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Design and Implementation of Virtual Simulation Software to Display Information on Weather Indicators to Manage and Control Urban Policy-Making

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ABSTRACT

This research focuses on the design, implementation, and development of software using virtual simulation technology for data visualization, aiming to present urban statistical information through an innovative tool that transforms raw data into 3D models for observation and analysis. The tool consists of two main components: a web-based data entry panel for user-friendly data input or upload, and a 3D data visualization module where information is displayed in a virtual reality simulator. Adhering to the principles of originality, honesty, and integrity, the software enables researchers to convert raw data into 3D models, facilitating easier observation and extensive analysis of events. Consequently, researchers can record and view their data in 3D, analyze their observations to derive information and results, and enhance public understanding through the visualized display of their findings.

Keywords: *Modeling, Virtual Simulation, Visualization, Data Utilization*

1. Introduction

The development of advanced software for data visualization using virtual simulation technology necessitates the integration of two critical components: an online web-based data entry section and a virtual reality data visualization system. The first component is designed to provide users with a simple and convenient means to input or upload their data. This facilitates an efficient and user-friendly process for data entry, ensuring that the information is easily accessible and manageable. The second component leverages 3D virtual simulation software to allow researchers to interact with the data in a more precise and detailed manner, significantly enhancing the level of data analysis (Farsi et al., 2020; Yaghoobi Karimi et al., 2023).

The concept of modeling plays a fundamental role in this software. Originating from the Latin term "modus," meaning "measured," a model is typically defined as a smaller, simplified representation of a larger object or system that functions similarly to the real-world counterpart (Soleimani & Geshani, 2023). Modeling helps in understanding phenomena and events that are otherwise difficult to observe directly. It involves creating a system that includes concepts, hypotheses, and indicators, and by testing these hypotheses through gathered information, it improves our understanding of real-world structures (Kellner et al., 1999; Soleimani & Geshani, 2023). This comprehensive and precise depiction of relationships among components simplifies complex phenomena, making them more comprehensible and manageable. Models, whether physical or abstract, serve as frameworks for theory and are instrumental in predicting events with high accuracy, diversity, and proportionality (Soleimani & Geshani, 2023).

Simulation, described as "expressing reality without the existence of reality", involves using computers to display the performance of a system or process (Kellner et al., 1999). This method provides a dynamic representation of systems, allowing for the identification of potential issues before they become problematic (Ferrin & Muthler, 2002; Kellner et al., 1999). Traditional simulation accurately replicates the performance of real processes over time through mathematical, logical, and symbolic relationships. Simulation offers numerous advantages, such as the ability to evaluate different strategies, manage risks, and predict future behavior of systems efficiently and cost-effectively (Farsi et al., 2020).

In the realm of data visualization, the goal is to present information in a visual and graphical format, enhancing comprehension and facilitating the identification of patterns (Friendly & Denis, 2001). The use of visualization in scientific computing has evolved significantly, particularly since the emphasis on visualization techniques began in the late 1980s (Opiła, 2019). Scientific visualization transforms complex data into visual representations, enabling detailed exploration and analysis. This process not only aids in data analysis but also facilitates knowledge transfer and communication of complex ideas (Opiła, 2019; Opiła & Opiła, 2018). Techniques such as using surfaces and textures to visualize scalar fields in three-dimensional space are particularly effective (Opiła & Opiła, 2018).

Additionally, the advent of advanced computer graphics has revolutionized how we approach data visualization. Initially used to solve scientific problems, computer graphics have evolved to provide powerful tools for creating interactive and engaging visualizations (Nielson et al., 1997; Opiła & Opiła, 2018). These tools allow for the representation of data in ways that are not only informative but also intuitive and accessible. For instance, the ability to manipulate 3D models and interact with them in real-time offers a level of engagement and insight that static graphs and charts cannot match. This interactivity is crucial for detailed data analysis and for communicating findings to a broader audience (Nielson et al., 1997; Opiła, 2019; Opiła & Opiła, 2018).

Moreover, the importance of visualization in the decision-making process cannot be overstated. Effective visualization provides a clear and concise view of complex data, making it easier for decision-makers to understand and act upon the information presented (Cook & Thomas, 2005; Farsi et al., 2020). This is particularly important in fields such as urban planning and public policy, where the ability to quickly comprehend and analyze large datasets can lead to more informed and timely decisions. By reducing the cognitive load associated with data interpretation, visualization tools enable decision-makers to focus on strategy and outcomes rather than getting bogged down in the details (Farsi et al., 2020).

Furthermore, visualization supports creativity and innovation in data analysis. By presenting data in new and interesting ways, visualization tools can uncover patterns and insights that might not be apparent through traditional analysis methods. This creative approach to data analysis can lead to new discoveries and improvements in various fields, from healthcare to transportation. The use of visual storytelling, for instance, allows for the presentation of data in a narrative format, making it more relatable and easier to understand (Opiła & Opiła, 2018).

Finally, the integration of virtual reality (VR) in data visualization represents a significant leap forward. VR provides an immersive experience that can enhance understanding and retention of information. In the context of urban planning, for example, VR can be used to create detailed, interactive models of cityscapes, allowing planners to visualize the impact of their decisions in a realistic and engaging way. This not only improves the planning process but also helps to communicate the benefits and implications of urban projects to stakeholders and the public (Farsi et al., 2020).

The aim of this study is to design, implement, and develop a software tool that utilizes virtual simulation technology to transform raw urban statistical data into 3D models, thereby facilitating enhanced observation and analysis of events. This innovative tool is intended to improve data accessibility, interaction, and comprehension,

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ultimately aiding researchers and decision-makers in deriving meaningful insights from complex datasets.

2. Methods and Materials

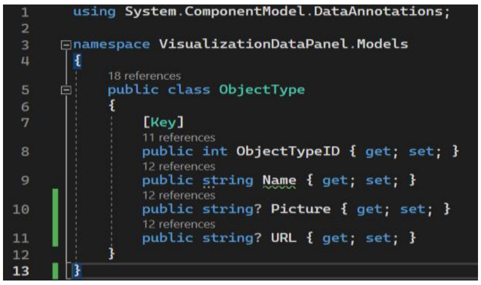
The software designed and implemented in this research utilizes Microsoft's .NET Core framework for capturing input information and the Unity engine for the virtual reality (VR) display of information. The development process is divided into two main sections: the web panel design and the virtual reality data visualization system.

2.1. *Web Panel Design*

The web panel is designed to introduce and manage various models, facilitating easy data entry and object management. Objects in our environment are represented as simple and complex geometric models. Simple three-dimensional objects include shapes like cubes, spheres, capsules, cylinders, and planes. To define these objects in the data panel, a model named "ObjectType" is implemented with the following features: a unique identifier (ObjectTypeID), a name (Name), an image (Picture), and an address (URL). These features allow for comprehensive management of the objects within the software.

Figure 1

ObjectType Class



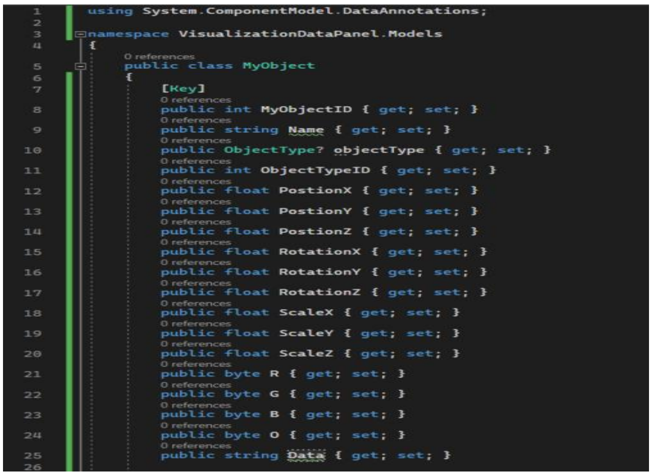
```
using System.ComponentModel.DataAnnotations;

namespace VisualizationDataPanel.Models
{
    18 references
    public class ObjectType
    {
        [Key]
        11 references
        public int ObjectTypeID { get; set; }
        12 references
        public string Name { get; set; }
        12 references
        public string? Picture { get; set; }
        12 references
        public string? URL { get; set; }
    }
}
```

2.2. *Defining Sample Objects*

In this research, samples of three-dimensional objects are defined, characterized by their shape type, spatial coordinates, rotation, size, and color. The "MyObject" model is implemented to represent these objects, including fields such as a unique identifier (MyObjectID), name (Name), object type (ObjectType), position (Position), rotation (Rotation), scale (Scale), color (Color), and additional data (Data).

Figure 2

MyObject Class



```
using System.ComponentModel.DataAnnotations;

namespace VisualizationDataPanel.Models
{
    0 references
    public class MyObject
    {
        [Key]
        0 references
        public int MyObjectID { get; set; }
        0 references
        public string Name { get; set; }
        0 references
        public ObjectType? objectType { get; set; }
        0 references
        public int ObjectTypeID { get; set; }
        0 references
        public float PostionX { get; set; }
        0 references
        public float PostionY { get; set; }
        0 references
        public float PostionZ { get; set; }
        0 references
        public float RotationX { get; set; }
        0 references
        public float RotationY { get; set; }
        0 references
        public float RotationZ { get; set; }
        0 references
        public float ScaleX { get; set; }
        0 references
        public float ScaleY { get; set; }
        0 references
        public float ScaleZ { get; set; }
        0 references
        public byte R { get; set; }
        0 references
        public byte G { get; set; }
        0 references
        public byte B { get; set; }
        0 references
        public byte O { get; set; }
        0 references
        public string Data { get; set; }

```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2.3. Creating Tables in the Database

Database tables are created using Microsoft SQL Server to store entities. The "ObjectType" table is created first, followed by the "MyObject" table, as shown in the following code snippets:

Figure 3

ObjectType Database Code

```
USE [VisualizationDataPanelDB]
GO
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[ObjectType](
    [ObjectTypeID] [int] IDENTITY(1,1) NOT NULL,
    [Name] [nvarchar](max) NOT NULL,
    [Picture] [nvarchar](max) NULL,
    [URL] [nvarchar](max) NULL,
 CONSTRAINT [PK_ObjectType] PRIMARY KEY CLUSTERED
(
    [ObjectTypeID] ASC
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF,
) ON [PRIMARY] TEXTIMAGE_ON [PRIMARY]
GO
```

After executing this code snippet, the table related to the Object Type will be created in the database.

Figure 4

Object Type Database Table

Column Name	Data Type	Allow Nulls
ObjectTypeID	int	☐
Name	nvarchar(MAX)	☐
Picture	nvarchar(MAX)	☑
URL	nvarchar(MAX)	☑
		☐

Figure 5

MyObject Database Code

```
USE [VisualizationDataPanelDB]
GO
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[MyObject](
    [MyObjectID] [int] IDENTITY(1,1) NOT NULL,
    [Name] [nvarchar](max) NOT NULL,
    [ObjectTypeID] [int] NOT NULL,
    [PostionX] [real] NOT NULL,
    [PostionY] [real] NOT NULL,
    [PostionZ] [real] NOT NULL,
    [RotationX] [real] NOT NULL,
    [RotationY] [real] NOT NULL,
    [RotationZ] [real] NOT NULL,
    [ScaleX] [real] NOT NULL,
    [ScaleY] [real] NOT NULL,
    [ScaleZ] [real] NOT NULL,
    [R] [tinyint] NOT NULL,
    [G] [tinyint] NOT NULL,
    [B] [tinyint] NOT NULL,
    [O] [tinyint] NOT NULL,
    [Data] [nvarchar](max) NOT NULL,
 CONSTRAINT [PK_MyObject] PRIMARY KEY CLUSTERED
(
    [MyObjectID] ASC
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF, ALLOW_ROW_LOC
) ON [PRIMARY] TEXTIMAGE_ON [PRIMARY]
GO
ALTER TABLE [dbo].[MyObject]  WITH CHECK ADD  CONSTRAINT [FK_MyObject_ObjectType_ObjectTy
REFERENCES [dbo].[ObjectType] ([ObjectTypeID])
ON DELETE CASCADE
GO
ALTER TABLE [dbo].[MyObject] CHECK CONSTRAINT [FK_MyObject_ObjectType_ObjectTypeID]
GO
```


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After executing this code snippet, the table related to MyObject will be created in the database.

Figure 6

MyObject Database Table

Column Name	Data Type	Allow Nulls
MyObjectID	int	☐
Name	nvarchar(MAX)	☐
ObjectTypeID	int	☐
PostionX	real	☐
PostionY	real	☐
PostionZ	real	☐
RotationX	real	☐
RotationY	real	☐
RotationZ	real	☐
ScaleX	real	☐
ScaleY	real	☐
ScaleZ	real	☐
R	tinyint	☐
G	tinyint	☐
B	tinyint	☐
O	tinyint	☐
Data	nvarchar(MAX)	☐

2.4. Model Management Controls: Controllers

Controllers are defined to manage data through various actions such as Index, Create, Details, Edit, and Delete. These actions facilitate the interaction with the database for both "ObjectType" and "MyObject" entities.

The Object Types Controller includes actions to display all records (Index), view details (Details), create new records (Create), edit existing records (Edit), and delete records (Delete).

Figure 7

ObjectType Index Action, Details Action, Create Action, Edit Action, and Delete Action Codes

```
// GET: ObjectTypes
3 references
public async Task<IActionResult> Index()
{
    return _context.ObjectType != null ?
                View(await _context.ObjectType.ToListAsync()) :
                Problem("Entity set 'VisualizationDataPanelContext.ObjectType'  is null.");
}
```

```
// GET: ObjectTypes/Details/5
0 references
public async Task<IActionResult> Details(int? id)
{
    if (id == null || _context.ObjectType == null)
    {
        return NotFound();
    }

    var objectType = await _context.ObjectType
        .FirstOrDefaultAsync(m => m.ObjectTypeID == id);
    if (objectType == null)
    {
        return NotFound();
    }

    return View(objectType);
}
```

```
[HttpPost]
[ValidateAntiForgeryToken]
0 references
public async Task<IActionResult> Create([Bind("ObjectTypeID,Name,Picture,URL")] ObjectType objectType)
{
    if (ModelState.IsValid)
    {
        _context.Add(objectType);
        await _context.SaveChangesAsync();
        return RedirectToAction(nameof(Index));
    }
    return View(objectType);
}
```


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```
[HttpPost]
[ValidateAntiForgeryToken]
0 references
public async Task<IActionResult> Edit(int id, [Bind("ObjectTypeID,Name,Picture,URL")] ObjectType objectType)
{
    if (id != objectType.ObjectTypeID)
    {
        return NotFound();
    }

    if (ModelState.IsValid)
    {
        try
        {
            _context.Update(objectType);
            await _context.SaveChangesAsync();
        }
        catch (DbUpdateConcurrencyException)
        {
            if (!ObjectTypeExists(objectType.ObjectTypeID))
            {
                return NotFound();
            }
            else
            {
                throw;
            }
        }
        return RedirectToAction(nameof(Index));
    }
    return View(objectType);
}
```

```
// POST: ObjectTypes/Delete/5
[HttpPost, ActionName("Delete")]
[ValidateAntiForgeryToken]
0 references
public async Task<IActionResult> DeleteConfirmed(int id)
{
    if (_context.ObjectType == null)
    {
        return Problem("Entity set 'VisualizationDataPanelContext.ObjectType'  is null.");
    }
    var objectType = await _context.ObjectType.FindAsync(id);
    if (objectType != null)
    {
        _context.ObjectType.Remove(objectType);
    }

    await _context.SaveChangesAsync();
    return RedirectToAction(nameof(Index));
}

1 reference
private bool ObjectTypeExists(int id)
{
    return (_context.ObjectType?.Any(e => e.ObjectTypeID == id)).GetValueOrDefault();
}
}
```

Similar actions are defined for the MyObject Controller to manage "MyObject" entities.

Figure 8

MyObject Index Action, Details Action, Create Action, Edit Action, and Delete Action Codes

```
// GET: MyObjects
3 references
public async Task<IActionResult> Index()
{
    var visualizationDataPanelContext = _context.MyObject.Include(m => m.objectType);
    return View(await visualizationDataPanelContext.ToListAsync());
}
```

```
// GET: MyObjects/Details/5
0 references
public async Task<IActionResult> Details(int? id)
{
    if (id == null || _context.MyObject == null)
    {
        return NotFound();
    }

    var myObject = await _context.MyObject
        .Include(m => m.objectType)
        .FirstOrDefaultAsync(m => m.MyObjectID == id);
    if (myObject == null)
    {
        return NotFound();
    }

    return View(myObject);
}
```


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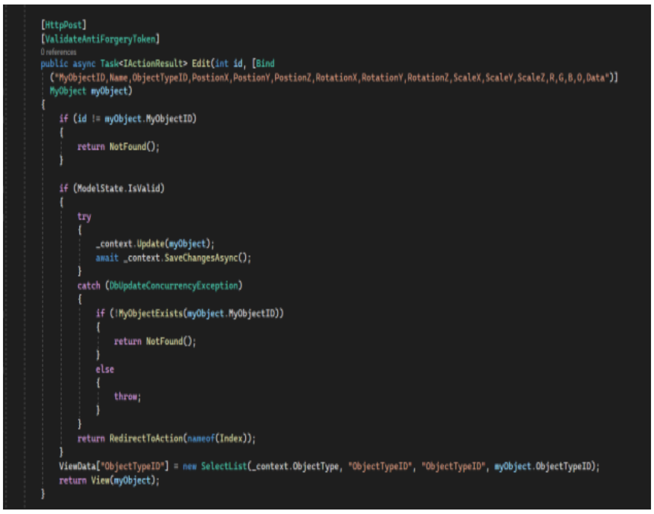
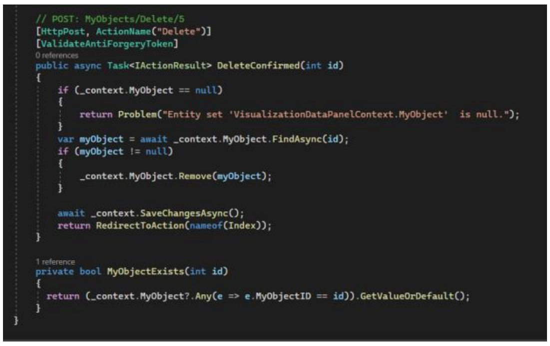
```
[HttpPost]
[ValidateAntiForgeryToken]
0 references
public async Task<IActionResult> Create([Bind
 ("MyObjectID,Name,ObjectTypeID,PostionX,PostionY,PostionZ,RotationX,RotationY,RotationZ,ScaleX,ScaleY,ScaleZ,R,G,B,O,Data")]
 MyObject myObject)
{
    if (ModelState.IsValid)
    {
        _context.Add(myObject);
        await _context.SaveChangesAsync();
        return RedirectToAction(nameof(Index));
    }
    ViewData["ObjectTypeID"] = new SelectList(_context.ObjectType, "ObjectTypeID", "ObjectTypeID", myObject.ObjectTypeID);
    return View(myObject);
}
```



```
[HttpPost]
[ValidateAntiForgeryToken]
0 references
public async Task<IActionResult> Edit(int id, [Bind
 ("MyObjectID,Name,ObjectTypeID,PostionX,PostionY,PostionZ,RotationX,RotationY,RotationZ,ScaleX,ScaleY,ScaleZ,R,G,B,O,Data")]
 MyObject myObject)
{
    if (id != myObject.MyObjectID)
    {
        return NotFound();
    }

    if (ModelState.IsValid)
    {
        try
        {
            _context.Update(myObject);
            await _context.SaveChangesAsync();
        }
        catch (DbUpdateConcurrencyException)
        {
            if (!MyObjectExists(myObject.MyObjectID))
            {
                return NotFound();
            }
            else
            {
                throw;
            }
        }
        return RedirectToAction(nameof(Index));
    }
    ViewData["ObjectTypeID"] = new SelectList(_context.ObjectType, "ObjectTypeID", "ObjectTypeID", myObject.ObjectTypeID);
    return View(myObject);
}
```



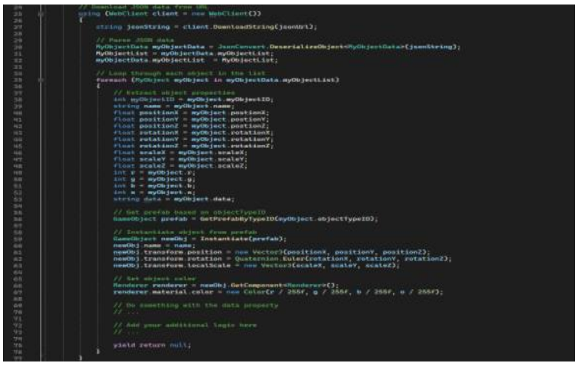
```
// POST: MyObjects/Delete/5
[HttpPost, ActionName("Delete")]
[ValidateAntiForgeryToken]
0 references
public async Task<IActionResult> DeleteConfirmed(int id)
{
    if (_context.MyObject == null)
    {
        return Problem("Entity set 'VisualizationDataPanelContext.MyObject'  is null.");
    }
    var myObject = await _context.MyObject.FindAsync(id);
    if (myObject != null)
    {
        _context.MyObject.Remove(myObject);
    }

    await _context.SaveChangesAsync();
    return RedirectToAction(nameof(Index));
}

1 reference
private bool MyObjectExists(int id)
{
  return (_context.MyObject?.Any(e => e.MyObjectID == id)).GetValueOrDefault();
}
}
```

2.5. *Visualization Simulation*

The visualization simulation is designed to display the created objects and all their associated information. Information is retrieved through a web API and displayed in the simulation software using REST API technology. The process includes retrieving data and creating objects in the simulated environment using C#.

Figure 9

Retrieving Data from Panel and Creating Objects



```
// Download JSON data from URL
using (WebClient client = new WebClient())
{
    string jsonString = client.DownloadString(jsonUrl);

    // Parse JSON data
    MyObjectData myObjectData = JsonConvert.DeserializeObject<MyObjectData>(jsonString);
    MyObjectList = myObjectData.myObjectList;
    myObjectData.myObjectList  = MyObjectList;

    // Loop through each object in the list
    foreach (MyObject myObject in myObjectData.myObjectList)
    {
        // Extract object properties
        int myObjectID = myObject.myObjectID;
        string name = myObject.name;
        float positionX = myObject.postionX;
        float positionY = myObject.postionY;
        float positionZ = myObject.postionZ;
        float rotationX = myObject.rotationX;
        float rotationY = myObject.rotationY;
        float rotationZ = myObject.rotationZ;
        float scaleX = myObject.scaleX;
        float scaleY = myObject.scaleY;
        float scaleZ = myObject.scaleZ;
        int r = myObject.r;
        int g = myObject.g;
        int b = myObject.b;
        int o = myObject.o;
        string data = myObject.data;

        // Get prefab based on objectTypeID
        GameObject prefab = GetPrefabByTypeID(myObject.objectTypeID);

        // Instantiate object from prefab
        GameObject newObj = Instantiate(prefab);
        newObj.name = name;
        newObj.transform.position = new Vector3(positionX, positionY, positionZ);
        newObj.transform.rotation = Quaternion.Euler(rotationX, rotationY, rotationZ);
        newObj.transform.localScale = new Vector3(scaleX, scaleY, scaleZ);

        // Set object color
        Renderer renderer = newObj.GetComponent<Renderer>();
        renderer.material.color = new Color(r / 255f, g / 255f, b / 255f, o / 255f);

        // Do something with the data property
        // ...

        // Add your additional logic here
        // ...

        yield return null;
    }
}
```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2.6. Defining Objects in the Panel

The system assigns unique codes to each 3D object defined in the panel, ensuring unique identification (Primary Key). Example primary keys include ObjectTypeID and MyObjectID.

2.7. Data Display and Analysis

Data generated by the web platform is displayed and analyzed. The APIs provide access to the data, enabling examination and evaluation of the information. Quantitative analysis ensures the data's accuracy and completeness, while qualitative analysis visually inspects the data within the simulation environment.

Figure 10

Output of MyObject API in JSON format


```
{
  "myObjectList": [
    {
      "myObjectID": 1,
      "name": "TestBox",
      "objectType": null,
      "objectTypeID": 1,
      "postionX": 0,
      "postionY": 0,
      "postionZ": 0,
      "rotationX": 0,
      "rotationY": 0,
      "rotationZ": 0,
      "scaleX": 1,
      "scaleY": 1,
      "scaleZ": 1,
      "r": 255,
      "g": 255,
      "b": 255,
      "o": 255,
      "data": "Box"
    },
    {
      "myObjectID": 2,
      "name": "Sphere",
      "objectType": null,
      "objectTypeID": 2,
      "postionX": 2,
      "postionY": 0,
      "postionZ": 0,
      "rotationX": 0,
      "rotationY": 0,
      "rotationZ": 0,
      "scaleX": 1,
      "scaleY": 1,
      "scaleZ": 1,
      "r": 255,
      "g": 0,
      "b": 0,
      "o": 100,
      "data": "0"
    }
  ]
}
```


The JSON output file from the MyObjectAPI matches the data stored in the databases, confirming the correctness of the data transfer process.

2.8. Quantitative Analysis: MyObjects

After activating the Visualization Simulation segment, the system connects to the web panel and sends a request to retrieve information. The result of the received information is printed in the console, ensuring all information is correctly transferred and displayed.

2.9. Qualitative Analysis: MyObjects

Upon executing the "Visualization Simulation" section, all objects defined in the "MyObject" section are displayed in the three-dimensional environment. This visual inspection ensures accuracy and correctness of the data representation.

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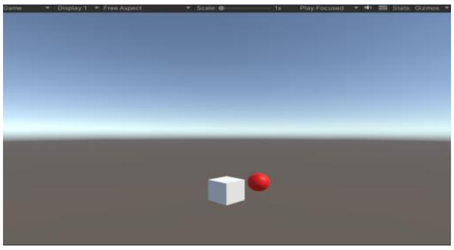
Figure 11

Display of created samples by simulation software



As observed, the two objects defined in the panel are displayed accurately and correctly in this section.

3. Findings and Results

The findings of this research indicate that using advanced software for data visualization through virtual simulation technology enables the display of urban statistical data visually and appealingly. This software can transform raw data and numbers into three-dimensional models in the virtual world, providing researchers with the ability to visualize information graphically and realistically. With this tool, researchers can easily examine various urban events and patterns in time and space and conduct more detailed analyses of the data. This is highly beneficial because interpreting raw statistical data may be challenging, but visualizing them in a three-dimensional environment improves data analysis and enhances researchers' understanding of urban events and patterns.

In this section, we engaged in the activity of collecting numerical data regarding air pollution indices in various districts of Tehran. Tehran, with its 22 districts and installed air pollution detection stations in different parts of the city, has extracted data related to air pollution indices from the website of the Air Quality Control Company. The collected information was presented in a tabular format, allowing for a detailed analysis of the pollution levels across different districts. This data was essential for visualizing pollution data in different areas of the city in three dimensions.

To visualize pollution data, we created a mapping structure that divided the city into different cubes based on the geographical locations of the areas and then categorized them according to each zone. Utilizing the official map of Tehran, we divided the cubes based on each region and assigned a specific color to each region for easy distinction. The surrounding cubes were removed, resulting in a clear and visible city map.

Figure 12

Displaying Tehran's 22 Districts Using Cubes in Different Colors

After obtaining the coordinates of all the cubes created for different areas of the city, we entered these coordinates into the panel. The data entry involved 576 cubes, with each cube requiring specific information such as name, object type, coordinates (X, Y, Z), rotations (X, Y, Z), RGBA color, and data related to each urban area. This

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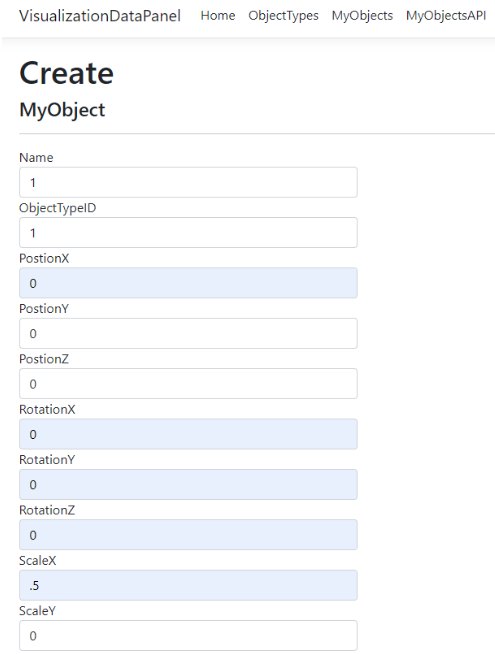
E-ISSN: 3041-9433

sequential data entry was essential for accurate representation in the database.

Figure 13

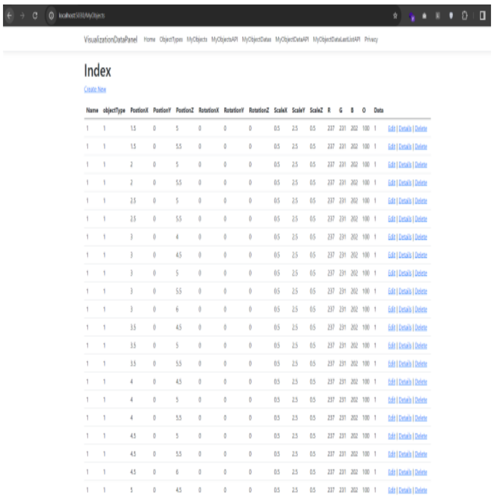
Object Data Entry Panel



Once the data entry was complete, the results were viewed in the index section, confirming the accurate registration of all cube-related information in the panel.

Figure 14

Panel After Entering All Data Related to the Cubes

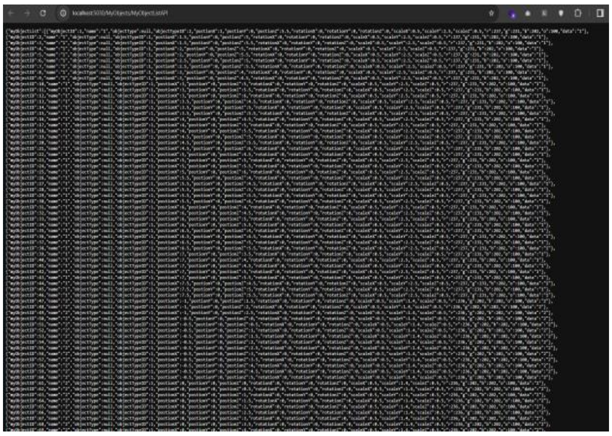


After ensuring accurate data entry into the database, we verified the data format through the MyObjectListAPI section, ensuring it was correctly formatted in JSON. This step was crucial for the data transfer between the panel and the simulation software.

E-ISSN: 3041-9433

Figure 15

MyObjectAPI JSON Output



We then ensured proper communication between the simulation software and the panel. Upon running the software, the connection was established, and all object-related information was accurately transferred from the server to the client and simulation software. The client received and printed the data in the console.

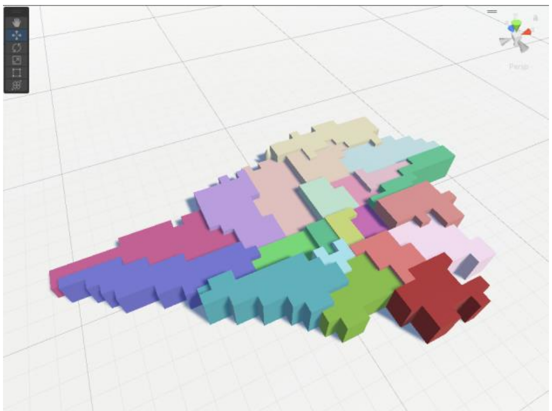
Figure 16

Receiving JSON Data from the Panel and Printing in the Console

To observe and present the output in three dimensions, we accessed the visualization and display section. The simulation software accurately examined all received information, visualizing all parcels and cubes in the three-dimensional space based on the received data.

Figure 17

Final Simulation Output of Registered Information in the Panel Related to the CO Index



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This final output confirmed that the software accurately represented the data in a visually appealing and comprehensible manner, facilitating detailed analysis and better understanding of urban air pollution patterns.

4. Discussion and Conclusion

The utilization of advanced software for data visualization through virtual simulation technology offers significant advantages in presenting urban statistical data in a visually appealing and comprehensible manner. This research demonstrated that the transformation of raw data into three-dimensional models provides researchers with a powerful tool for visualizing and analyzing information graphically and realistically. The ability to visualize complex data in a three-dimensional environment enhances the understanding of urban events and patterns, making data analysis more intuitive and effective.

One of the key findings of this study is that virtual simulation technology facilitates a more detailed examination of urban phenomena by allowing researchers to interact with the data spatially and temporally. This interactive approach is crucial in fields such as urban planning and management, where understanding the spatial distribution and temporal evolution of data is essential for informed decision-making (Opiła, 2019). By converting raw statistical data into three-dimensional models, researchers can easily identify patterns and trends that might be obscured in traditional two-dimensional representations (Opiła & Opiła, 2018).

The importance of visualization in the data analysis process cannot be overstated. Effective visualization techniques provide a clear and concise view of complex data, making it easier for decision-makers to comprehend and act upon the information presented (Cook & Thomas, 2005). This study confirms that data visualization using virtual simulation not only enhances the accuracy of data interpretation but also facilitates easier access to information, which is invaluable for extensive analyses and urban management decisions (Friendly & Denis, 2001). The findings suggest that incorporating virtual simulation technology into urban data analysis processes can significantly improve the quality and efficiency of research outcomes.

Considering the advancements in virtual simulation technology, this study highlights the potential of such tools in the development of smart cities. By enabling a detailed and interactive examination of urban data, virtual simulation technology supports better resource management and planning. This approach aligns with the concept of smart cities, which rely on advanced technologies to enhance the quality of urban living through efficient and sustainable management of resources. The ability to visualize and analyze urban data in three dimensions provides a deeper understanding of the underlying patterns and dynamics, contributing to more informed and effective urban management strategies (Farsi et al., 2020).

The implications of these findings extend beyond the academic realm to practical applications in urban management and planning. The use of virtual simulation technology as a tool for data visualization is recommended for relevant organizations and decision-makers in urban areas. By adopting this technology, cities can enhance their decision-making processes, improve resource allocation, and ultimately contribute to the development of more efficient and livable urban environments (Rahmani-Seryasat et al., 2015). This study underscores the value of virtual simulation in transforming complex data into actionable insights, facilitating the creation of smarter and more sustainable cities.

In conclusion, the research demonstrates that advanced software for data visualization using virtual simulation technology offers a transformative approach to presenting and analyzing urban statistical data. The ability to convert raw data into three-dimensional models enhances the comprehensibility and usability of information, providing researchers with a powerful tool for detailed and interactive data analysis. The findings highlight the significant benefits of this technology in understanding urban patterns and events, supporting more informed and effective urban management decisions.

The study confirms that virtual simulation technology is a valuable addition to the data analysis toolkit, particularly in the context of urban planning and management. By facilitating a clearer and more detailed examination of data, this technology supports the development of smart cities and the efficient management of urban resources. The adoption of virtual simulation tools is strongly recommended for organizations and decision-makers looking to enhance their analytical capabilities and improve urban living conditions.

The integration of virtual simulation technology into urban data analysis represents a significant advancement in the field, providing new opportunities for research and practical applications. This study contributes to the growing

E-ISSN: 3041-9433

body of knowledge on the use of advanced visualization techniques in urban studies, offering insights that can guide future research and policy development. The successful implementation of this technology in visualizing and analyzing urban data underscores its potential to drive innovation and improve outcomes in urban management and planning (Asaseh et al., 2023; Soleimani & Geshani, 2023).

By leveraging the power of virtual simulation, cities can achieve a higher level of understanding and control over their environments, paving the way for more sustainable and resilient urban development. The research presented in this study serves as a foundation for further exploration and application of virtual simulation technology in various domains, ultimately contributing to the advancement of smart and sustainable urban futures.

Despite the promising findings, this study has several limitations that should be acknowledged. First, the scope of the research was limited to the visualization of air pollution data in Tehran, and the results may not be directly applicable to other urban contexts with different environmental, social, or infrastructural conditions. Second, the implementation of the software relies heavily on the quality and accuracy of the input data, which can vary significantly and potentially affect the reliability of the visualizations. Additionally, the complexity of three-dimensional modeling and simulation requires substantial computational resources and expertise, which may not be readily available in all research or municipal settings. The study also did not explore the user experience extensively, which is crucial for understanding how effectively researchers and decision-makers can interact with and interpret the visualizations. Future research should address these limitations by applying the methodology to diverse urban settings, ensuring high-quality data inputs, and incorporating user experience evaluations to enhance the practical applicability and usability of the visualization tools.

Authors' Contributions

M.F. and M.M. conceptualized the study and developed the research framework. A.F. led the design and implementation of the virtual simulation software, overseeing the technical aspects and ensuring the integration of the web-based data entry panel with the 3D visualization module. M.B. managed the data collection and entry processes, ensuring data integrity and consistency. Y.G. conducted the testing and validation of the software, providing feedback for improvements and enhancements. All authors collaborated on writing the manuscript, with M.F. and M.M. drafting the initial sections, while A.F., M.B., and Y.G. contributed to the technical details and data analysis sections. All authors reviewed and approved the final manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

Not applicable.

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