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A Data-Driven Approach to Urban Water Quality Prediction Using Ubiquitous Sensing

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Abstract

By providing a more exact assessment of how new buildings and items appear and visually impact environmental surroundings, this study aims to enhance the process of design and urban planning. There are already a number of VR city visualization systems available, each of which offers a variety of features, including spatial visualization. There is still a considerable gap between virtual buildings and actual structures, despite recent technology that give lifelike simulations on stereoscopic displays and screens. Finding a means to employ augmented reality so that urban planners may walk the streets while projecting virtual three-dimensional buildings, enabling them to view both the actual city and the virtual structures at the same time, is the primary goal of this work.

1. Introduction

Virtual and augmented reality technologies are evolving at a breakneck pace, with better performance characteristics and wider availability making it imperative to find novel ways to use these tools in a variety of fields. Both architecture and urban planning play crucial roles in Augmented reality is one example of a cutting-edge technology that has the potential to improve our lives and make a major contribution to this sector (AR). For AR to break out of its current niche in two-dimensional data representation and marker-based systems, it is crucial that more people have access to high-quality solutions. When it comes to urban planning, it is essential that 3D data be accurately shown, and augmented reality (AR) technologies make this feasible, allowing for a more exact appraisal of how new buildings and things will appear and how they will visually affect the surroundings. Despite the fact that virtual reality (VR) solutions for city visualization already exist, augmented reality (AR) technologies are essential for achieving better results and improving the immersion level of the planning process. However, not all ideas can be reached immediately, and there is still a great deal of work and research to be done for AR's logical and physical structure. Although Furht [1] brings forth four sorts of applications that are most typically utilized for AR research, these applications include advertising and commercial, entertainment and education, medical, and mobile apps for smart phones. Despite this, Furht [1] also encourages novel approaches, since augmented reality (AR) faces both novel opportunities for creative application and new obstacles on the road from the lab to the workplace. In this article, we present an innovation based on the creation of a new application for city planners called City 3D-AR. This program makes it possible To combine actual cityscapes with computer-generated 3D structures (Fig. 1).

Figure 1: A new public meeting and urban-planning space attached to the existing bus station.

The primary objective is to figure out how to utilize these tools to increase the realism of the urban planning solution. By using AR, city planners may walk the streets while simultaneously seeing 3D models of proposed structures superimposed on the streetscape. Centres for Architecture, Local Government, Architectural Firms, Art Galleries, Municipal Archives, Museums, and Market Participants. Such interactive solutions are a great way to increase public participation in urban planning processes, as demonstrated by Allen et al. [2]. However, the system's functionality should be restricted so that users can only view the available 3D models and cast votes for the models based on their personal preferences. The goal is to minimize the number of moving parts so as to improve the system's usability. Therefore, these features have to be integrated as naturally and intuitively as possible into the GUI. Head-mounted displays (HMD) with augmented reality (AR) support and a wearable computer can be prohibitively expensive for professionals but affordable for average consumers in the form of tablets (Fig. 1). However, the most recent achievements in HMD development from Vuzix [3] offer a lightweight and high-performance HMD set, the price of which is expected to decrease annually. The arrival of HMDs with augmented reality capabilities for mobile devices is a step in the right direction, as they promise to be a practical alternative to the cumbersome wearable computer solutions that have previously been available.

Detecting the location of buildings based on the distance and viewing angle of the participant is one of the primary difficulties in this article and the City 3D-AR project. The standard method with fiducially markers can only be utilized for very close-range problems, such as those encountered in a building. Projects carried on at the Vidzeme University of Applied Sciences' Institute of Sociotechnical Systems Engineering's Virtual and Augmented Reality Laboratory. There were two rudimentary systems of hardware and software in play. Tablet PC (Asus Transformer Pad TF300TG) running Android; has in-built location sensors and software libraries for visualizing data (more detailed in last section). The second group consists of a laptop (Asus G71Vseries), an augmented reality head-mounted display (Vuzix Wrap 920AR), USB position sensors (Ocean Server evolution kit OS5000, Phidgets GPS, and Spatial 3/3/3), a gyroscopic mouse (Logitech MX Air Mouse), and a virtual reality/augmented reality authoring platform (3DVIA Virtools) with AR support.

2. Merging real and virtual environments on mobile devices

There has always been a pressing need to combine the physical and digital worlds, but it is only in the past several decades that clear definitions have emerged. Although attempts to merge the real and the virtual initially surfaced in film in the 1950s, the term "mixed reality" wasn't formally defined until 1997, according to the work of Azuma [4]. Kent [5] sums up the historical facts, in 1957, cinematographer Morton Heiling developed the patented Sensorial simulator, which combined sight, hearing, vibration, and olfactory stimulation. In 1990, airplane maintenance specialist Tom Caudell first used the phrase "augmented reality" in his writing. According to Azuma's [4] 1997 definition, augmented reality is the "merging of the real and virtual in three-dimensional space with the ability to interact in real time." Despite this description, the majority of current AR apps only provide flat data overlays over the actual environment. The vast majority of apps available on Google Play and the Apple App Store for Android and phones-based smart phones and tablets only display two-dimensional data. Some examples include ineffective interactive marker solutions for integrating 3D objects, explanations or instructions that rely on text or images, and navigational arrows and directions. There has been a significant increase in the number of people using mobile devices, and a corresponding increase in the number of supported features, which has prompted experts in several fields to consider novel approaches. Digital cameras and/or optical sensors (Nintendo Wiki, Sony PlayStation Move, and Microsoft Kinect), accelerometers, GPS, gyroscopes, solid state compasses, RFID, and wireless sensors are all used in today's mobile and entertainment augmented reality systems. In terms of precision and accuracy, these methods differ widely. According to Kent's review of the relevant literature [5], consideration should be given to the user's head position and orientation. The 6DoF interaction approach may be achieved by following the user's hands or portable input device. For Furht, [1] success is the most important factor. The computer platform for real-time photography applications is still very restricted if done on a cell phone's platform, despite the fast development of mobile devices. However, because to bandwidth constraints, many apps instead transmit data to a distant computer, which then delivers the output back to the mobile device.

3. Technologies and approaches of augmented reality (AR)

Our ability to extrapolate 3D details of the environment from 2D photos has greatly improved as image processing and computer vision technology have advanced. More and more vision-based AR applications have appeared as a result of the widespread use of these technologies. The term "augmented reality" describes the process of combining interactive virtual item with the real-world setting to create a convincing illusion of realism for the user [7]. Different methods and platforms for implementing augmented reality are now available. These methods may be broken down into two primary categories, marker-based and marker-free systems. Marker-based systems, as described by Kan et al. [7], use a unique marker to determine the location and orientation of a person or thing in three dimensions. To locate the relevant digital asset in the physical world, this identifier is used. It is necessary to register the marker and the virtual objects it is linked to in advance for it to be utilized as a tracking target. The registered data is separate for each AR system; therefore markers created for one system may not work in another without extra registration. As a result, RFID technology might be used efficiently. The low-cost visualization solution for logistics presented by Ginters et al. [8] uses augmented reality and radio-frequency identification.

AR-RFID technology is utilized to provide a visual representation of the components in the warehouse that need to be transferred to the assembly bay. This allows for more thorough quality control checks to be performed. So, the chances of making mistakes are decreased, and any damages are minimized. A 3D representation of the product is shown on the screen when an RFID reader deciphers the code for each individual part. Because just one marker is needed for tracking in AR-RFID by Ginters et al. [8], the issue of creating a stable and distinguishable fiducial marker is avoided. As a result, the most stable single marker may be used. An RFID tag's unique code is utilized to determine which 3D model is being referred to. Using the unique identifier, the tablet PC locates the 3D model and brings it up for inspection. Likewise, Kan et al. detail a sizable marker-based variant. [7] How QR codes are used in lieu of conventional fiducial markers to make augmented reality accessible to public-sector organizations. Any user may create a QR code, and the AR system will be able to read the data contained therein. With the advent of FullHD video cameras and advancements in computing power, it has become simpler to break down traditional marker restrictions. Seac02's Linear authoring platform allows users to use their own photos as markers, expanding the possibilities for object-marker alignment and removing the need to hide the fiducially marker, which can negatively affect the user's sense of immersion.

4. New usage possibilities and necessities of AR

However, the needs of real-world situations and the opportunities that AR provides don't always align. In this article, we will present the most flexible technologies for providing AR tracking and placement capabilities, including global positioning systems, electronic compasses, and inertial sensors. Following the example provided by Retime and Drummond [9] there are downsides to this technology as well. GPS is reliable and accurate enough for use in wide areas, but it struggles greatly in congested areas. Shadows from buildings and reflected signals lower the precision and availability of GPS location estimations. Just as magnetic sensors are affected by the local magnetic fields found in metropolitan areas, inertial sensors wander when exposed to these fields. However, widespread use of GPS and associated local sensor technologies suggests that they are increasingly present in public and professional settings across the globe. It is popular for the public to access augmented reality programs designed for urban exploration, museums, travel and history, shopping, customer service, safety and rescue operations, relocating and decorating the house. Popular programs like Wikitude, Nokia City Lens, Google Goggles, and Meatier Junior already exist. In 1999 [11], Azuma began studying the effects of superimposing digital labels on top of real-world landmarks, and in 2000 [12], Thomas et al. launched their A Quake video game. The inability to show marker-less 3D objects, whether they are in motion or at rest, is a major gap in the currently available software. The precession and stability capacities of modern sensors have advanced greatly. Differential GPS, or DGPS, for instance, improves GPS accuracy [13] by bringing readings to within 1–3 meters of the target, as opposed to the 4–20 meters of standard GPS. Networks of fixed GPS receivers are the backbone of the DGPS system. The error factor is the discrepancy between their desired location and the location determined by the satellite signals. The nearby GPS receivers detect this error component as an FM signal and adjust their values accordingly. Or Real Time Kinematic (RTK) satellite navigation is used for both land and hydro graphic surveys, and it relies on real-time corrections from a single reference station to pinpoint positions to within a few centimetres.

Nevertheless, the majority of the AR community's research efforts have been put into model-based tracking, hybrid solutions, and the analysis of video sequences [6, 10, 14, 15, 16, 17, 18, and 19]. The paper concludes with a description of the algorithm and formulae used in the City 3D-AR project, which augments real-world environments with virtual 3D models and sensors in anticipation of their broad use in the near future. The Netherlands Architecture Institute has confirmed the usefulness of such a solution for urban planning by implementing it in their first UAR (Urban Augmented Reality) project.

5. Implementation of City 3D-AR for urban planning efficiency improvement

The primary objective of the City 3D-AR prototype product is to allow for the deployment of 3D objects in real space based on GPS longitude and latitude coordinates. Figure 2 depicts the physical structure. Additionally, viewers' or participants' GPS locations are continuously tracked to facilitate mobility. As well as instantaneous adjustments of perspective, rotation, and scaling for 3D objects. Live video is captured by either a single camera built into the HMD or two cameras, one for each eye, in the case of a tablet. Since it is assumed in the present implementation that a single 3D object (building) is stationary while the participant is free to move about, a GPS sensor is utilized to determine the participant's position inside the 3D environment. While a digital compass is used to detect and measure changes in the viewer's line of sight, a gyroscopic sensor is utilized to determine the position of the tablet or viewer's head. It is not possible to alter the location of pre-existing buildings without access to a database containing 3D models of such structures. To give a more engaging AR experience, the option to customize the colour, material, and shadier attributes of an object should also be made available. At the moment, only basic 3D object formats like OBJ and OFF are supported.

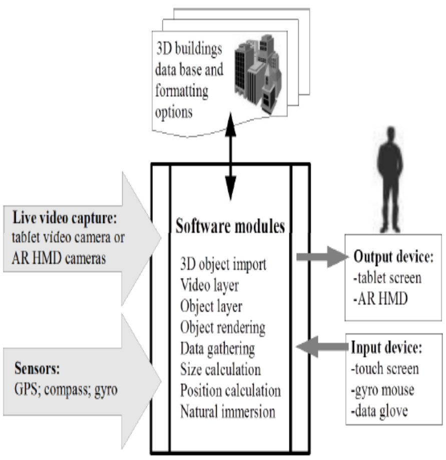

Fig. 2. City 3D-AR physical structure

The user relies on his sight to take in data from the augmented world; to engage with it, he employs the tablet's touch screen or other portable, wireless devices such as a gyroscopic mouse or data glove. Flowchart detailing City 3D-AR outcomes in detail (see Fig. 3). As noted up front, the first release runs on the Androids-powered Asus Transformer Pad TF300TG tablet PC. The Open Graphics Library (OpenGL), and more especially the OpenGL ES API, are supported by Android OS to provide high-performance 2D and 3D graphics. OpenGL is an open-source graphics application programming interface (API) that defines a uniform API for 3D graphics processing devices [22]. The Android Software Development Kit (Androids) and the Eclipse (Juno) IDE with the Android Development Tools (ADT) plug-in are used throughout the coding process. The OBJ and OFF file formats are employed to portray 3D objects in block number 2, and the drawing code for the Model View application [20] for the Android platform is used. Block 8 depicts a movie, and Block 14 displays a 3D model, both of which may be seen in full screen mode by superimposing two panels. Data from a video camera may be found at the bottom (in the Surface View class), whereas information about a 3D model can be found at the top (GLSurfaceView class). To address the issue of transparency in OpenGL rendering [21], GLSurfaceView provides a Surface View implementation that makes advantage of the dedicated surface. The natural size of a structure may be obtained by changing the unit of measurement value in the 3D object attributes to meters.

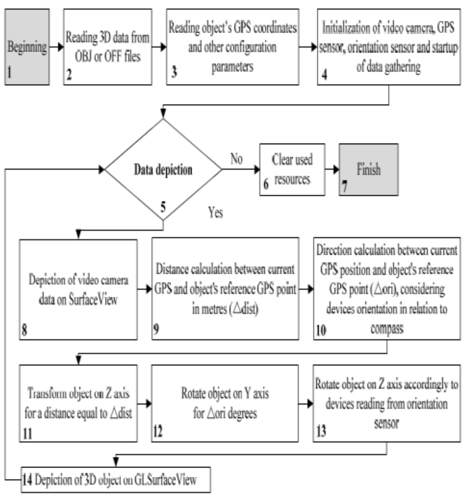

Fig. 3. City 3D-AR detailed flow chart

A tablet PC is utilized as both the origin and the reference point of the whole coordinate system. When determining the distance to an object and the direction of travel in degrees, the local orientation of the tablet PC with respect to North is a factor. How Far Is It Between These Two GPS

Coordinates? Block 9 Use of the have sine formula [23]:

$$a = \sin^2(\Delta\varphi/2) + \cos(\varphi_1) * \cos(\varphi_2) * \sin^2(\Delta\lambda/2)$$
$$c = 2 * \mathrm{atan2}(\sqrt{a}, \sqrt{(1-a)})$$
$$d = R * c \quad (1)$$

where φ is latitude, λ is longitude, R is earth's radius (6371km)

When two GPS locations need more accuracy between them, the distance between any two locations on the surface of a spheroid may be calculated using Vincent's formula [24], which is used in geodesy and is based on two similar iterative techniques invented by Thaddeus Vincent. They presume that the number of Great-circle distance and other approaches that presume a spherical Earth are less precise than those that take into account Earth's oblate shape. There is a bearing formula [23] that may be used to determine the direction from the current GPS location to the object's reference GPS point (block nr. 10).

$$\theta = \mathrm{atan2}(\sin(\Delta\lambda)*\cos(\varphi_2), \cos(\varphi_1)*\sin(\varphi_2) - \sin(\varphi_1)*\cos(\varphi_2)*\cos(\Delta\lambda)) \quad (2)$$

The actual translating, rotating, and scaling is done using OpenGL's built-in functions [21, 22]:

```
glRotatef(float angle, float x, float y, float z)
glTranslatef(float x, float y, float z)
glScalef(float x,float y,float z)
```

Whereas, in each case, the current matrix is multiplied by a rotation matrix, a translation matrix, and a general scaling matrix. Further, OpenGL [22] effectively addresses concerns with the visibility of edges and faces.

6. Conclusions

In the early phases of city development, the ability to visualize data in three dimensions (3D) is essential. There's no denying the significance of adopting cutting-edge technology. Many resources may be saved before building even begins if the appearance and impact of new architectural elements can be accurately predicted. Until the point when it's done. Improvements in population satisfaction and collective decision making may also result from a discussion process that makes it simple to include public concerns.

City 3D-AR is an augmented reality application for city planning that combines actual and virtual 3D structures. Its logical framework may be applied to a variety of physical building configurations. The geodesy, trigonometry calculations, and graphics libraries used by augmented reality technologies are built upon the same GPS, gyroscopic, compass, and inertial sensors used by GPS devices. There is still a long way to go before the aforementioned technology sees widespread professional use, and validation under urban planning criteria is ongoing. In addition, the collection of software modules built and combined acts as an experimental platform for further development, in order to determine real and successful use cases, taking into account viewing distance, movement speed, and density of buildings, performance concerns, and complexity of models.

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