SOLAR ENERGY CONTROL STRATEGY USING INTERACTIVE MODULES

ملخص. ظهر مفهوم مظلات المباني التفاعلية كمظهر بارز للمباني الذكية في المساعي المعمارية باستخدام تطبيقات الذكاء الاصطناعي في العمارة الحوسبية. وجاءت المظلات التفاعلية كاستجابة لمكافحة الكائنات الحية للتغيرات البيئية الخارجية وكذلك للتقليل من استهلاك الطاقة في المباني. يهدف هذا البحث إلى استكشاف العمارة ذات الكفاءة العالية من خلال تأثير العوامل البيئية التكنولوجية على شكل التصميم من خلال إدخال الطاقة الشمسية في عملية التصميم عن طريق تنفيذ ستائر تفاعلية تتفاعل مع الشمس على شكل مظلة. والهدف الرئيسي من استخدام المظلات هو حماية المستخدمين من أشعة الشمس الضارة. بعد الانتهاء من تصميم خلية تفاعلية باستخدام برنامج جراسهوبر، تتبع منهجية البحث نهجًا تحليليًا وتجريبيًا. يشمل القسم التحليلي دراسة حالة لنماذج متعددة وتحليل التقنيات المستخدمة في هذه النماذج لاكتشاف المزايا والعيوب الهامة للتصميم. بينما يشمل القسم التجريبي آلية تنفيذ الوحدات التفاعلية. ويقترح البحث طرق للحفاظ على مستوى إضاءة أكثر توازناً من خلال تصميم مظلة تفاعلية تستجيب للتغيرات الخارجية وتستشعر الإشعاع الشمسي عندما تزداد شدة الإشعاع الشمسي وتكون الشمس متعامدة مع الوحدات الديناميكية. وتتم دراسة كفاءة العمل من خلال محاكاتها بواسطة برنامج استوديو المناخ.

الكلمات المفتاحية: الراحة الحرارية البصرية، العمارة الحوسبية، العمارة الحركية، المظلات المتفاعلة، بابل.

1. Introduction

Interactive designs are characterized by interacting with the conditions of the external environment on a daily - monthly - annual basis (Attia 2017). Its main principle is to control daylight through the use of light sensors, with the use of interactive blinds on the facade of the building, the amount of daylight entering the space can be controlled as it balances the outside vision and perception of daylight and also reduces the building's energy load and solar glare (Tabadkani et al., 2020; Lechner, 2014). The reason for focusing on the building envelope is because it is the barrier between the outdoor environment and the indoor environment. Adaptive building facades can provide improvements in the amount of energy efficiency consumption through their capacity, changing its condition in accordance with external and internal parameters (Aelenei et al., 2016). This envelope can exclude undesirable influences from the external environment while accepting desired effects. A well-designed building envelope provides 40% of the ecological solution, creating an efficient building that interacts with its surroundings (Etman, 2013; Phillips, 2013). In their study, it is demonstrated that if the artificial lighting system is combined with the natural light of the architectural space, will lead to a 30-40% reduction in energy consumption. In recent years, there has been a large body of research on lighting and its direct impact on human health and comfort on the one hand and energy

consumption on the another, daylight-based design is a new era in buildings as more designers are beginning to grasp the important value of daylight as a source of renewable energy and an alternative to artificial light. Reducing the amount of artificial light is an important step in the direction of sustainable buildings and energy savings (Mahdavinejad et al. 2012). Therefore, especially in recent years, a considerable number of modern buildings is designed with large window facades in order to solve the problem of lighting and avoid the use of electricity for lighting, but it was found that buildings in general and office buildings and companies in particular record high rates of energy consumption (EIA, 2021), the reason why this research will take administrative offices as a case study. The main objective of this research is to investigate ways that can maintain the visual comfort of administrative space in the province of Babylon, Iraq, by balancing the daylight entering the interior space and by reducing the lighting units. 100 watts of electrical power to 100 watts of light and heat. Through testing the design and implementation of an administrative space model that uses the property of dynamic disinformation, and then study and analyze the performance of this model in terms of reducing the amount of solar glare entering the space during working hours, and to identify the simulation process by mentioning the inputs and outputs. In addition to documenting the simulation process, identifying the variables and criteria used for each step-in order to help build an identifiable model tailored for the study context.

2. Literature review

Numerous studies have addressed the impact of dynamic facades on the internal performance of buildings. For example, Sanchez (2010) designed a model for a dynamic deception device. This research explores the potential of parametric techniques, programming and digital fabrication to design and build a skin responsive to bioclimate, where he studied its ability to control lighting and heat by placing sensors, the researcher chose the triangle shape in the design of the dynamic units and chose two types of transparent and semi-transparent materials. The solar cells were placed on the opaque part. Lighting and heat, as well as because of its location within the courtyards, contributed to the flow of air to the interior, and enabled the flexible shape of the panels to cover different types of surfaces. Babilio et al., (2019) also used the method of moving the deception units used in the famous sea towers and explained how to use the tensile property for the purpose of moving the panels. Through the analysis of the forces needed to tighten the panels and the presence of the research that it is possible by applying the tensile concepts for the purpose of producing modern techniques for the implementation of lightweight building envelopes characterized by rigidity

and the ability to perform their work. T, Pankratov & Grobman, Jacob (2014) built a model consisting of nine elements of deception units in the form of boxes that revolve around an axis from top to bottom and vice versa, and studied cases of central control so that the entire group is connected to a single sensor unit and decentralized, which means that each deception unit contains a sensor unit to measure the levels of illumination, their research found that decentralized disinformation provides a better distribution of illumination within the interior spaces of space. However, through the study of previous research, we found that few studies specifically address the problem of administrative spaces as a case study, despite the fact that the percentage of energy consumption in administrative and commercial spaces is high as mentioned earlier, in addition, previous studies did not consider contexts that suffer from severe climatic conditions, and lastly, previous studies did not outline the exact methodology or design stages that can be followed to design a model of dynamic deception
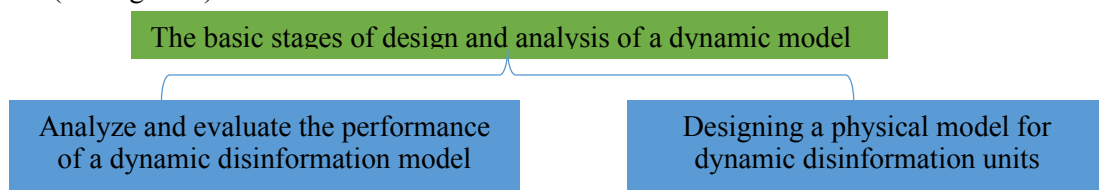
3. Methodology

The methodology depends on the use of the analytical method using the analysis program, studying the results, and comparing them

3.1. Software used

The plugin Rhinoceros and Grasshopper were used for the purpose of dynamic unit design and canopy geometry. These two software programs, especially Grasshopper, have the ability to handle complex designs. Arduino and firefly were used for the purpose of physical model design. Firefly is a plugin included in Rhinoceros that bridges the gap between Grasshopper and Arduino as it allows data to flow almost in real time between the digital and physical worlds, while Arduino is a tool for making devices that can sense and control the physical world through Connected to sensors and controllers

3.2. Research process

This research is based on the executive and analytical method by implementing and designing a first model for a dynamic interface, and then in the second stage, the performance efficiency of this model is analyzed and studied in terms of responding to daylight by making a virtual simulation (See figure 1).

The basic stages of design and analysis of a dynamic model

Analyze and evaluate the performance of a dynamic disinformation model	Designing a physical model for dynamic disinformation units

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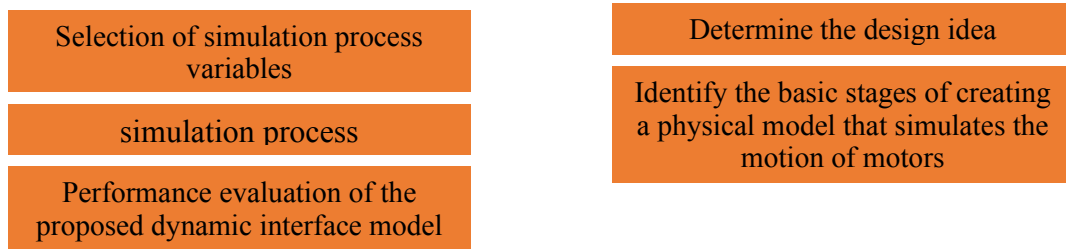|	
Selection of simulation process variables	Determine the design idea
simulation process	Identify the basic stages of creating a physical model that simulates the motion of motors
Performance evaluation of the proposed dynamic interface model	

Figure 1. Research framework

4. Designing a physical model for dynamic disinformation units

This section consists of two main stages as demonstrated below:

4.1. Design Idea
In order to create the image of interactive curtains, the designer sought to combine ancient Babylonian symbols with modern technology. As a result, the revival of an architectural symbol from the roots of ancient Babylonian thought as a research hypothesis consisting of two layers, a layer indicating the star of Ishtar and a layer indicating digital applications.
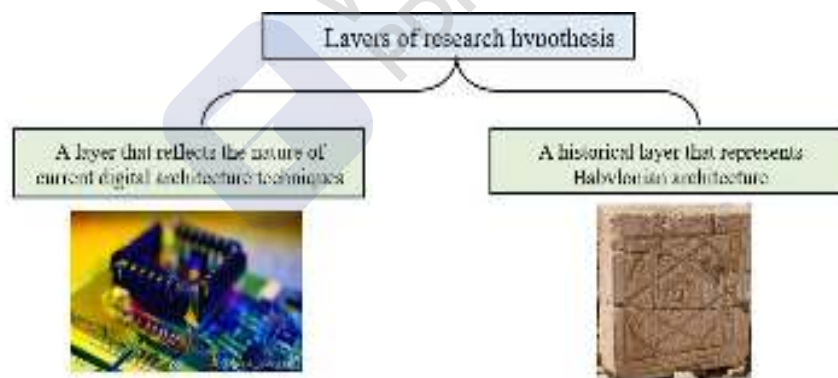
Figure 2. The concept for the design unit

A polygon consisting of six sides as found in the star of Ishtar was chosen, then the shape was divided into triangles, by connecting each point at the end of each side to the center to form six triangles that meet each other in the center of the hexagon and thus form the main axes on which it moves dynamic units. As for the last stage, it included dividing the triangles

resulting from the second stage into smaller triangles. The method of finding the center of each of these six triangles and then repeating the same lines by connecting the end and beginning of each side with the center and thus we have the form of dynamic units.
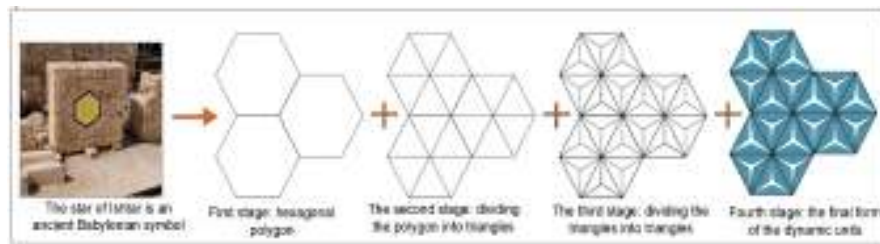

Figure 3. Stages of unit formulation

4.2. The basic stages of creating a physical model that simulates the movement of motors
The steps of creating the model suggested for the study can be divided into five stages, as follows:

4.2.1. Stage one: Determine the proposed type of movement for dynamic units:
 The movement selected in the design of the dynamic units was rotation on a specific axis and the table below depicts the stages of the movement of the dynamic units in terms of the closing ratio
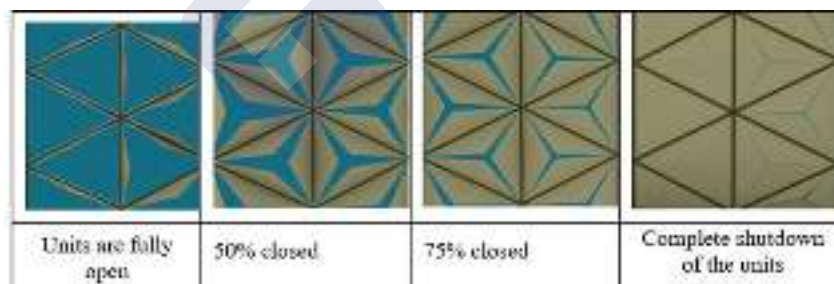
Figure 4. Stages of units' movement.

4.2.2. Stage two: The design of the sectors for the physical model
Dividing the physical model in Rhino software was designed for the purpose of understanding how the parts of the dynamic units move and the interconnection of the pieces to each other, as well as for the purpose of

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preparing the pieces for the laser cutting process by drawing them in a 2D format so that the laser machine is ready for the laser cutting process
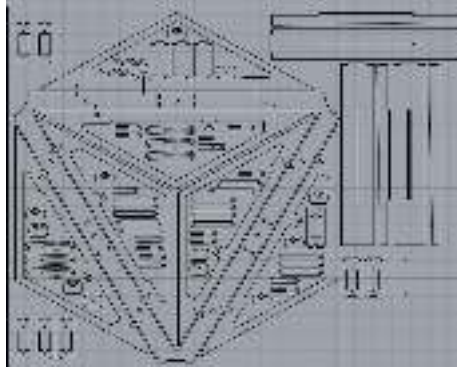
Figure 5. Designing sectors for dynamic units for the purpose of preparing them for the laser cutting process
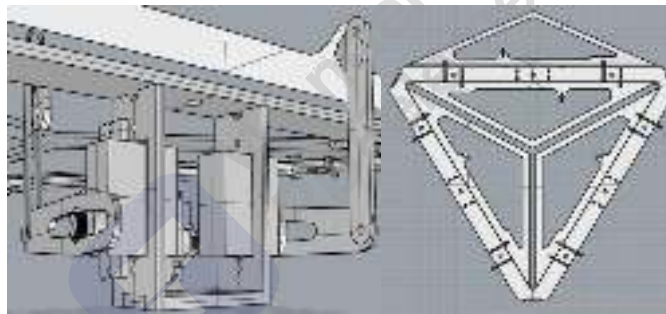

Figure 6. 3D design of dynamic unit segments

4.2.3. Stage three: Preparing the physical model.

The model was prepared from High Density Fibreboard (HDF) wood with a thickness of 3 mm and the parts were joined together to make a realistic simulation of the movement of the model.

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Figure 7. A depiction of some stages for the physical model-building process
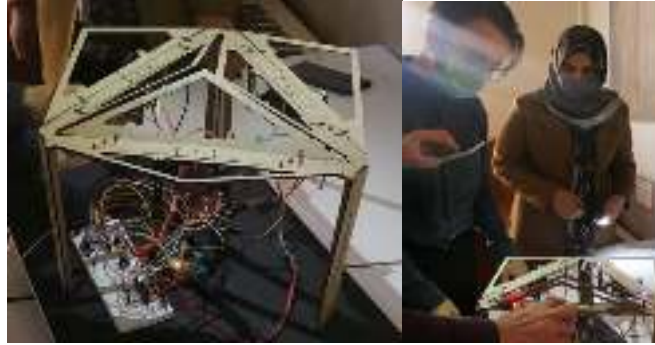
Figure8.The final form of the physical model

4.2.4 . Stage four: Identifying the required electronic sectors and linking them to the physical model.
In order to build the simulated physical model for the movement of the engines responsible for the movement of the proposed dynamic interface, some Physical Design tools were used as demonstrated in the table below

TABLE 1. Mechanical parts used in the model

Servomotors MG90S	Arduino Uno
Jumper Wire	Breadboard
Adapter 5 volts 3 amps	Resistance
LDR sensor	

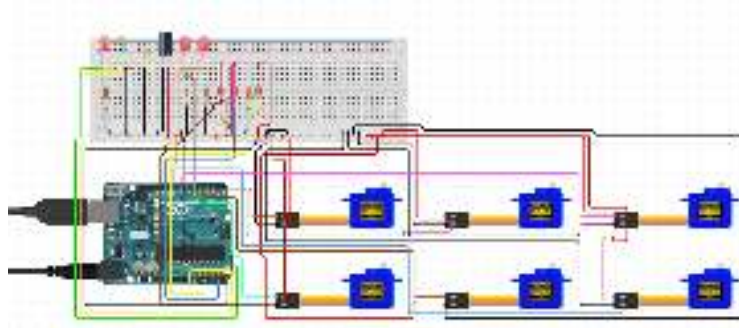SOLAR ENERGY CONTROL STRATEGY USING INTERACTIVE MODULES

Figure 9. Simulation of the component electrical circuit of the
physical model of the dynamic modules, as shown in Connecting the
motors and sensor module to the Arduino board

4.2.5. Stage five: Suggesting a methodology for interacting with changing
climatic conditions.
For the purpose of interaction between reality and simulation programs, the
Arduino control board was used, which allows the interaction of the
geometry with the sun. An LDR sensor was installed that can monitor the
intensity of illumination and then link the reading to the angle of movement
of the motor, and to do this step, Remap was used, a directive that works on
filtering reading the minimum and maximum value of the measurements of
the luminescent sensors, and then in the target section, the minimum and
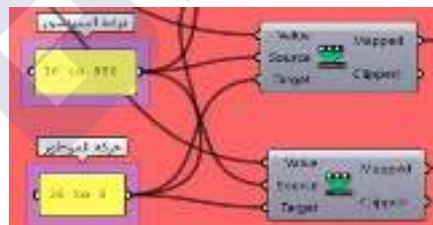maximum angles were added to the movement of the servo motor

Figure 10. The Remap variables to read the light and motion sensor
of the motor sensor

Where the maximum value of the sensor reading resulting from the
simulation process in the case of clear and sunny skies is 850, and the
minimum value represents the reading of the sensor in the case of cloudy
skies or at night. For the servo motor movement value, the minimum value
represents the closing of the units in the case of clear sky and sunlight
perpendicular to the dynamic units, and the value 36 represents the

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maximum value of the servo motor movement, where according to the tests conducted on the motor movement and the movement of the dynamic units in the physical model, it was found that when 36 degrees, the units will be fully opened and will be perpendicular to the support structure When the units are closed, the light in the interior space will decrease, which is why the designer sought to follow a mechanism, which is that the less light in the interior space, the more LED will glow, and vice versa when the amount of indoor lighting is appropriate, it decreases until it reaches zero based on the external readings.
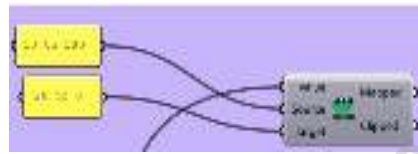

Figure 11.The minimum and maximum value of the LDE reading

The control panel is linked to the Grasshopper program via the Firefly plugin. Figure 12 shows the inputs and outputs of the Arduino board, which is to read the sensor unit as one of the main outputs, and the values of the motors' movements as basic inputs. Each motor separately and also the same process is repeated in the operation of the LED.
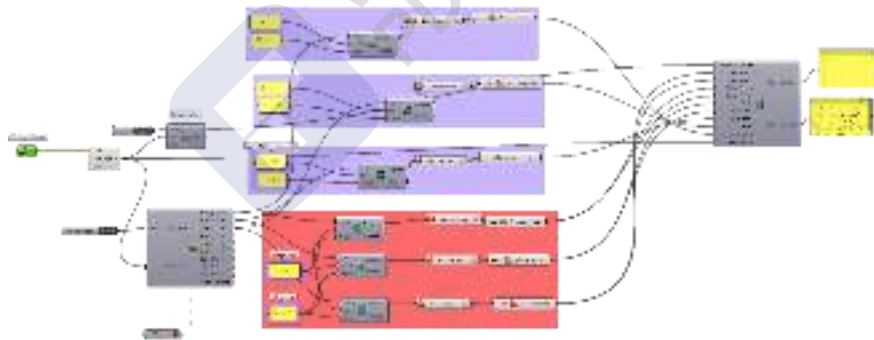

Figure 12.Arduino control panel definition strategy within Grasshopper

5. Analysis and evaluation for the performance of the dynamic disinformation model

This section includes a group of main and secondary stages. The first step begins with collecting the variables of the simulation process. The first stage of collecting the variables can be summarized as follows:

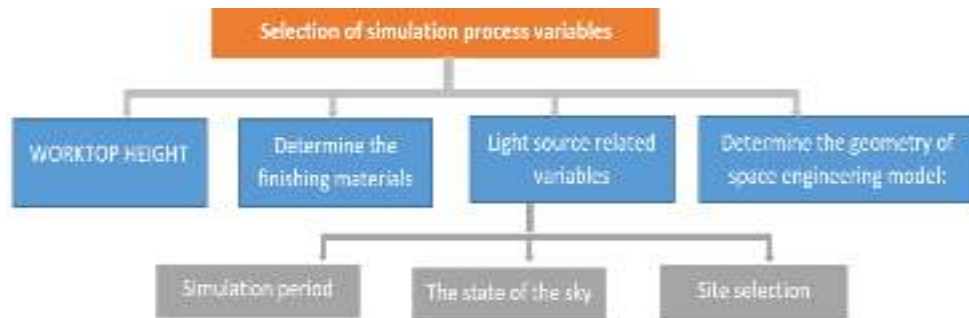SOLAR ENERGY CONTROL STRATEGY USING INTERACTIVE MODULES

Figure 13. The first stage of determining the variables

5.1.determine the geometry of space engineering model

Dimensions of the office space used in the simulation process are shown in Figure 14.

Figure 14. The internal dimensions of the researcher's space

5.2 Variables related to the light source

There are different variables directly related to the light source. These variables and the reasons for choosing their values can be explained as follows:

5.2.1. Site selection

The selected site is located in Iraq - Babil - Hilla, where the area is characterized by high temperatures. According to the simulation process that was conducted in the Climate Studio program, the results were obtained in Figure 15 for weather and climate information for the city of Hilla.

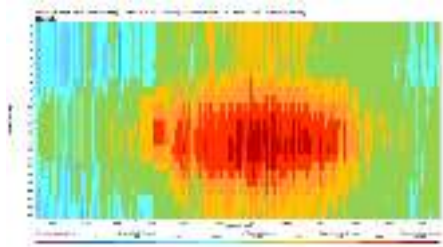SOLAR ENERGY CONTROL STRATEGY USING INTERACTIVE MODULES

Figure .15. A picture showing the temperatures in Hilla

Also, the chosen site is located within the urban fabric center of the city of Hilla and next to many administrative and commercial buildings and on 60th Street from the western side and University Street from the southern side, which is considered an important street in the region

Figure 16. Pictures showing the elected site (source: Google Earth Iraq)

5.2.2.The state of the sky
The state of the sky has an effect on the amount of light distribution within space (Faraj, Mamdouh. 2015) in this analysis. It was chosen when the weather was clear and sunny because most of the conditions prevailing in the Iraqi climate are clear, and this situation needs to be improved due to direct sunlight that causes visual disturbance to users.

5.2.3 Simulation period

As for the selection of simulation months, the research in this section relied on choosing the first day of each month (January and August).

5.3. Variables related to material properties
The office space consists of four main parts ((Floor - Ceiling - Wall - Window)) The values of reflection differ from one material to another and thus affect the distribution of light in the interior space according to the table of Figure 17, there are standard values recommended to be used,

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Building Component	Reflectivity	Visual Transmissivity
Walls and partitions	0.5	-
Ceiling	0.8	-
Floor	0.2	-
Shading	0.9	-
External ground	0.2	-
Glass	-	0.87

Figure 17. Reflection values required for the simulation process. Source : (Carlucci, S .2015).

5.4. Worktop height

Since the space under analysis is a desk and the work is done by computer, the height of the work surface here is 1.20 cm because it represents the variable height of the employee's eye from the floor.

6. Simulations

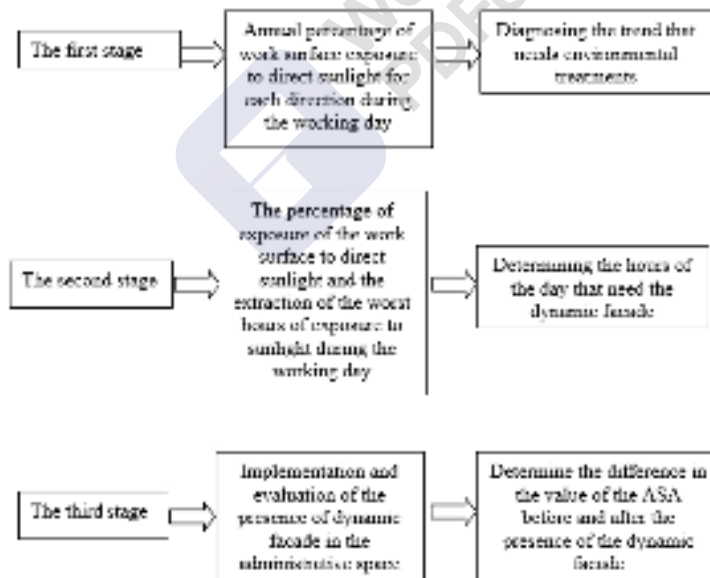After determining the fixed and variable inputs to the simulation process, the simulation steps begin.

Figure 18.Determine the objectives and stages of the simulation process

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The first stage: determining the path that needs environmental modification, in this stage the path that needs environmental treatment (dynamic interface) is determined by observing the values of the ASE scale of the work surface which describes the annual exposure to sunlight (ASE). where it is defined as the amount of area receiving direct sunlight, which may cause visual disturbance (glare) or increased cooling loads. Specifically, it is also expressed as the percentage of land receiving at least 1,000 lux for at least 250 hours of occupancy per year. (Jakubiec, 2014; Pilechiha et al., 2020; Mahdavinejad, 2012). It is possible to calculate the number of hours during which the work surface should not be exposed to more than 1000 lux Measurement equation (Pilechiha et al., 2020):

$$ASE = \frac{\sum_{i=1}^{N} AT(i)}{N} \; with AT(i) = \begin{cases} 1: at_i \geq T_i \\ 0: at_i \leq T_i \end{cases} \tag{1}$$

At this stage, 4 simulations were performed, and the evaluation of this stage is important in determining the worst interface that gives negative results for the lighting behavior within the space. the ASE scale values are displayed on the work surface, where each value monitored by the sensors displays its location on the grid with a color gradient indicating the extent of the problem.
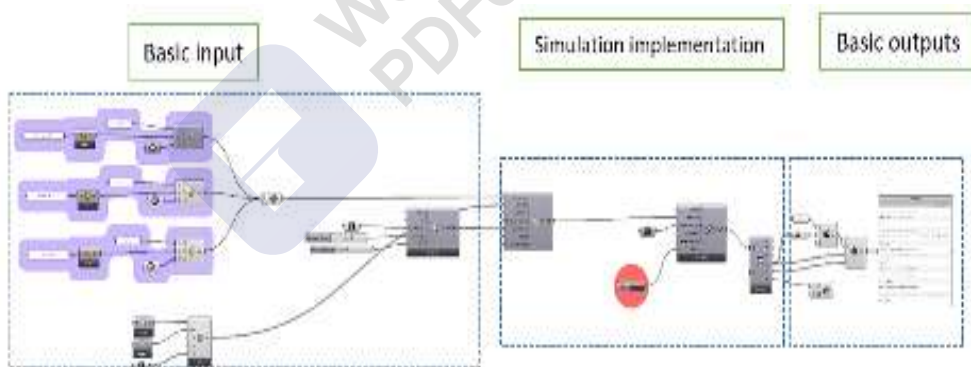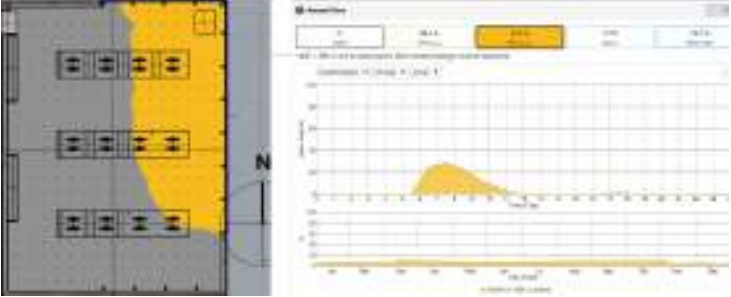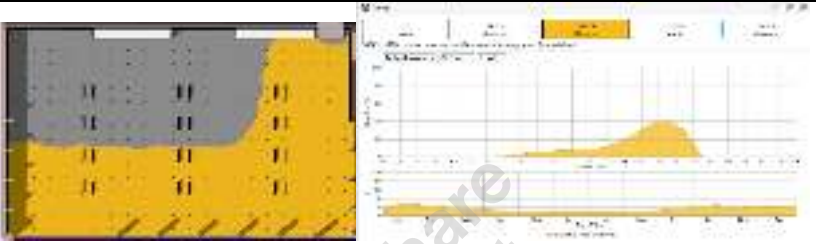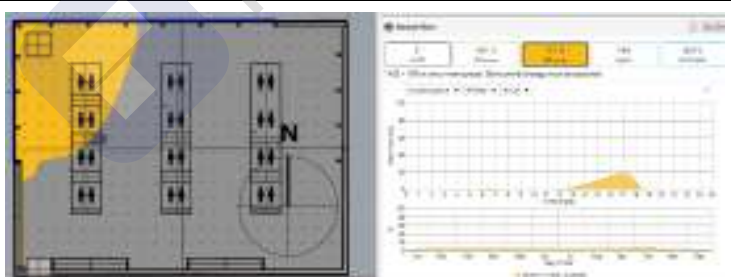

Figure 19. The full stages of the simulation process in Climate Studio

The simulation process is included in the table 2 so that the orange color indicates the amount of ASE

TABLE 2. The table below shows the results of the analysis for each of the four trends

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Eastern routing results ASE =32.8%	
Western routing results ASE =58%	
Southern Direction Results ASE = 40.6%	
North routing results of ASE = 17.1%	

According to the results, the western direction can be considered the most direction in which the work surface is exposed to direct sunlight, which causes glare and affects in some way on human vision, followed by the southern direction, then the eastern direction, and then the northern direction. As shown in the figure

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Figure 20. ranks the four trends of office space from worst to best.

According to previous studies, if the ASE value is equal to 10% or more, it indicates the visual comfort is not satisfactory, 7% can be considered a neutral value and 3% can be considered acceptable. (Advanced buildings).

In the western facade, more than 58% of the work surface is exposed to intense light of more than 1000 lux for more than 250 hours out of 1560 hours, which causes visual problems for 16 out of 24 employees during the year.

The second phase: For the second stage (determining the time periods that require environmental treatments) in this paper, the western (worst) interface was studied. In this step, the time periods needed to use the environmental improvements are determined. This is done by observing the values of the ASE scale of the work surface to the west during the working hours of the employees as one is simulated for one variable, the time period of work by keeping all the variables constant. Evaluation of this stage is important because it determines the worst time periods for the western facade
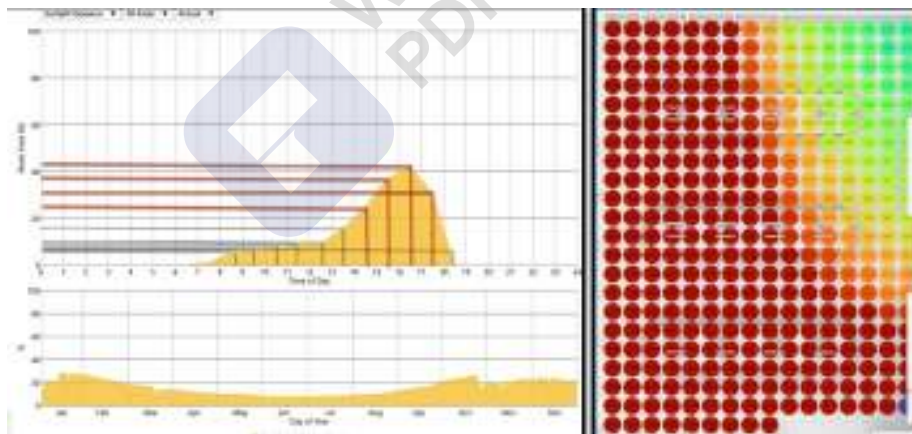

Figure 21. determining the time of day that requires environmental treatments.

The third stage: Before entering the evaluation stage, the components of the dynamic model and the proposed type of movement must be determined, and then the time rate of movement of the dynamic units

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Components of a dynamic interface model:
The dynamic interface consists of a set of levels as shown below.
1- Glass: It is a pane of glass with a transmission coefficient of 0.6 that is fixed directly to the wall.
2- Dynamic Facade Support Frame: It is an aluminum frame on which the parts of the dynamic units are attached.
3- Dynamic Interface Units: Each unit consists of a plate that rotates around an axis and is suggested to be made of PTFE with a reflectivity of 0.35 and a heat-resistant and currently corrosion-resistant fluoropolymer (Blumm, A.2011).
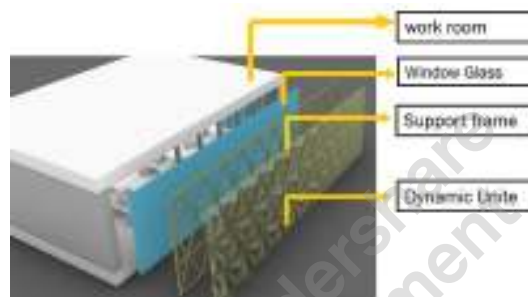

Figure 22. Components of the proposed dynamic unit's model.

7. Discussion

The discussion section will be thematized as follows:

7.1. Suggested movement type for dynamic units:
 The type of motion for the proposed dynamic facade units is the rotation of the axis see figure 23.

Figure 23. Movement type of dynamic modules.

7.2. Suggested strategy for dynamic interface unit's movement
The methodology used is the stability of all values with the change in the movement of the dynamic units and the ratio of opening and closing of the dynamic units, which corresponds to the distance between the point of direct light on the work surface and the center of solar radiation where the lower

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the distance the dynamic units will be closed and vice versa the farther units will open, and the analysis is performed During the daylight hours specified in the previous section
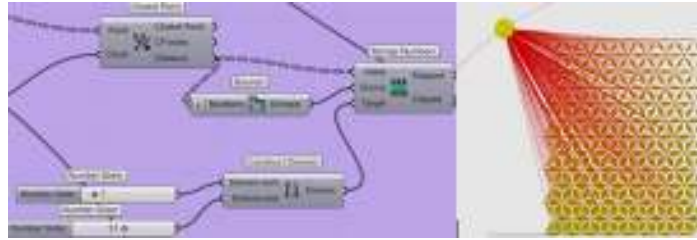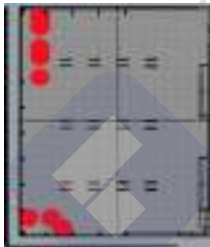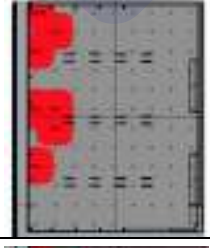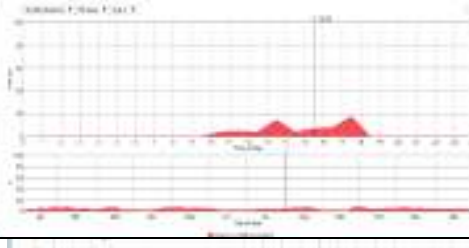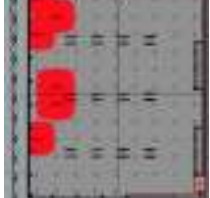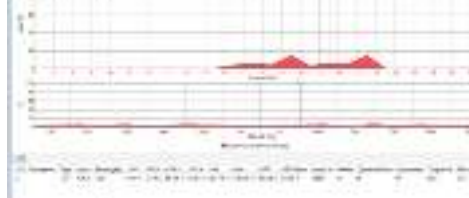

Figure 24. The relationship between the movement of the sun and the opening and closing of the dynamic units

7.3. Performance evaluation of the proposed dynamic interface model
To evaluate the performance of the proposed dynamic rendering model. The scale of the visual problem in office space had to be monitored before and after using the dynamic interface model

TABLE 3. Dynamic facades assessment on the first day of August

2:30 pm on the first day of August	
3:30 p.m. on the first day of August	
4:30 pm on the first day of August	

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5:30 pm on the first day of August	

Figure 25. Results of environmental treatments for the month of
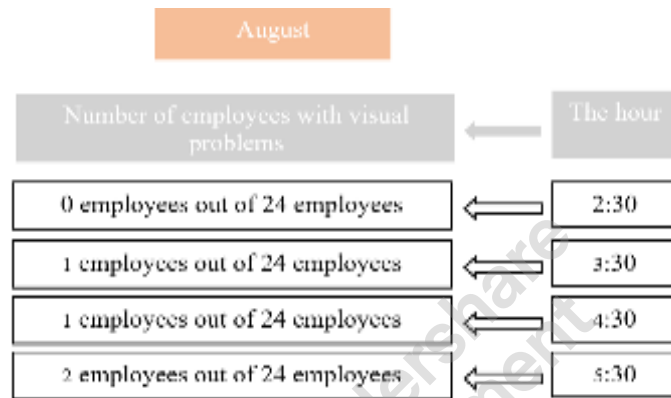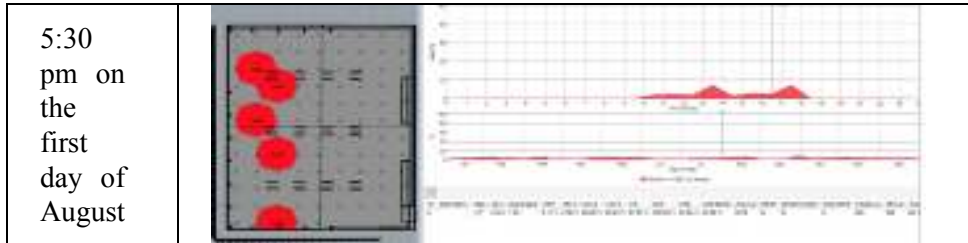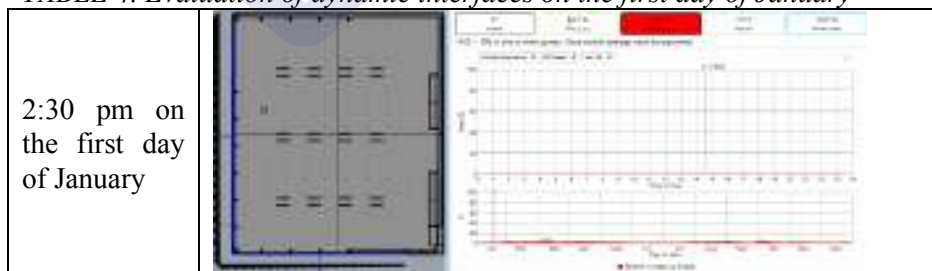August

After finding the results of the month of August, the researchers measured the effect of the presence of dynamic facades on the comfort of users for the first day of January and during the previously specified hours, as shown in Table 4.

TABLE 4. Evaluation of dynamic interfaces on the first day of January

2:30 pm on the first day of January	

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3:30 p.m. on the first day of January	
4:30 pm on the first day of January	
5:30 pm on the first day of January	

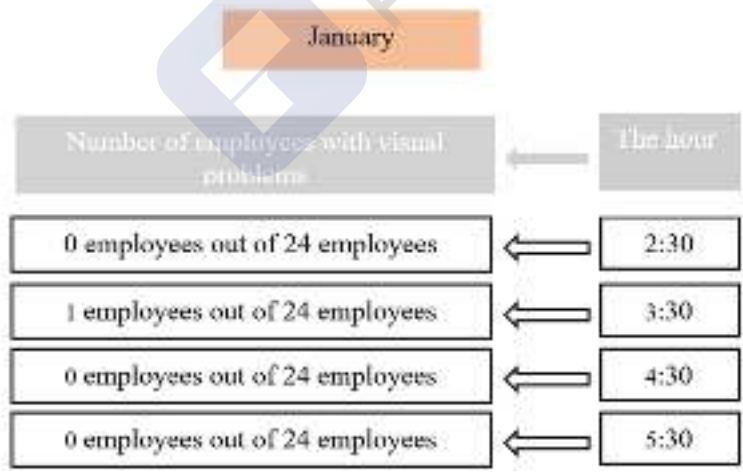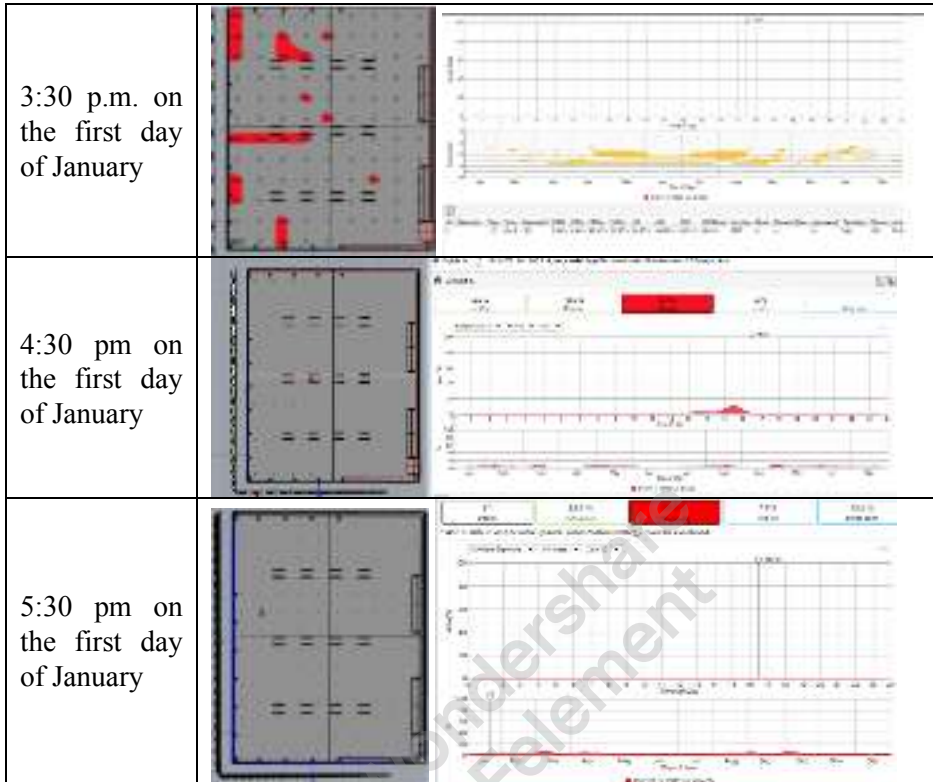| Number of employees with visual problems	The hour
0 employees out of 24 employees	2:30
1 employees out of 24 employees	3:30
0 employees out of 24 employees	4:30
0 employees out of 24 employees	5:30

Figure 26. Results of environmental treatments for the month of January

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8. Results

In this paper, an administrative space model before and after using dynamic canopies was studied and simulated by integrating grasshopper algorithms with Climate Studio environmental analysis plugin. The simulation was carried out based on the parameters of glare and brightness of daylight, the results of the simulation process show acceptable readings in reducing glare to imperceptible levels and at the same time enlarging external vision. Therefore, the strategies applied not only make space users happier and more energetic, but also improve their health through proper distribution of daylight and thus increase their productivity. Also, a method has been obtained to design a dynamic canopy to increase and maximize energy efficiency using Arduino and some electronic components.

This paper suggests using a Raspberry Pi instead of an Arduino, due to its high storage capacity and Wi-Fi, so it can be easily connected to a weather station to get weather information. This research also suggests using heating, cooling and energy saving in lighting as strategies for this study in order to achieve a more effective parameter-dependent adaptive interface. Operating in a Balance of Glare Reduction and Maximization of Outside Visibility is a precursor to future work as balancing thermal comfort and visual comfort is an objective in the design and integration process.

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