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## Optimizing a Smart City's Urban Park Lighting using Monkey Algorithm

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**Abstract.** Mexico City, one of the world's most densely populated metropolises, features numerous urban parks for recreational use. To accommodate nocturnal visitors, these parks require well-designed lighting systems. Proper lighting is crucial to avoid negative impacts on ecosystems and human health while ensuring safety, preventing accidents, and reducing light pollution. This study utilizes the "Monkey Algorithm" to optimize the number and placement of luminaires in Mexico City parks. This algorithm, inspired by monkeys' resource-finding behaviors, involves three steps: climbing, watch-jump, and somersault processes. Factors such as lamp position, height, power consumption, and light intensity are considered to maximize coverage. The research adheres to strict electrical installation standards (NOM-001-SEDE-2012) and seeks luminous efficiency as per NOM-030-ENER-2016 and NOM-031-ENER-2012, which set the energy efficiency requirements for LED luminaires in public areas.
**Keywords:** Monkey Algorithm, Public lighting, Optimization, Range Problem, LED lighting, Smart City's Urban Park.

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## 1 Introduction

### Smart City Concept

Smart Cities are cities that use information and communication technologies (ICT) to improve the quality of life of their inhabitants. These cities incorporate smart solutions in areas such as transportation, energy, waste management and public lighting to create more efficient and sustainable environments.

### Importance of Lighting in Public Spaces

Lighting in public spaces, such as parks, has a significant impact on the safety of citizens and their ability to enjoy these areas during nighttime hours. In addition, adequate lighting enhances the aesthetics of public spaces and promotes a sense of community.

However, the design, placement, and distribution of such lighting must be meticulously orchestrated to avert potentially dire consequences. These consequences extend beyond the immediate environment and encroach upon the delicate ecosystem surrounding parks. Moreover, the implications reach into the domains of human health and societal dynamics, encompassing disarray in circadian rhythms, mood disorders, metabolic imbalances, disruptions to predator-prey interactions, and the escalated susceptibility to cancer due to the perturbation of melatonin production, among other concerns.

**Fig. 1.** Lighting in Urban Park.

The significance of these considerations cannot be overstated, as they not only guarantee a heightened degree of safety for those who frequent these public spaces but also assume an indispensable role in the prevention of visual impairments, accidents, and falls. Simultaneously, they play a crucial part in mitigating the troubling issue of light pollution, which not only obfuscates the night sky but also inflicts adverse consequences on the natural environment and overall quality of life. Thus, the conscientious planning and execution of lighting systems in public spaces, especially parks, emerge as a nexus where human well-being, ecological sustainability, and the preservation of the night's tranquility converge in a harmonious symphony.

**The Monkey Algorithm**

The Monkey Algorithm is inspired by the foraging and mountain-climbing behaviors displayed by individual monkeys or groups of monkeys. This algorithm employs a metaheuristic approach, widely applied in computer science and engineering, to address intricate optimization problems where identifying the optimal solution can be particularly challenging.

**Urban Parks**

Urban Parks are Parks that have free access and are generally located in the urban core. They usually have playgrounds, green areas, restrooms, exercise areas, etc.

The population can enjoy these spaces for the purpose of recreation, wellness and, in addition, environmental awareness is promoted.

These places not only bring benefits to the community, but also generate economic, social, and cultural advantages. In some cases, classes can be offered for people to learn sports or participate in recreational activities.

## 2 Design and Characteristics of the Public Park

**Park Description**

The public park under examination spans an expansive 7-hectare area, serving as a vital communal space for the local population. Within this park, a wide range of activities unfolds, including jogging, leisurely walks with pets, contemplative moments on park benches, and the simple pleasure of connecting with nature.

While we have not singled out a specific park as the subject of our study, we have intentionally directed our focus to a park situated in Mexico City.


**Fig. 2**. Visual representation of the urban park

**Lighting Requirements for Nighttime Activities**

To ensure the safety and comfort of visitors, adequate lighting requirements should be established for nighttime activities such as jogging, pet walking and resting on benches.

**Fig. 3.** Importance of Lighting

To comply with the standards established in Mexico, it is necessary to consider the following aspects of NOM-031-ENER-2012, Energy efficiency for luminaires with light emitting diodes (LEDs) intended for roads and public outdoor areas. Specifications and test methods where paragraph 6.52 mentions that outdoor lamps shall have a minimum color performance index value of 70 (Secretaría de Energía, 2019). The power factor on LED lights must have a minimum power of 0.90 and the total harmonic distortion in electric current must be less than 20%.

NOM-030-ENER-2016, Luminous efficacy of integrated light-emitting diode (led) lamps for general lighting. Limits and test methods. This standard establishes minimum luminous efficacy limits that LED lamps must comply with, as well as the test methods to be used to measure the luminous efficacy of these lamps in a standardized manner (Secretaría de Energía, 2016).

NOM-001-SEDE-2012, Electrical Installations (Utilization). It is mentioned that to ensure an adequate design of electrical installations, the following factors must be taken into consideration: a) It must provide protection for individuals and living beings and b) its operation must be satisfactory according to the intended use.

Additionally, it is stated that light fixture supports, and lamp holders must be securely mounted. If any light fixture weighs more than 3 kg or exceeds 40 cm in any of its dimensions, it should not be supported by the threaded socket of a lamp holder. All supports that are not part of junction boxes, adapters, tripods, among others, must be made of materials such as steel or malleable iron (Secretaría de Energía, 2012).

**Existing Lighting Arrangements**

It is of utmost importance to conduct a comprehensive assessment of the existing arrangement of lighting fixtures within the park to gauge their effectiveness and identify areas where improvements can be made. To optimize the lighting, it is crucial to fine-tune the placement and intensity of the luminaires to align with the park's specific needs.

In the model, we employed a 4-meter-tall luminaire with precise specifications. This luminaire, the decorative urban Simon ALYA Istanium LED (TALYA LH), is constructed from die-cast aluminum and is designed for lateral or suspended installation. Notably, this luminaire excels in providing the necessary illumination for public lighting with a remarkable degree of energy efficiency. Its outstanding features include: a minimum luminous flux of 1,760 lumens. and an impressive luminous efficiency of up to 138 lumens per watt (lm/W).

The choice of this luminaire was based on its similarity to the lighting fixtures commonly used in other urban parks throughout Mexico City.


**Fig. 4.** Features model Talya LH.

## 3 Monkey Algorithm Fundamentals

**Origin and Principles of Monkey Algorithm**

The Monkey Search Algorithm (MSA) was proposed by Zhao and Tang in (2007), inspired by the foraging behavior of monkeys as they search for food by scaling mountains. This algorithm operates under the assumption that the higher the mountain, the more abundant the food at its summit. In the initial phase, each monkey begins its ascent from a starting position and continues climbing until it reaches a mountain peak. Upon reaching the peak, the monkey undertakes a series of random-local jumps in the hope of discovering an even higher mountain, repeating the upward movement cycle. Following an extensive exploration of its current surroundings, the monkey then makes a global leap to explore another area of the terrain. These actions are repeated according to a predefined numerical value. The objective of the algorithm is to identify the highest vertices attainable.

**Advantages of Applying Monkey Algorithm in Illumination Optimization**

The monkey algorithm has several advantages for solving the lighting problem. Skillfully navigates through the solution space by discerning locations, making comparisons, and constantly searching for new options, all in search of the optimal solution. This dynamic process encompasses the Climbing process, the Watch-jump process, and the Somersault process, each contributing to the pursuit of the optimal lighting arrangement.

**Fig. 5.** Lighting distribution

**Description of the Monkey Algorithm**

To apply Monkey Algorithm in park lighting optimization, one must understand in detail how the algorithm works, including particle initialization, fitness functions, and update operators.

Beneath, you will find an illustrative diagram that delineates the sequential steps for implementing the Monkey algorithm. This diagram serves as a visual guide to facilitate a clear understanding of the algorithm's application process, making it easier to follow and implement in practice.

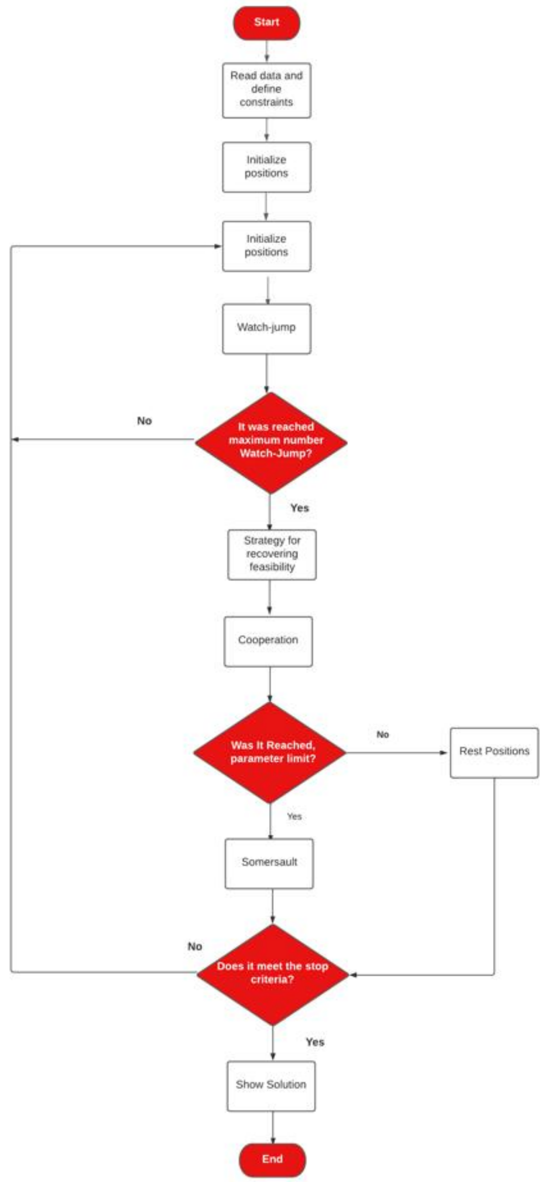


**Fig. 6.** Flow Chart Monkey Algorithm

# 4 Implementation of Monkey Algorithm in Luminaire Optimization

**Data Collection and Initial Parameters**
In this case, the Monkey Algorithm is used to adjust the location and intensity of the luminaires iteratively, seeking to maximize energy efficiency and meet the lighting requirements. The following is an explanation of the process that was followed.

Monkey Algorithm implementation begins with data collection on the current luminaire layout, park topography, and lighting requirements for specific activities. Initial parameters for the algorithm must also be established.

As initial parameters, we have the following: For the application of the Monkey Algorithm, we had to start with the initialization phase. Where each vector generated a region with potential solutions (monkeys) to the problem, marked as positions. A value N was set to represent the population size of the decision vector. It is important to mention that each of the monkeys represents possible optimal solutions. This vector is denoted as follows:

So, each of these solutions will have values for the decision variables established by the model (Number of luminaires, power, luminous efficacy, value of the "X" coordinate, and value of the "Y" coordinate). The first parameter defined was the vector size (N), with a value of 10 monkeys. Along with a second parameter indicates the step size to be applied for the Climbing Process. This has a value of 0.0001, with a 0.5 probability of being positive or negative.

Subsequently, the Climbing Process was carried out. This allows for the optimization of the objective function. First, the pseudo-gradient needs to be generated using the following formula (Zhao,2007):

$$f'_{ij}(x_i) = (f(x_i + \Delta x_i) - f(x_i - \Delta x_i)) / (2\Delta x_{ij})$$

Where, by means of the ten positions (solutions) of the monkeys, it was evaluated using the previously mentioned formula. With the help of the pseudo-gradient and the following formula (Zhao,2007):

$$y_j = x_{ij} + a \cdot \text{sign}(f'_{ij}(x_i)), \quad j = 1, 2, ..., n$$
$$y = (y_1, y_2, ..., y_n)$$

A vector 'y' was successfully generated, which contains all the new positions created. Subsequently, the new positions contained in vector 'y' are analyzed to check if they meet the constraints. Otherwise, they are retained as the original position of the vector 'x.' The process is repeated until there is a significant change in the objective function.

Once the coordinates of the potential positions are obtained, it is important to determine whether that point is the best or if there might be another one with better characteristics that allows us to achieve a different position. It's important to note that a parameter with an initial positive value called 'c' must be determined.

The environment is explored by generating random values within a range ($x_{ij}$ - c, $x_{ij}$+ c) for each decision variable 'j,' and these values are stored in the vector 'y.

Subsequently, it is evaluated whether the new solution represented by the vector 'y' is better than the current feasible solution, which must satisfy all necessary constraints. If the generated solution is feasible, the position is changed to the new one (xi = y). If not, other values are generated until a feasible solution is found.

The somersault process continues, during which new domains can be explored. Here, a random real number α is chosen within a defined interval [d, e]. A somersault is performed from the current position xi in the direction of the somersault pivot. To calculate the new somersault point, it is necessary to sum and average all coordinates to obtain the point p = (p1, p2, ..., pn).
If the value is feasible, xi = y is set as the new position. If it is not feasible, the previous procedure is repeated.

**Modeling the Optimization Problem**

The optimization problem involves finding the optimal location and intensity of luminaires to meet the lighting requirements. This can be modeled as a multi-objective optimization problem.
For the development of the model, the following objective function was used:

$$Z = \text{Max } p_6 - (p_1 + p_2 + p_3 + p_4 + p_5) \quad (2)$$

Where:
$p_1$ = |Average Expected Intensity − $((x_1 \cdot x_2)_i / 177.273 \text{ m}^2)$|; Average expected intensity and the actual value at the points.
Where $x_1$ = power [Watts], $x_2$ = luminous efficacy [lumens/Watt] and 177.273 $m^2$ is the area projected of each circle generated by the LED lighting.

$p_2$ = |Average Expected Intensity − $((1 / 177.273 \text{ m}^2) \cdot \Sigma_{i=1}^{n} (x_1 \cdot x_2)_i) / x_3$|
Where: $x_3$ = number of luminaires, $p_3 = x_2 \cdot x_3$, $p_4 = \Sigma_{i=1}^{n} r_i \leq \sqrt{((x_i - x_{i+1})^2 + (y_i - y_{i+1})^2)}$, $i \geq 4$, ; Sum of radios ≤Distance between two points. Where the radios have a constraint value equal to 7.5118 $m^2$. In each of these we consider the distance of each of the radius of the protected light plus the distance generated by the arm of the luminaries. And $x_i, x_{i+1}, y_i, y_{i+1}$are coordinates of each luminary.

$p_5$ = |Expected Variance − $((\text{Average } I_n - (x_2 \cdot x_1 / 177.273 \text{ m}^2))^2 / x_3)$|
$p_6 = \pi \cdot r^2 \cdot x_3$

Determined with the following decisions variables:
$x_1$: Power in Watts.
$x_2$: Luminous efficacy
$x_3$: Number of luminaires
$x_i, x_{i+1}, y_i, y_{i+1}$: Coordinates of each luminary.

As a reference, we collected data on the luminaires in the following parks located in Mexico City.
Data:
Lomas Park

- Radius for each area= 7.5118 $m$
- Area per luminary = 177.27$m^2$

Mexicana's Park

- Radius for each area= 5.0726 m
- Area per luminary = 80.838 $m^2$

Average Expected Intensity: 15.727 lux ($\frac{lumens}{m^2}$)
Variance: 1.8243

**Results and Optimization Evaluation**

Optimization results are evaluated using metrics such as energy efficiency, lighting uniformity, and satisfaction of safety requirements. Positive results translate into a significant improvement in the quality of life for park visitors.

The expected results through the metaheuristic were those achieved and are presented in Table 1 as shown below.

**Table 1.** Results of the Metaheuristic

| Number of Luminaires | % of Lighting | Monthly Lighting Cost | Night Activities to Perform | Target Population |
|---|---|---|---|---|
| 10 | 61% | 75000 | 20 | 350 |
| 12 | 74% | 87950 | 25 | 427 |
| 15 | 83% | 126780 | 26 | 484 |
| 20 | > 100% | 187976 | 27 | 507 |

**Fig. 7.** Metaheuristic using 8 Luminaries.

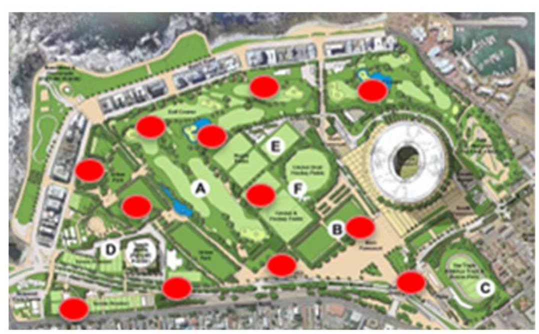

**Fig. 8.** Metaheuristic using 12 Luminaries.

**Fig. 9.** Metaheuristic using 15 Luminaries.

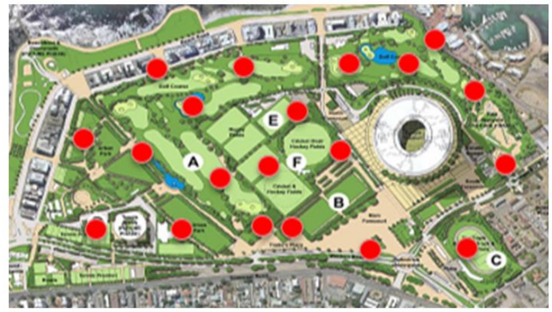

**Fig. 10**. Metaheuristic using 20 Luminaries.

Through the proposed Metaheuristic, we determined that the ideal, optimal, and affordable value is 17 luminaires. This provides the highest level of brightness without exceeding the coverage area of each luminaire, while also specifying the maximum allowable energy cost and maximizing the number of nighttime activities for the target population.

## 5 Benefits of Lighting Optimization in the Park

**Improved Energy Efficiency**

Optimizing lighting in the park not only leads to greater energy efficiency by reducing electricity consumption, but also contributes to environmental sustainability by reducing carbon emissions associated with public lighting. As a fact 25% of the energy consumption is caused by lighting systems.

**Improved Safety for Visitors**

Community safety is one of the most important priorities. Feeling safety There are studies which mention that better illumination will lead to improved safety. As the user's visibility increases while using common areas. If this cannot be provided, the consequences can be significant (Prihatiningrum, et al., 2021).

In addition, it is important to mention that better illumination will lead to improved safety. As the user's visibility increases while using common areas.

**Reducing Light Pollution**

Light pollution has become a critical factor to consider in recent times. This is due to the exponential growth that different cities have had, which need a lighting system for the activities that take place at night. Despite being a support, over time it has been counterproductive both for humans and for the environment if it is not developed in an appropriate way. In humans they can be related with physical, performing, mental health and safety problems. Such as mood changes, weight gain, increased risk of contracting diseases or even cardiovascular and diabetes problems. All of this can be attributed to the alteration of circadian rhythm that causes all the damage already mentioned (Lunn et al., 2017).

Once the negative effects caused by light pollution have been mentioned, its importance becomes evident. Which can be reduced through lighting optimization. To provide better quality and experiences when using public spaces. This approach considers the well-being of the city’s inhabitants and the environment that surrounds them.

**Positive Impact on the Environment**

Similarly, in the ecosystems, implications can be observed due to the alteration of the circadian rhythm. Causing changes on the natural light patterns for different and affecting activities such as interactions between predators and preys. This disruption could lead to a larger scale problem in the ecosystem (Zapata et al., 2019).

# 6 Smart Technology Integration

A Smart technology integration is a cornerstone of modern urban development, enabling efficient resource management and improving the quality of life for city dwellers. In this chapter, we delve into several key aspects of smart technology integration, highlighting the potential for enhanced sustainability and livability in urban environments.

**Light Sensing and Lighting Control**

The integration of light sensors in luminaires represents a significant advancement in urban lighting systems. Light sensors, often integrated with motion detectors, provide the capability for real-time adaptive lighting control. These sensors continuously monitor ambient light conditions and detect the presence of people within their vicinity.

One of the core concepts underpinning this technology is the utilization of feedback loops, which can be represented by the following control system equation:

$$L(t)=P(t)\cdot G(t)\cdot E(t) \tag{3}$$

In this equation, L(t) represents the luminance of the artificial lighting, which we seek to control(t) signifies the reference level of illumination, a value that should ideally match the required lighting level. G(t) denotes the gain or control factor that modulates the output of the lighting system, and E(t) signifies the error signal, which is the discrepancy between the reference level and the actual illumination level.

Light sensors continuously measure the current ambient luminance, enabling the system to compute the error signal, E(t), by subtracting the measured luminance from the reference level. This error signal is then processed by the control factor, G(t), to adjust the luminaires' intensity accordingly. The result is dynamic and adaptive lighting that responds to natural light conditions and occupancy.

**Light Sensing and Lighting Control**

Centralized lighting management systems further enhance the efficiency of urban lighting. These systems use intelligent control platforms to manage lighting networks across the city. By centralizing control, it becomes possible to implement precise lighting patterns tailored to the specific needs of different times of the day.

The management system employs algorithms to calculate optimal lighting configurations, considering factors such as traffic density, weather conditions, and pedestrian movement. This dynamic adjustment of lighting patterns not only ensures energy savings but also contributes to improved safety and comfort for urban residents.

**Interconnection with other Smart Infrastructures**

One of the defining features of smart cities is the interconnection of various infrastructures to create a cohesive and efficient urban ecosystem. Smart lighting is no exception. It can be seamlessly interconnected with other smart infrastructures in the city, such as public transportation and waste management.

The interconnection allows for the efficient exchange of data and coordinated control. For instance, when integrated with public transportation systems, smart lighting can adjust illumination levels to enhance safety at bus stops and train stations during late hours. Additionally, waste management vehicles can optimize their routes based on real-time lighting conditions, improving efficiency, and reducing energy consumption.

This interconnected approach represents the future of urban development, where data and resource optimization lead to more sustainable and livable cities. Smart lighting plays a pivotal role in this vision, offering adaptive, efficient, and interconnected illumination solutions that benefit both the environment and urban residents.

## 7 Ethical and Social Considerations

**Privacy and Responsible Use of Data**

The collection of data through sensors and monitoring systems raises concerns about the privacy of citizens. It is essential to establish policies and regulations to ensure the responsible use of this data.

**Community Consultation**

Community inclusion in the decision-making process is crucial. Since these are the beneficiaries of projects, such as lighting optimization, it is necessary to consult their opinion. Because their participation enables them to get to effective and sustainable solutions. This research is given the importance it deserves. Having different points of view and active feedback allows focusing efforts on areas of opportunity that had not been considered. Therefore, conducting surveys, questionnaires, and the use of social networks is proposed to achieve the stated objectives. It is important that each of these responses can be provided either publicly or anonymously. This allows them to have the confidence and security to express their point of view in a satisfactory manner according to their preference. It's going to be based on the methodology that was applied on the paper named "Aboriginal patients driving kidney and healthcare improvements: Recommendations from South Australian community consultations". The aim is to get in touch with the community to receive their feedback and comments to provide an effective service (Kelly et al., 2022).

**Inclusion of User Diversity**

The benefits of lighting optimization apply for everyone regardless of race, gender, sexual preference, religion, or physical ability. That's why it's necessary to consider a diverse population. To adapt the lighting considering all possible considerations to prevent any attack on the health of the inhabitant.

## 8 Conclusions and Recommendations

The application of Monkey Algorithm to optimize lighting in the park has proven to be effective in terms of energy efficiency, safety, and light pollution reduction.

The optimization of lighting in the park has improved the quality of life of residents by providing a safer and more sustainable environment for nighttime recreation.

It is recommended to continue to research and develop smart lighting technologies for application in other urban spaces and to consider expanding optimization to the city level.

Based on the results of this study, recommendations are offered for other Smart Cities seeking to improve the quality of life of their inhabitants through smart lighting solutions.

In this research, we have explored how the Monkey Algorithm can be used to optimize lighting in a 7-hectare urban park in a Smart City. We have highlighted the benefits of this optimization, ranging from energy efficiency to improved safety and reduced light pollution. We also discussed important ethical and social aspects related to the implementation of this technology.

This research has explored in detail how the optimization of lighting in a public park of a Smart City by applying Monkey Algorithm can have a significant impact on the quality of life of citizens. From improving energy efficiency to promoting safety and reducing light pollution, lighting optimization represents an important step towards a smarter and more sustainable city. However, it is essential to address ethical and social considerations, as well as consult with the community, to ensure that these improvements benefit all residents equitably.

This research provides a solid foundation for future research and developments in the field of smart lighting in Smart Cities and will hopefully inspire other cities to follow a similar path towards a more advanced and livable urban environment.

Using Unity to model the amenity experience in Smart Cities urban parks is a promising approach to meet the needs of Generation Z and improve the quality of life in urban environments. As we move towards a more connected and technological future, the adaptation and continuous development of these solutions will play a key role in creating attractive and sustainable urban spaces for future generations.

In an ever-evolving world where technology and urbanization continue to transform our urban spaces, the use of Unity to model the amenity experience in an urban park within a Smart City presents itself as an exciting and necessary opportunity. This approach not only enables the creation of engaging virtual environments, but also aligns with the expectations and preferences of Generation Z, a generation that values personalization, interactivity, and connectivity.

The experience of amenities in urban parks is critical to the quality of life in cities. Generation Z is looking for spaces where they can relax, connect with nature, engage in outdoor activities and, at the same time, be immersed in technology. Unity offers a versatile platform that allows them to combine these elements in a harmonious way. From simulating outdoor sports to creating relaxing virtual landscapes, Unity can provide a unique and engaging experience.

However, it is important to address technical challenges and consider privacy and security concerns when implementing these technologies. User-centered design is critical, and personalization of the experience is essential to meet the evolving expectations of Generation Z.

Future work in this area is promising. The integration of virtual and augmented reality can take the amenity experience to the next level, allowing users to interact more immersivity with their environment. In addition, continued research into the community impact and sustainability of these technologies is required to ensure that they continue to contribute positively to urban life.

In summary, the use of Unity to model the amenity experience in Smart Cities urban parks has the potential to improve the quality of life in cities and meet the demands of Generation Z. Technology, when applied in a strategic and user-centric manner, can enrich our outdoor experiences, and contribute to the sustainable development of the cities of the future.

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