquainted with the color terminology that is used in this paper, steps of the color limiting process, circumstances and factors that influence it.

2.1 COLOR TERMINOLOGY

This point presents a briefly overview for the terminology related to colors (as pigment), that are used in this paper.

2.1.1 Color properties:

Colors may be said to be the quality of reflected light from a surface or a light source (Isaac, 1971). The word "color" refers to a companion of three properties: Hue, Value and Saturation.

HUE is the property that distinguishes one color from another, the property that enables us to name the color.

VALUE/ LIGHTNESS is the darkness or lightness of a color.

SATURATION refers to the purity of color or the vividness of a color (Cleaver, 1972).

2.1.2 Color Attributes

From thermal point of view, colors are classified into Warm and Cold colors (Porter and Byron, 1976).

Warm colors are the colors of the warm area of the spectrum. It includes yellow, orange, red and in-between colors.

Cold colors are the colors of the cold area of the spectrum. It includes green, blue, purple and in-between colors.

"Complementary colors" is earned attribute (which color earns it through its relationship with other colors), the opposite colors in a color wheel are complementary colors. When two complementary colors mix together, they compose a neutral color (Arnheim, 1974).

2.2 STEPS OF COLOR LIMITING PROCESS

Like all other architectural design stages, an architect follows some steps that lead him to obtain the most suitable color range for the facade that is under design. These steps are:

a. The first step in this process is collecting the circumstances of the facade and all factors influencing it.
b. The architect begins to Study and analyze the circumstances of the facade and all factors influencing it
c. Depending on the studies in field the of color and building facades (which provides him with all necessary knowledge in this field to take the right decisions), the Architect begins to get out the rules that control the relation between these factors, circumstance and the suitable color range.
d. Consequently, he uses these rules to infer the properties of the suitable color range for every one of the influenced factors.
e. In this step, the architect gets the crossed color properties in all partial color ranges that inferred in the previous step. The result is the color properties of the suitable color range for the facade and its circumstances.
f. The last step is applying the result onto a color palette for deleting the undesired colors and leaving the suitable colors in the palette (Figures 1 and 2).

After addressing the color limitation as a process, it is important to study and analyze the inputs of this process that are represented in the influenced factors and circumstances.

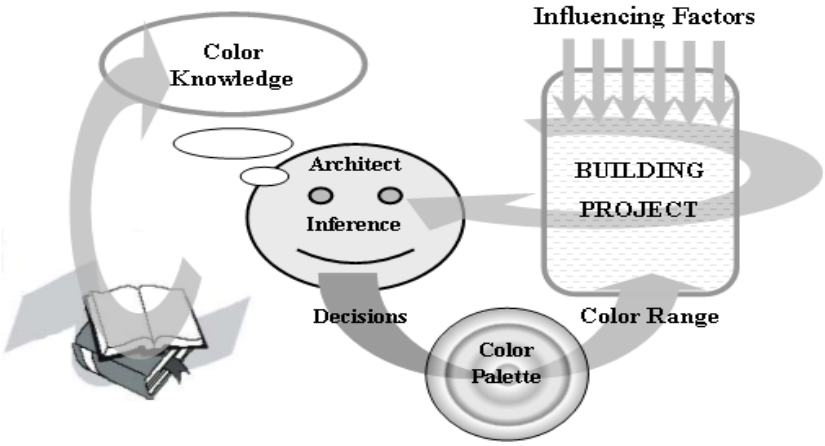

Figure 1. Method of getting the suitable color range for a facade

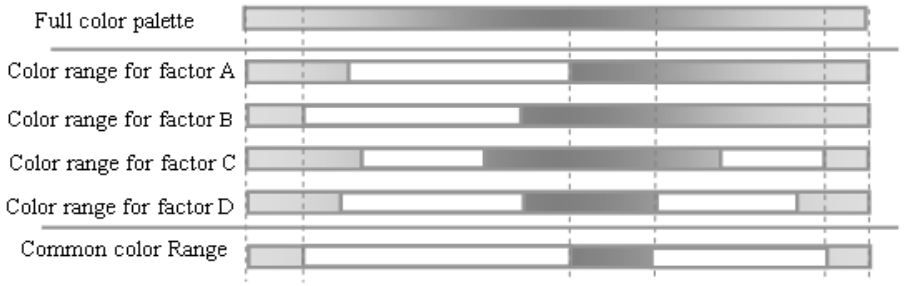

Figure 2. Method of getting the common color range for all factors

2.3 FACTORS THAT INFLUENCE THE COLOR LIMITING PROCESS

Factors that influence the design process are divided into three groups; the functional factors (requirements of building function), the natural factors (climate, material, environmental factor) and the human factors (psychological, cultural, social, aesthetical, economical, legislation and political factor).

Some of these factors don't influence the color limitation process and influence other stages in color selecting process. One of these factors is the material factor, which dealing with it is the last step in the color selecting process. The other factor is the aesthetical factor, which influences the way of organizing and distributing colors on the different components of a facade.

The human factors influence the desires and preferences of members of the architectural work (the architect, the investor, the user, the society and the municipality), and consequently influence the color limitation process (Abdelmagid, 2000).

These factors can classify into two groups; inevitable factors and commendable factors.

2.3.1. Inevitable and coercive factors

- **Legislation factor:**

The most inevitable factor is the legislation factor. It may cancel the limitation process if there are any laws that control selecting the colors of building facades.

- **Function:**

The suitable color range for the functional factor is tied to the emotions and feelings that the facade should present in accordance with the building function. Previous studies present the relation between colors and feelings, functions and feelings (AbdelMagid, 2000). The relation between building function and facade colors is derived and presented in Table 1.

TABLE 1. The suitable color range for the different building functions.

Building Function	Color Properties		
	Hue	Lightness	Saturation
Residential	All Hues	High & Medial	All
Governmental	All Hues	All	Medial & Low
Administrative	All Hues	All	Medial & Low
Trade	All Hues	High & Medial	High & Medial
Service	All Hues	High & Medial	All
Cultural	All Hues	High & Medial	All
Educational	All Hues	High & Medial	All
Health	All Hues	High	Medial & Low
Recreation	All Hues	High & Medial	High & Medial
Tourist	All Hues	High & Medial	High & Medial
Social	All Hues	High & Medial	Medial & Low
Industrial	All Hues	All	Medial & Low
Religious	All Hues	High	Low
Funeral	All Hues	All	Low
Sport	All Hues	High & Medial	High & Medial

- **Climate:**

Climate Studies in field of architecture confirm that color helps in thermal adaptation of the building. These studies clarify that hot climate requires light colors that can decrease heating penetration into the building. Also it requires cold colors that can realize sensation with coldness towards the buildings. On the contrary, cold zones require dark and hot colors (Zelanski and Fisher, 1989). The temperate zones don't require any color conditions (Table 2).

TABLE 2. Thermal circumstances and its suitable color range.

Thermal Factor	Color Properties		
	Hue	**Lightness**	**Saturation**
Hot Zone	Cold Hues	High	All
Temperate Zone	All Hues	All	All
Cold Zone	Warm Hues	Low	All

- **The sun shine**

Saturated colors in zones that have a strong and direct sun shine (like the tropical areas) vanish with time. So these zones don't require saturated colors. Otherwise, zones that have a weak and indirect sun shine require saturated or light colors that can resist effect of shades and the lake of the light (Zelansky, 1989). Table 3 presents the suitable color range for sun shine probabilities.

TABLE 3. Sun Shine factor and its Suitable color range.

Sun Shine	Color Properties		
	Hue	**Lightness**	**Saturation**
High	All Hues	Low	Medial & Low
Medial	All Hues	All	All
Weak	All Hues	High	High

- **Orientation:**

In the north of the equator, north facade s is shaded most of the day. Shades on this facades lead to decreasing the visual saturation and lightness of the color, so colors in these facades appears less in lightness and saturation. Such facades require saturated and light colors (AbdelMagid, 2000). East and west facades don't require any special conditions. Also, the suitable colors for a south facade (sunny facade) are the non saturated colors. Otherwise, dealing with the building that has multiple orientations, and in order to avoid the

separation of colors of facades, it is good to ignore the effect of this factor in such case (Table 4).

TABLE 4. Orientation and its suitable color range.

Orientation	Color Properties		
	Hue	**Lightness**	**Saturation**
North	All Hues	High	High
East / West	All Hues	All	All
South	All Hues	All	Medial & Low

- **Pollution:**

Pollution leads to a visual decreasing for saturation and lightness level of colors. Also, the effect of pollution will appear fast and strong in colors with high and low level of lightness. So, polluted atmosphere requires using saturated colors with medial lightness.

Otherwise, Medial lightness level colors are suitable for the medial level pollution. The low level and no pollution don't have any special conditions (AbdelMagid, 2000) (Table 5).

TABLE 5. Pollution level and its suitable color range.

Pollution Level	Color Properties		
	Hue	**Lightness**	**Saturation**
High	All Hues	medial	High
medial	All Hues	medial	All
low	All Hues	All	All

- **Surrounded Colors:**

The surrounded colors - in the built environment - represent a reflection of some human factors (like the social, political and sometimes the cultural) on the color preferences of the society.

Taking this factor in consideration has three directions: The first is the similarity between color properties of facade colors and the surrounding colors. This direction means canceling of the limitation process.

The second is the negligence of its effect in case that there isn't a dominant surrounded color.

The third direction is considering the facade colors as a part of big colored image that includes facade colors and dominant surround color. This leads to deal with the color of the facade as a component of color schemes, where the dominant surround color is essential.

2.3.2. Commended Factors

Some of human factors like cultural, social, economical, technological, political and psychological factor are considered as commended factors.

Studies clarify that these factors are crossed, for example, it is difficult to separate the effect of the cultural factor away from the psychological factor or the technological factor away from the economical factor. Also it explicates the different forms of effects and its reasons.

Because these factors influence color preferences of members of the architectural work (architect, investor, user and municipality), the influence of them can replace by preferences of members of the architectural work. But some studies warn from the danger of obligation the human preferences because they may lead to a mill color choice (Mahnke, 1987). So, and as a principle, a human preference is respected if they belong to the suitable color range of the inevitable factors.

3. DESCRIPTION OF LSCR

After becoming acquainted with the steps of color limitation process and the influencing factors, it is clear that such program can depend on four essential components that represent all requirements to emulates and perform procedures of color limitation process. These components are Knowledge Base, Inference Engine, Color Palette and User Interface (Figure 3). For constructing LSCF and its components, the author used “Visual Basic” as a programming language.

3.1 THE USER INTERFACE

It is a means of communication between the program and the user (the architect). He inserts the inputs of the program (influencing factors and circumstances), which is necessary to the inference engine in order to work. The probabilities of each factor are presented as a pull-down menu that, and through it, the user selects the corresponded case.

Also and through it, the user receives the suitable color range for every factor and for the crossed range as a final result. Components of the user interface are shown in Figure 4.

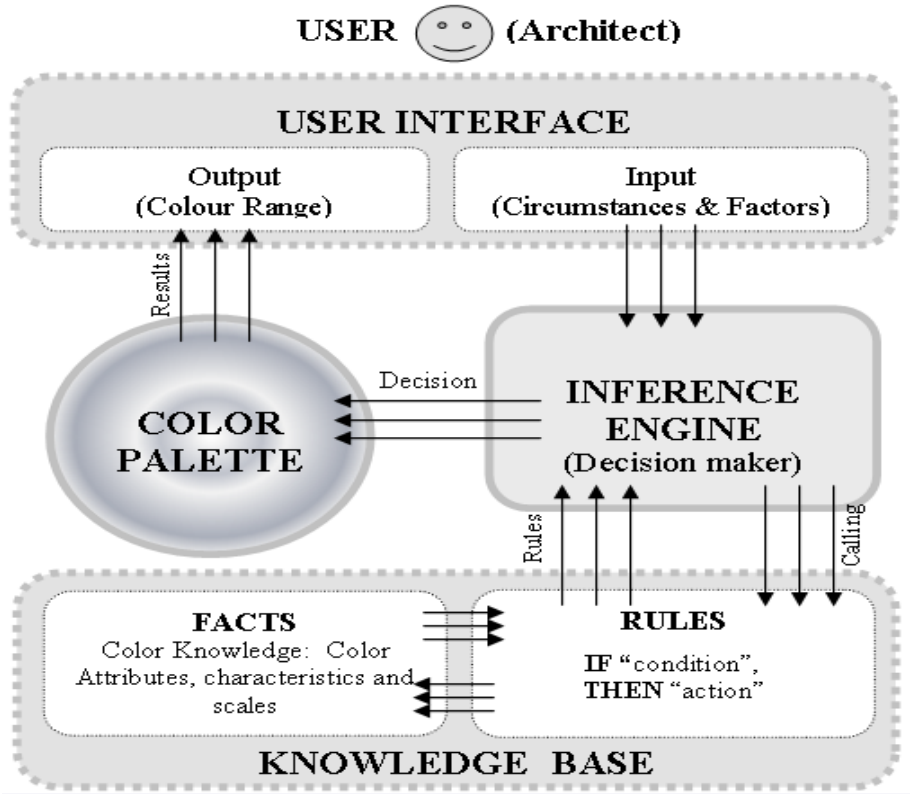

Figure 3. Structure of a program for limiting the suitable color range for a facade -LSCR

3.2 THE KNOWLEDGE BASE

That contains a representation of knowledge related to circumstances that may influence the process of limiting the suitable color range. One widely used representation is the production rule, or simply "Rule". A rule is composed of an IF portion and a "THEN" portion. The IF portion lists a set of conditions. The piece of knowledge represented by the rule is relevant to the line of reasoning being developed if the IF part of the rule is satisfied; consequently, the THEN portion can be concluded, or its problem-solving action taken.

LSCR Knowledge base consists of 27 rules that inference engine use to cover 1215 probabilities of inevitable influencing circumstances.

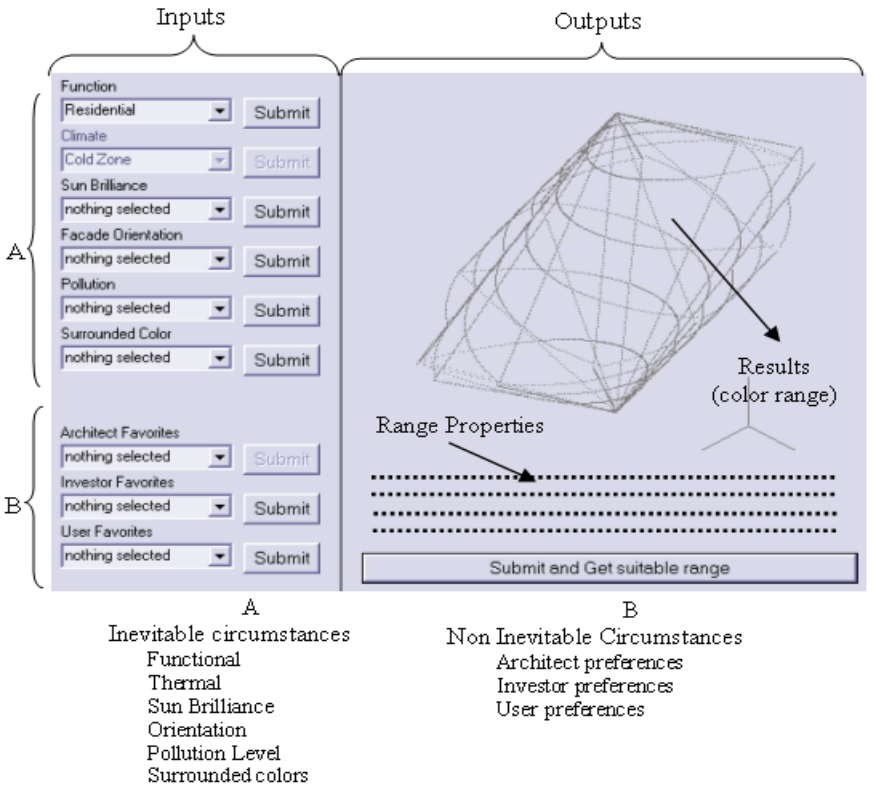

Figure 4. Components of User interface in LSCR

The following are examples of rules in knowledge base of LSCR.

RULE
IF
Building function is ***Residence***
THEN
Properties of suitable color range are:
Hues are ***All Hues***
and Lightness is ***Medial*** and ***High***
and Saturation is ***High***

RULE
IF
Thermal zone is **Hot**
THEN
Properties of suitable color range are:
Hues are ***Cold Hues***
and Lightness is ***High***
and Saturation is ***All***

A part of the encoded knowledge base of the program is presented in Figure 5.

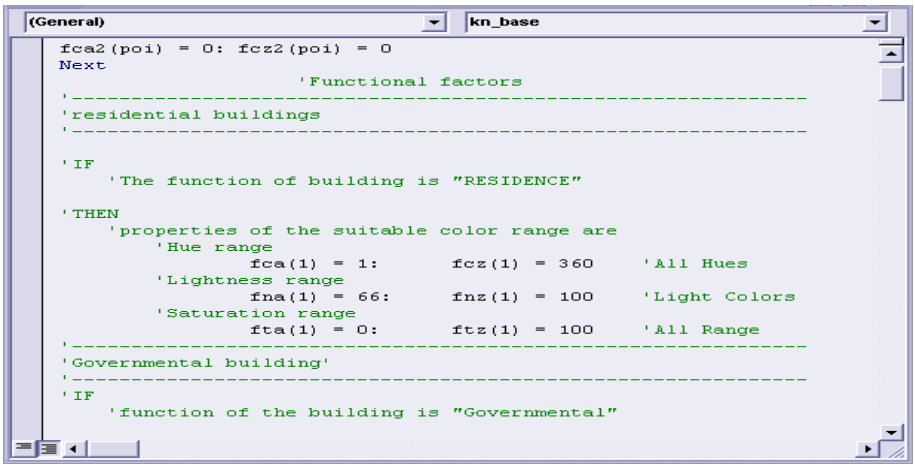

Figure 5. A part of the Knowledge Base of LSCR

Beside rules, it contains encoded facts like the color attributes: Hue, Lightness and Saturation, color characteristics: hot and cold colors and color scales for Hue, lightness and Saturation.

3.3 THE COLOR PALETTE

That is the color model, which represents a source of colors in the program. It is also a source of the relations between colors and their attributes. The color palette receives the decisions from the inference engine in order to apply it and to get out the suitable color range as a result.

As a color palette, LSCR depends on PCM (Figure 6) as a suitable computerized color palette for the architectural field, which was been derived by the author in the end of 2002 (AbdelMagid, 2003; AbdelMagid, 2004).

PCM palette is belonged into a computer program that can call colors in correspondence with colors properties that the inference engine presents them in the decision.

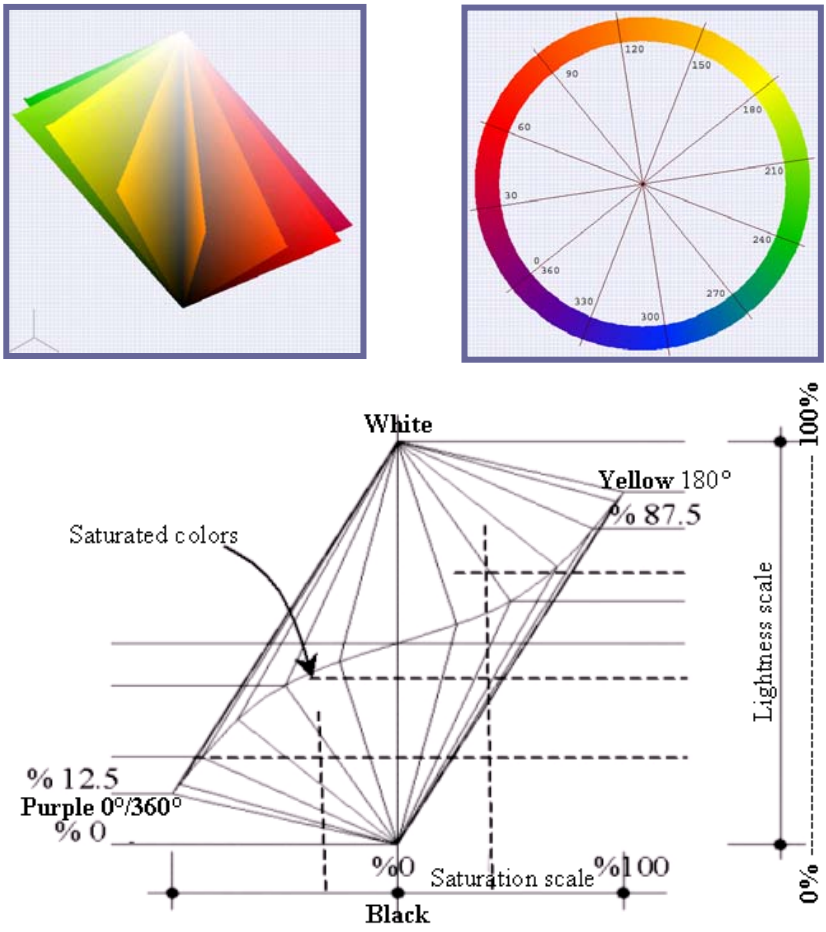

Figure 6. Properties of the Pigment Color Model "PCM" as a suitable color palette for the architectural field

3.4 THE INFERENCE ENGINE "IE"

IE is the head of the program. It receives the entered circumstances and influencing factors, and then it searches the knowledge base for necessary rules.

After collecting the needed rules, it selects a rule and then the actions of the selected rule are executed. IE selects another rule and executes its actions. This process continues until no applicable rules remain.

Through a treatment for rules execution results, the inference engine infers the decision that limits the properties of the crossed color range and

represents the properties of the suitable color range for inserted circumstances.

4. RUNNING LSCR

4.1. LSCR Working sequence

The next steps present the work sequence of such a program:

a. The program receives, from the architect, the circumstances and the factors influencing the facade. These factors divided into two main groups. The inevitable factors: Function, Thermal, Sun, Pollution, Orientation, Surrounding colors. The second is the human factors represented in their color preferences. The program does this function through the Input part of the user Interface (Figure 7).

b. Using the Inference Engine (The Reasoning Engine), LSCR begins to collect the rules related to the inserted circumstances and factors.

c. IE executes the collected rules and shows the color range that corresponds to every rule in the output part of the user interface. Then it makes a reasoning process in order to get the crossed color range of the inevitable factors group and then to the human factors group (that is represented in color preferences of the architect, the investor, and the users of the building).

d. The IE makes a comparison between the results of the two groups of factors and then takes its decision.

e. LSCR passes the decision through the color palette to obtain the suitable color range as colors and properties.

f. LSCR presents the results to the user (the architect) in order to complete the color choosing process manually or passing it to another program that can do the next steps in this process.

g. The program presents a simple report that includes all the inserted information, circumstance, factors, the program decision and all data related to color range. The report file type is a text file beside a bitmap file that shows the color range into PCM color palette. Both two files are printable and saveable.

4.2. PRACTICAL EXAMPLE

After inserting circumstances that influence the building through the user interface, some hidden processes run and then the user receives the suitable color range for inserted circumstances.

4.2.1. Inserting circumstances

One of the 1215 case that program covers, is a residential building in a hot zone, medial sun brilliance with a north facade in a polluted atmosphere and the surrounded colors is light colors. On the other hand users prefer the green tones and the investor prefers light colors without any preferences for the architect. Through the user interface, the architect passes the previous circumstances in the correspondence place to every factor (Figure 8).

Inevitable Circumstances:

- The building is Residential.
- The climate is Hot.
- The sun brilliance is Medial.
- The orientation of the facade is North.
- The atmosphere pollution level is High.
- The surrounded colors are Light Colors

Commended Circumstances:

- The architect hasn't any color preferences.
- The investor prefers the High Lightness colors.
- The user prefers the Greened colors

After inserting all circumstances, the user presses the button "Submit and Get the Suitable Color Range". Then the program begins to do its hidden procedures.

4.2.2. Hidden procedure

It includes calling and executing rules related to every one of the inserted factors.

After getting the suitable color range for the inevitable circumstances (Table 6), LSCR begin to get the color preferences of the architect, the investor and the user (Table 7). Then he gets the crossed range between the two ranges (Table 8)

Figure 8 shows the results of reasoning and inference process due to the sequence of running.

TABLE 6. The suitable color range for the inevitable circumstances.

Circumstances	**Color Properties depending on PCM palette**					
	Hue (1:360)		**Lightness (%)**		**Saturation (%)**	
	from	**to**	**from**	**to**	**from**	**to**
The Building Function is Residential	1	360	33	100	0	100
The Local Climate is Hot Zone	180	360	66	100	0	100
The Sun Shine Level is Medial	1	360	0	100	0	100
The Facade Orientation is North	1	360	66	100	63	100
The Pollution Level is Low Level	1	360	0	100	0	100
The Surrounded Colors is Light	1	360	66	100	0	100
Properties of the crossed color range for inevitable circumstances	**180**	**360**	**66%**	**100%**	**63%**	**100%**

TABLE 7. The suitable color range for the commended circumstances.

Circumstances	**Color Properties depending on PCM palette**					
	Hue (1:360)		**Lightness (%)**		**Saturation (%)**	
	from	**to**	**from**	**to**	**from**	**to**
The Architect ‘s Preferences is Ignored	1	360	0	100	0	100
The Investor ‘s Preferences is Light colors	1	360	66	100	0	100
The User‘s Preferences is Specific (greens)	210	270	67	87	27	90
Properties of the crossed color range for commended circumstances	**210**	**270**	**67%**	**87%**	**27%**	**90%**

TABLE 8. The suitable color range for all circumstances.

Circumstances	**Color Properties depending on PCM palette**					
	Hue (1:360)		**Lightness (%)**		**Saturation (%)**	
	from	**to**	**from**	**to**	**from**	**to**
Properties of the crossed color range for inevitable circumstances	180	360	66%	100%	63%	100%
Properties of the crossed color range for commended circumstances	210	270	67%	87%	27%	90%
Properties of the crossed color range for all circumstances	**210**	**270**	**67%**	**87%**	**63%**	**90%**

4.2.3. Result

LSCR found that the color ranges of the inevitable and the commended circumstances are crossed. So, there is a common color range for all inserted circumstances. LSCR presented a report for limitation process as a text file (Figure 9) that shows all inputs, reasoning and outputs of the limitation process.

LSCR shows the suitable color range for all circumstances and its properties in the output section of the user interface and saves it as a bitmap file (Figure 10). Result corresponded to the circumstances of the facade (as it is shown in figure 10 and the report) depending on the PCM color palette is:

Suitable color Hues from 210 to 270
Suitable Lightness from 67 % to 87 %
Suitable Saturation from 63 % to 90 %

Now the architect obtained the common color range, suitable for all circumstances that influence the facade that he studies.

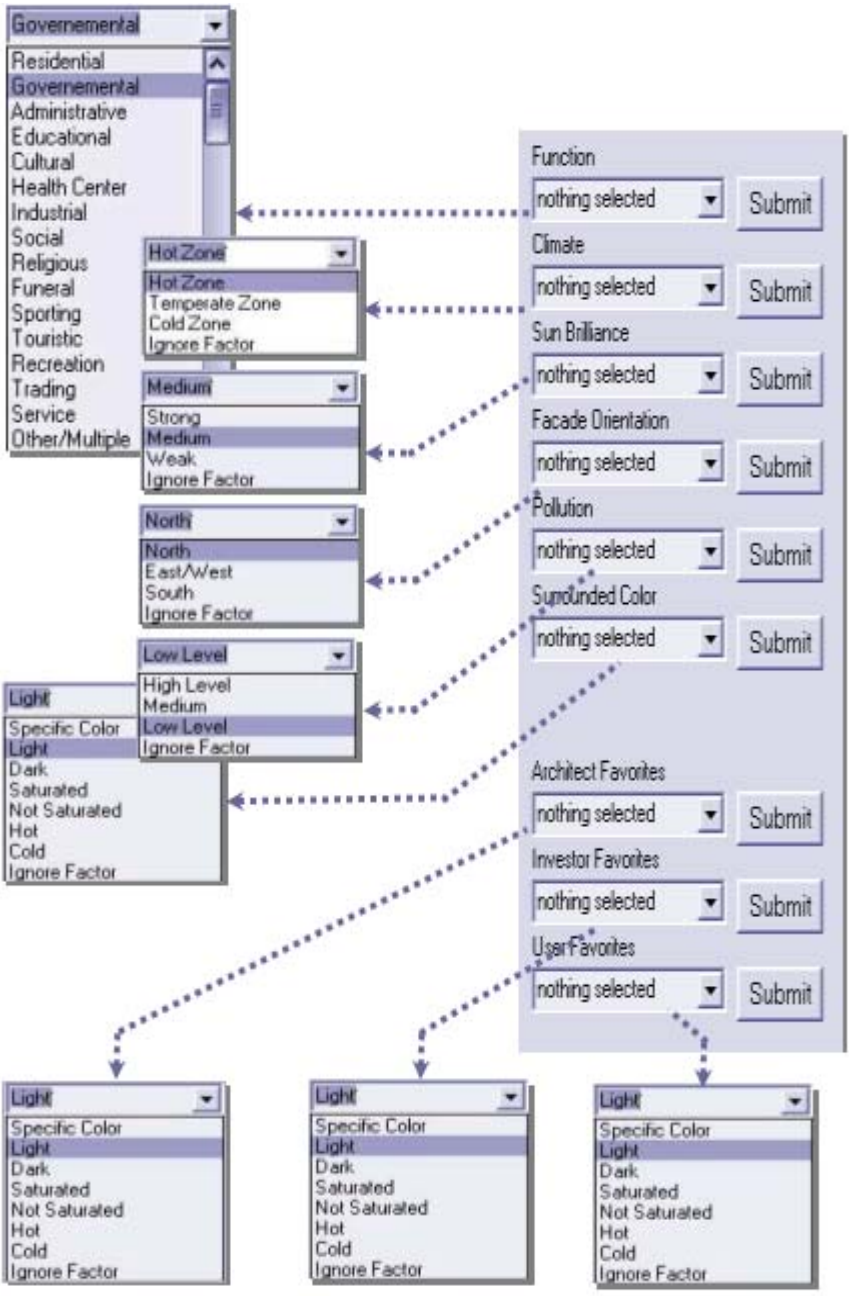

Figure 7. User inserts circumstances of the facade into LSCR through the Input part of the user interface.

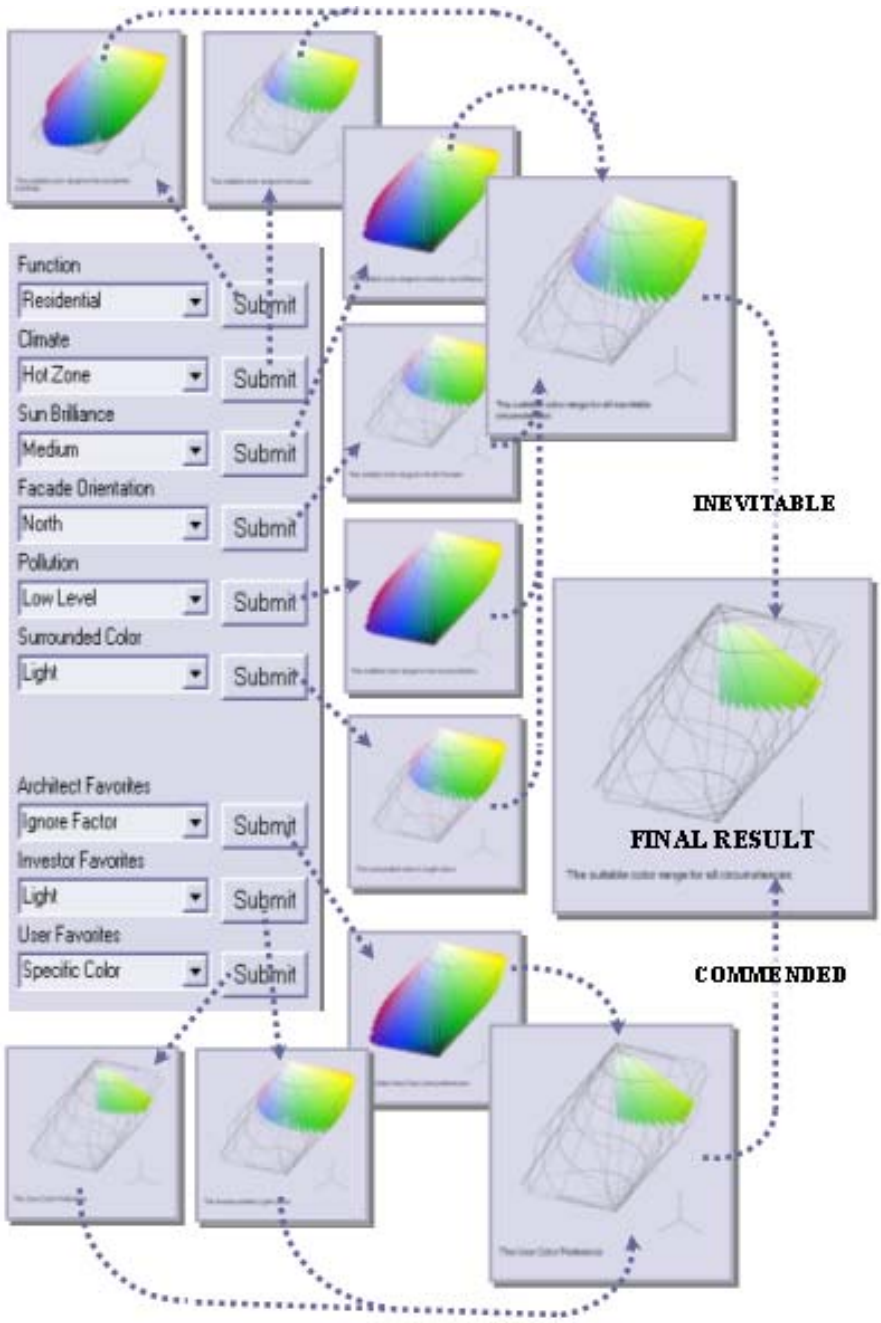

Figure 8. The hidden process to get the suitable color range for the inserted circumstances

LSCR RESULT REPORT

The suitable color range for Facade No. 95/59
for building: ABC

I. General Information

Date: 8/15/2004 7:17:52 PM

Building Name: ABC
Address: 50 M. A. Makarem St.
City: Assiut
Country: Egypt

Architect: DARCO
Investor: UNITED GROUP LTD.
User/s: Multiple

II. THE INSERTED CIRCUMSTANCES

The Inserted circumstances for the facade are:

1- The Inevitable circumstances:

The Function is Residential
The Climate is Hot Zone
The Sun Shine is Medium
The Orientation is North
The Pollution Level is Low Level
The Surround Color is Light

2- The Commended circumstances:

The Architect Preferences are Ignore Factor Colors
The Investor Preferences are Light Colors
The User Preferences are Specific Color Colors

III. REASONNING

LSCR found that properties of the correspondence color range for the inserted circumstances are:

1- For the inevitable circumstances:

	Color Properties depending on PCM palette					
Circumstances	HUE (1:360)		LIGHTNESS (%)		SATURATION (%)	
	FROM	TO	FROM	TO	FROM	to
The Building Function is Residential	1	360	33	100	0	100
The Local Climate is Hot Zone	180	360	66	100	0	100
The Sun Shine Level is Medium	1	360	0	100	0	100
The Facade Orientation is North	1	360	66	100	63	100
The Pollution Level is Low Level	1	360	0	100	0	100
The Surrounded Colors is Light	1	360	66	100	0	100
Properties of the crossed color range for inevitable circumstances	180	360	66 %	100 %	63 %	100 %

2- For the Commended circumstances:

	Color Properties depending on PCM palette					
Circumstances	HUE (1:360)		LIGHTNESS (%)		SATURATION (%)	
	FROM	TO	FROM	TO	FROM	to
The Architect Preferences is Ignore Factor	1	360	0	100	0	100
The Investor Preferences is Light	1	360	66	100	0	100
The User Preferences is Specific Color	210	270	67	87	27	90
Properties of the crossed color range for commended circumstances	210	270	67 %	87 %	27 %	90 %

LSCR found that the two color ranges weren't conflicted and they are crossed.
So, there is a common color range for all inserted circumstances.

IV. DECISION OF LSCR

Depending on PCM palette, Properties of the Suitable color range for the facade are:

Suitable color Hues are from 210 to 270
Suitable Lightness are from 67 % to 87 %
Suitable Saturation are from 63 % to 90 %

An illustration for the suitable color range for the inserted circumstances of the facade
is presented in image file at: c:\colorizer\results\SCRange_59_95.bmp

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Figure 9: A snapshot for LSCR report that shows limitation process and its results.

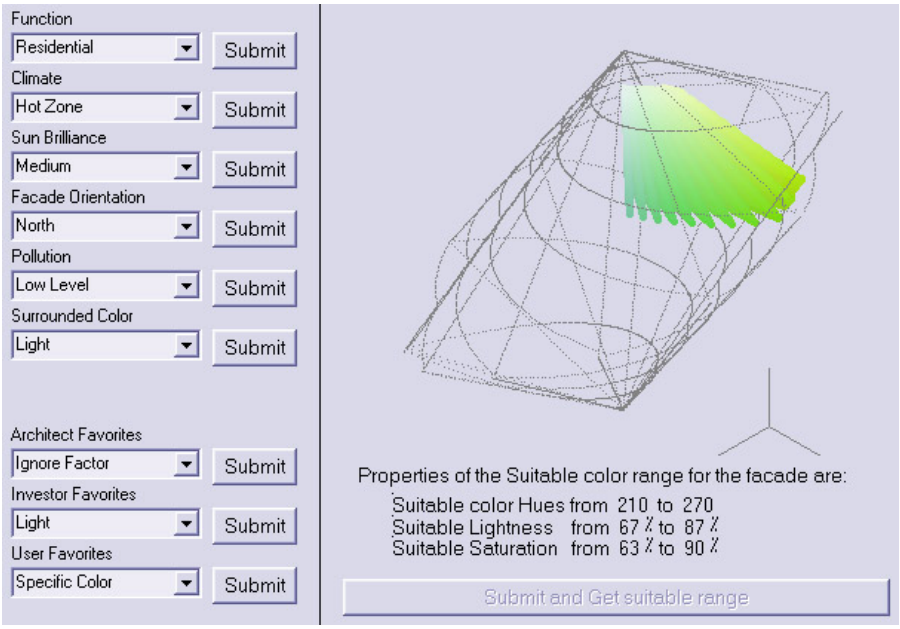

Figure 10. The suitable color range of the facade due to the inserted circumstances and its properties.

5. Conclusions and Future work

The paper presents a rule-based program LSCR that simulates the architect in limiting the suitable color range for a facade, due to the entered circumstances. Program developed by the author using Visual Basic as a programming language.

The future work is integrating LSCR with some other components (that presented by the author in previous studies) in order to construct an expert system that can present the correct color alternatives for building facades, that LSCR is its central program.

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