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Original Research Article

Modeling the Visual Illusions of "Resize in Urban Landscapes" on the Perception of the Urban Focal Points

Case Study: Visual Corridor of Ayatollah Tabasi Sidewalk to the Holy Shrine of Imam Reza*

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Abstract | Visibility of focal points is the result of visual information on the retina and how the form is perceived. Developing the principles of visibility of focal points requires understanding the visual space in the "horizon dimension" and "distance dimension" and background signals. This research seeks to answer the question that How can the focal points (urban landmarks) be located based on the visual illusion and the effects of the background (annoying) elements? In general, the purpose of this study is to develop a methodology that can be used to increase the visibility of the focal points of the city by arranging buildings and designing urban space and architecture. This Research is developmental in terms of nature and causal method in terms of purpose. Geometric modeling and virtual reality techniques were used to measure the relationship between physical structure, visual perception, and visual illusion. A case study of the focal point and indicator of the holy shrine of Razavi and sidewalk buildings of Ayatollah Vaez Tabasi was modeled with sketch up software. Based on the research literature, there is a point (M) in the visual corridor, where, based on binocular vision, the height of the focal point and the marker are equal; before that, the focal point height is perceived higher than the marker height but after that, is perceived smaller. Therefore, based on geometric calculations, the position of point M was modeled according to the height of the focal point-marker and the distance from the focal point to the marker. according to the three dimensional model of Ayatollah Vaez Tabasi sidewalk to the holy shrine of Imam Reza by virtual reality technique, the accuracy of the model was confirmed. Therefore, the arrangement of urban signs should be done following this issue in urban space.

Keywords | *Visual illusion, Visibility, Focal points of the urban landscape, Field of view, Depth and perceptual distance.*

Introduction| The problem of the spatial arrangement of the created landscape as a "manifestation of space and objects" is as old as the existence of ancient man. Since the formation of the first human habitation, "visibility" has been of great

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importance in the arrangement of buildings and space. During the Renaissance, Alberti introduced the concept of perspective in urban design, and Bernini designed St. Peter's Square as a link between spaces, axes, and buildings to create a kind of interaction between movement and perception (Bada & Farhi, 2009, 2). Yarbus (1967) introduced the focal points of urban space as the main elements or strategic focus in space, which provide more information than other components of the urban landscape and serve as a "space magnet" or destination. A focal point provides information about direction and distance, which can be considered as a landscape design tool to start moving (Nijhuis, 2011, 12).

According to the new psychological theories of visual perception, particularly in urban spaces, the dominance and emphasis of the focal points in the urban landscape spaces and scenes are explainable. The geometric arrangement of the urban landscape components is not the only way the layout of urban space, but also the focal points should be Outstanding in terms of visual physiology in the urban space. Focus point visibility is the product of an appropriate geometric organization of the physical structure of the nearer/ farther or larger/ smaller set that requires the understanding of a complex visual interaction with observers based on the principles of perception and visual illusion.

This paper aims to develop a focal point layout method by using the new theory of visual illusion of urban landscape, recognizing the perceptual nature of the urban landscape components, and considering the motion parameter and physiological characteristics of the eye. Designing the urban landscape based on this method, promotes the visibility and splendor of the urban focal points.

In fact, the main question of this research is that How can the focal points (urban landmarks) be located based on the visual illusion and the effects of the background (annoying) elements?

Research background

The deliberate use of visual illusions in design has been known since ancient times, and scientific work on visual illusion began in the nineteenth century with the study of visual perception by scientists and so far continued (Fermuller & Malm, 2004).

In the field of theory and science, the research of Hermann Helmholtz (1821-1894) in the field of physiology of the eye and vision drew attention to the spatial perception of art, architecture, and the city and its consequences in urban design. Helmholtz's main endeavor was a book published between 1856 and 1867. In this comprehensive book, he not only noted that the human eye sees a small part of the details of the field of view but also outlined how it can be measured (Colonnese, 2017).

Nijhuis (2011) In a study entitled "Visual Research in Landscape Architecture" introduced the basic concepts of landscape perspective related to landscape architecture using mathematical modeling and related software in a spatial landscape. An investigation was performed on the effect of statistics related to visual calculations on visual geometric illusions and deceptive patterns caused by motion signals in linear drawings (Fermuller & Malm, 2004). Frankel (1968) emphasizes that design involves a perceptual space and visual reality, and deals with a sensory experience that appears only with movement. In contrast to material form, he has proposed "visible form" as an important aspect of three-dimensional composition in design. The "visible form" appears in the three-dimensional shape and its visual relation with background and foreground. Given that the cognitive organism acts based on the visual information projected in the retina, the "observable form" in terms of content can be considered as flattened information of three-dimensional physical space.

Theoretical foundations

• Visual perception

Visual perception of focal points is affected by the visual information of the visible form on the retina, which has very different dimensions from the geographical or measured space, and each dimension has a different environmental capability. This perceptual space includes the horizontal-field of view dimension (retina image or image plane) and the distance dimension (depth) (Fig. 1) (Nijhuis, 2011, 6-8). The field (marker) is the focal point and the difference in the angle of view of the binoculars that the generated visual signals impair the perception of the size and distance of the focal points.

Multiple theories have answered the question of how the human visual intellect analyzes and recognizes distance and/or depth dimension. Richardson (2006) has examined three of these theories: the theory of the symptomatic approach (Helmholtz, 1866), the computational theory of the snake (1982), and the theory of context (Gibson, 1950, 1979). Among the above approaches and theories, the symptom approach is more important.

• Theory of symptomatic approach

This theory was first formulated by Hermann Helmholtz in 1866. In general, the goal of this approach is to identify the sources of information in the environment that enable people to deduce and analyze distance. In these sources of information, as signs of depth or distance, they present two separate types of information of distance and size. Most distance perception signals provide information about the relative (apparent) distance that informs the observer of the relative distance between objects observed in their surroundings. The most well-known distance signs are usually referred to as "visual cues" that provide

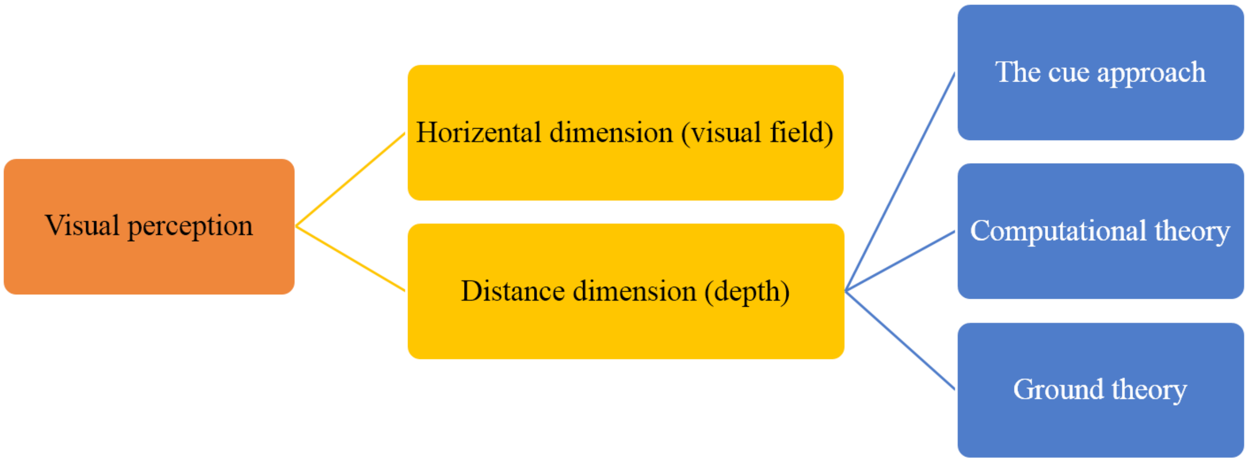

Fig. 1. The dimensions of visual perception and its theoretical approaches. Source: Richardson, 2006; Nijhuis, 2011.

information about the depth perceived by an observer standing at a certain point. In a general classification, information is divided into two categories based on the observer's movement in the sign-on approach:

1. Spatial information available to the stationary observer, which includes: conformity, convergence, binocular mismatch, relative size, familiar size, texture, visual height, angular slope, aerial perspective;
2. Information available to the moving observer in space which includes; Obstruction/ non-obstruction, the difference in movement angle of view, perspective of movement (Shakibamanesh, Alalhesabi, Behzadfar, 2014, 3-5).

• Visibility components

Development of design principles regarding visibility of focal points (urban landmarks) comprises determining the boundaries, organizing, and framing the urban landscape components. actualization of this aim depend on sufficient knowledge of all dimensions of visual space in both horizon and distance dimensions and peripheral signals (visual illusion). Components of urban landscape according to Gestalt theory include background, foreground (marker), and middle ground (focal point).

Development of design principles regarding visibility of focal points (urban landmarks) is comprised of determining the boundaries, organizing, and framing the urban landscape components. The actualization of this aim depends on sufficient knowledge of horizon and distance dimensions, and peripheral signals (Visual illusion) in visual space.

Reading an image in a symptomatic approach is possible due to the contrast between the shape (subject-focal points) and the background. This perceptual principle depends on contrast and contrast. In an image, what attracts our attention the most and is considered as the focus of attention is the shape and another context (Shafighi & Rahbarnia, 2018).

-Focal points (F): An architectural and urban landmark (or part of it) that is the main subject of the observer's attention located in the central part of the field of view. What is important about the broad concepts of perspective in the cognitive nature of the "observable form" is that; Focal points can be distinguished as "shape" from the background in the "shape-background" principle. In this regard, the focal points should show a lot of capabilities by creating unity, emphasis, and attracting the attention of the audience.

-Background (visual indicator): The visual indicator "R" is a variable in the visual field that is in a competitive relationship with the main focus. The marker "R" is part of an architectural/urban element; that is closer or far from the center of the urban landscape scene. The indicator volume often consists of one or more architectural elements or part of them or vegetation.

• Theories of visibility

In general, the purpose of the "visibility approach" is to identify the effect of urban space layout on the perception of the moving observer, which enables people to receive environmental information and draw a mental image of the environment. Among the theoretical approaches related to the research topic, Herman Martens' applied research entitled "Coordination Theory" and Gibson's "Perception of Perception and Peripheral Vision" pay more attention to the physiological features of the eye and visual acuity and its consequences in designing focal points. In the urban landscape, it gives a spatial perception of art and architecture. To this end, these approaches are examined in more detail below.

- **Martens Coordination Theory:** Herman Edward Martens (1870) defined a general range for the presentation of focal points with different scientific (binocular) and artistic (visual aesthetics) principles (Colonnese, 2017, 2). Martens showed that accurate and complete observation is possible only in a realm that can be viewed from a

certain angle of view. This visual realm expands with areas and domains that are less clear (Moravánszky, 2012).
Martens's approach is based on the amplitude and angle of view of the binoculars (human horizontal vision) in the perception between the exterior view and the details of the elements of space, which led to the ideal proportions of observer distance and height (vertical proportions). He considered the visual field on a vertical plane and, measured the two variables of distance and threshold by experimenting with visual angles, and defined three angles for the observer's view of the architectural element. He put these angles inside a set of images with different angles. Eventually, he concluded that the 18-degree angle was the proper angle for representing the artwork or the building so that part of the surround will be in the full image. The other representing angles were the 27-degree angle at which the image will appear complete and the 45 degrees at which most observers will be attracted to the details (Colonnese, 2017, 5).
- **Gibson Theory of Direct Perception:** Gibson expressed his views in 1950 in a book entitled Perception of the Visual World. His theoretical approach is "direct perception" in which stability is one of the most important concepts of the theory. In direct perception theory, Gibson states that an object appears smaller by distancing the observer from it at a constant speed. Therefore, it considers the amount of area reduction in proportion to the square of the distance. He expresses this relation with some conditions, like the observer`s regular distance from the object, and considers leaving it as changing the observer`s speed or the size of the object. With the theoretical approach of "stability", Gibson stated that "environmental vision" are higher-order patterns or relationships that remain constant despite changes in stimulation. This means that if we move closer to the object, despite changing the angle of view and changing the size of the image in the retina, the size of the object is perceived as constant and no change in its size is felt (Gordon, 2005, 151).

Methodology

This research is developmental in terms of nature and causal method in terms of purpose. Based on the reserch literature, there is a point (M) in the visual corridor where based on the binocular vision, the height of the focal point and the marker are equal; after that, the focal point height is perceived smaller than the marker height, and before that is perceived higher (Dordevic & Vujic, 2010). Therefore, in this study, to achieve the arrangement of buildings and design of urban space-architecture based on the visibility of focal points of the city, the position of point M in the visual corridor was modeled geometrically. The spatial realm of implementing geometric modeling of research is the sidewalk of Ayatollah Vaez Tabasi as a visual corridor to the holy shrine of Imam Reza (AS). The focal point and marker include the dome of the holy shrine of Razavi and adjacent buildings of Ayatollah Vaez Tabasi sidewalk. This visual corridor Was modeled in three dimensional by using virtual reality technique and Sketch-Up software that verify the accuracy of the geometric model of point M.
M point position modeling is performed since the perception of the set of elements is equal to the perception of their angle of view (V). During the movement in the path, the angles of view V are different and according to the observer distance between the marker/focus and the change of depth plates, their visual perceptions also changes, see Fig. 2. When moving observer, the perception of the linear size of the focal point and the marker is in contrary to the linear perspective law. The observer`s visual angle to the focal point is V(F) and to the marker is V(R), which is influenced by existing background signals. The underlying signal is due to the effects of binocular difference in visual perception, which is referred to as the visual illusion. Changes in actual/physical dimensions of the angle of view V are determined by the "size of the line S" according to the perceived size S in relation ($V` = V \pm \Delta^o$).
Therefore, to calculate Δ^o (observer's visual illusion angle) based on the actual/physical viewing angle V, we can calculate the difference between the two visual angles K (F) and the visual angle of the indicator K (R) for each observer position, which is equal to following formula (No. 1), which is how to calculate the amount of visual illusion angle relative to the actual visual angle V:

$$\Delta^o = V(F) - V(R)$$

Given that the focal point and the marker at the M point are perceived as heights, so the angle of view of the two is equal at this point, and therefore Δ^o (the magnitude of the observer's visual illusion angle) or the observer's visual illusion is zero. And considering that at the point before

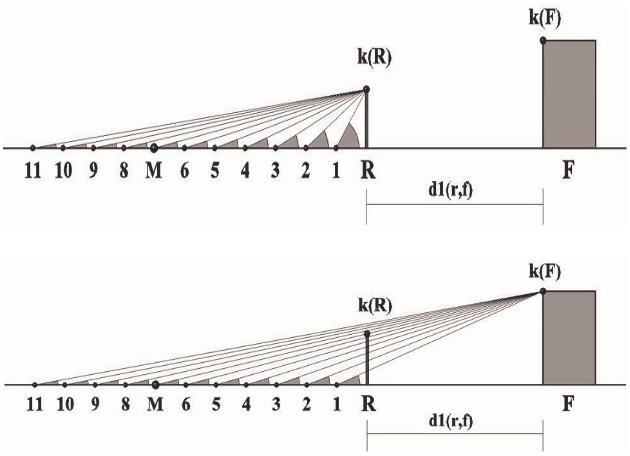

Fig. 2. visual angle to the focal point and the marker. Source: Authors.

M, towards the focal point, V (R) <V (F) then $\Delta^o > 0$ and the focus is larger than the indicator, and after the point M in the visual corridor towards the focal point, V (R)> V (F), then $0 > \Delta^o$ and the focus is smaller than the perceived indicator.

The linear constant of the focal point in the retina of the moving observer "S" and the fixed distance of the observer from the element "D" is determined by the physical/perceptual angle "V (S)", which is the function of the relationship between the dimensions "S" and "D". In Fig. 3, TGV (S) = S / D is specified.

The point M is the point where the angle of view of the pointer and the focal point are equal, or in other words, their V(S) is equal, so according to formula $\Delta^o = V(F) - V(R)$ and Figs. 3 & 4, the following formula (No. 2) is established that indicates the mathematical function of point M concerning the height of the marker-point:

$$\frac{S_{(R)}}{d_{(\acute{R})}} = \frac{S_{(F)}}{d_{(F)}}$$

Therefore, according to above formula, the position of point M is determined based on the ratio of the height of the focal point and the marker and the distance from the observer to the focal point, and the mathematical function of the height distance between the focal point and the marker is equal to point M following formula (No. 3), which is the mathematical function of theoretical distance (Y) of focal point and marker with point M.

$$d_M = \frac{h_F}{\sin \beta_M}$$

In the above relation, the angle β is equal to the angle of perception of details in the ideal proportions in urban space, which according to Herman Edward Martens' theory is equal to 27 degrees. Therefore, the height of the focal point can be calculated with the variables, the distance between the indicator (foreground) and the focal point, and the vertical and horizontal viewing angles of the observer in following formula (No. 4):

$$\overset{D,C}{\Longrightarrow} h = \text{۲}R \sin \beta_M \times \cos \alpha$$

Discussio

To confirm the validity and accuracy of Formula No. 2, the visual corridor of Ayatollah Vaez Tabasi sidewalk, and the dome of the holy shrine of Razavi, were modeled by using the virtual reality technique and Sketch-Up software according to Figs. 5, 6.

In this modeling, the dome of the holy shrine of Razavi, as the center and the immediate buildings of the route in the visual corridor of the holy shrine, are considered. The test route should have a direct, clear, good, and continuous view at different distances to the center (urban sign) that

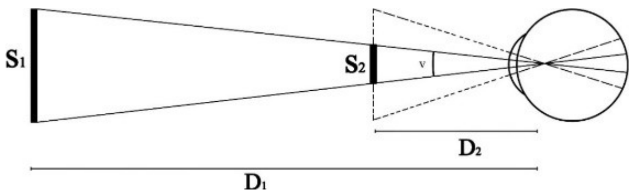

Fig. 3. Binocular vision to the marker and focal point. Source: Authors.

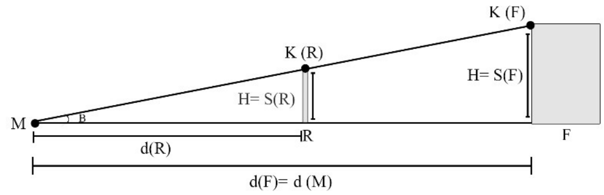

Fig. 4. lateral vision of the height and the position of the focal point, marker, and point M. Source: Authors.

the selected location has the above characteristics. Just as the space perceived by the observer is realistic, the shape, size, color, and position of its constituent elements are often fixed that the visual. The visual system tends to maintain its (perceptual) stability. Accordingly, focus and marker are considered as perceptual variables. As a result, the indicator becomes a sign of depth. If the observer cannot understand the other signs of depth, the size (height) of the indicator is the only available sign.

Hence, the apparent change in the volume of the F-focus concerning the volume of the R marker is determined by following the apparent change in the alignment line above the focus and the marker. The position of the point m was modeled by geometric features such as a distance between the focus and the marker and the height of them and the height /distance of the focal point and the marker relative to each other are determined.

The relationship between focal points and position M relative to the focal plane of the holy shrine (F) and the (R) indicator is calculated using the following formula (No. 5):

$$\frac{S_{(R)}}{d_{(\acute{R})}} = \frac{S_{(F)}}{d_{(F)}} \overset{M}{\Rightarrow} \frac{\text{۱۶}}{\text{۲۳۷}} = \frac{\text{۳۲}}{\text{۴۷۴}}$$

Accordingly, the alignment line of the focal point and the marker was examined in different positions, and according to Formula No. 5, where the position of the M point in this model was determined, this feature was examined based on the observer's view. The height of the focal point and the marker is not only equal to the perception but also characteristic of the before and after point M, that is, the focal point and the marker will be perceived smaller or larger (visual illusion),

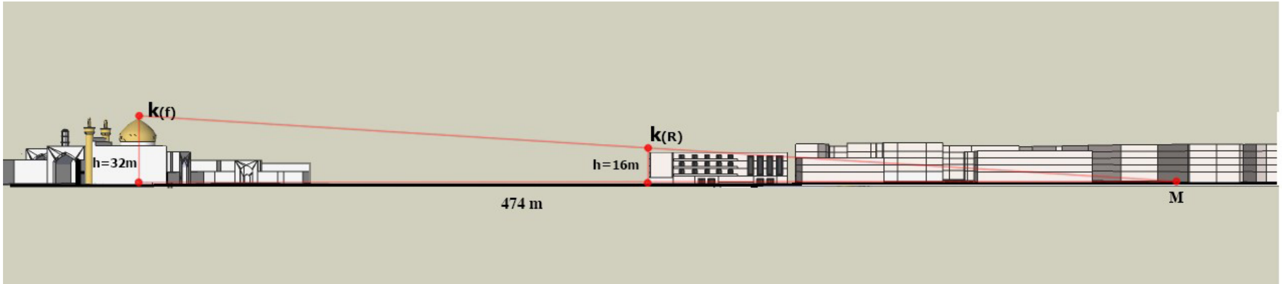

Fig. 5. Lateral vision of the the focal point, marker, and point M in Ayatollah Vaez Tabasi sidewalk. Source: Authors.

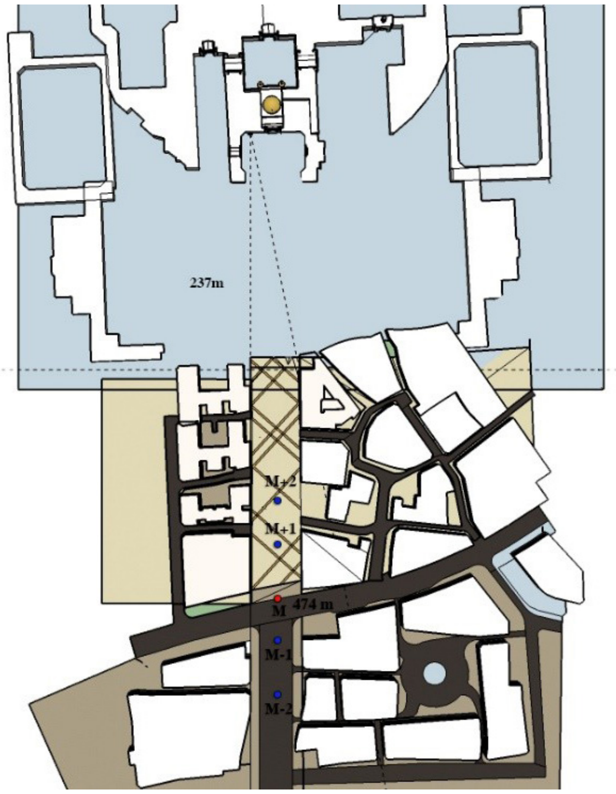

Fig. 6. plan of the research modeling and position of the point. Source: Authors.

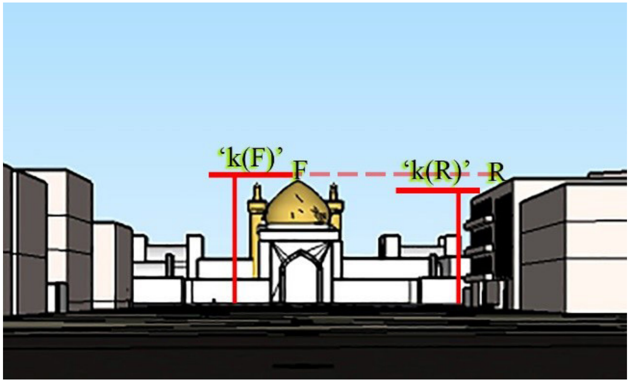

Fig. 8. The height of the focal point and the marker before the point M. Source: Authors.

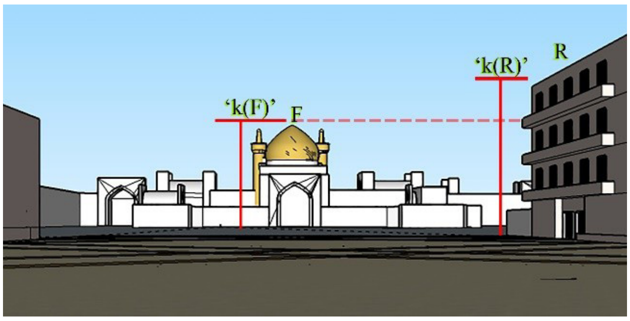

Fig. 9. The height of the focal point and the marker after the point M. Source: Authors.

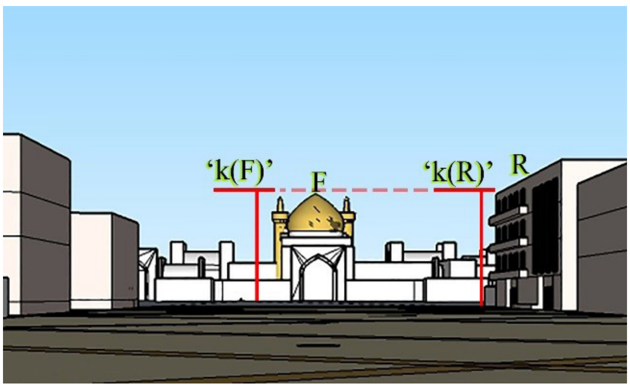

Fig. 7. The height of the focal point and the marker at the point M. Source: Authors.

that confirms based on Figs. 7- 9. As a result, the visual illusion of resizing the focal point and the marker, based on pint M has a significant effect on observers, and the artistically planned designed of the focal point makes the urban landscape glorious.

Conclusion

Visibility of the urban focal points is crucial in the way of layout and design of the urban landscape and the architectural buildings. Focal points in urban design is an architectural and urban goal (or part of it) with significant features or a special logo in the space that is located in the central part of the field of view. In terms of perceptual concepts, focal points as the organization of the background shape are not part of the physical stimulus, but the result of the perceptual process, which is perceived by the observer's position; can be distinguishable as the form of the other components ("background and background"). But according to modern theories of environmental design in urban spaces, background component signals affect the perception of visual angles of focal points and perception of "linear size / distance measurements" of the observable form of focal points.

The results show that by increasing the distance of the observer from the background component in the urban landscape, the focal points are perceived to be larger than their actual size, which can be calculated by modeling the spatial elements of the landscape, its optimal position.

The results of this study can be widely used in locating focal points, and the spatial-local characteristics of background spatial elements, and indicate that the arrangement of urban elements is not just a product of dimensioning, realizing, or processing the unique constituent elements of the landscape (or Compositions), but in the process, attention should be paid to the creation of prominent visual elements. These elements (focal points) of urban space are the product of an appropriate geometric organization of the physical structure of the set of elements that requires an understanding of a complex visual interaction with observers based on visual illusions. As a result, with the proper design of the urban morphological structure and consideration of the motion parameter, it is possible to plan visual phenomena/illusions for some components of the urban landscape by aggregating preconditions that increase (or decrease) the effect of increasing their volume. Increasing (decreasing) the observer distance makes it possible to be more permanent (or deliberately degrade), which is phenomenologically against the rules in a linear perspective. Three-dimensional model of the observer's motion in the Ayatollah Vaez Tabasi Sidewalk proved the effect of the background signal on the size of the focal point of the holy shrine of Razavi (AS).

Finally, when planning and designing, an urban matrix, including a range of constructive parameters of these illusions, must be created and with adequate modeling and dimensioning, and positioning of a broad spectrum of elements located marker closer or more distant setting of the urban focal point.

Acknowledgments

In the end, we would like to thank Dr. Golmakani (Ph.D in Mathematics) and Mr. Nakhaei (Master of Mathematics) for their help in compiling the model and geometric structure.

Endnote

*This paper is taken based on Bibi Sara Mirheydar Turan's thesis of Ph.D., that the title is: "Formulate the Urban Space Design Based on Visual-Geometric Illusion Arising from the Vision System Performance". This thesis Supervised by Dr. Maryam Ostadi and Dr. Fatemeh Mohammadnia Qaraee and Advised by Asieh Ehsaei in Mashhad branch of Islamic Azad University that was done on February 8, 2021.

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