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Research paper

RAISING ENVIRONMENTAL AWARENESS IN THE URBAN CONTEXT USING GEOSPATIAL AUGMENTED REALITY

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Abstract

Environmental awareness is crucial for fostering sustainable urban development and enhancing citizens' engagement with their surroundings. In this study, we developed a mobile application based on geospatial augmented reality to promote environmental awareness in outdoor urban spaces. The application aims to immerse users in multimedia interactive content related to the environmental benefits of urban green spacecs (UGS), on-site and in real time. The application aims to assist individuals in understanding the ecosystem services of UGS and its potential future scenarios. The research highlights the potential of geospatial augmented reality (AR) in smart cities, emphasizing its role in education, citizen participation, and sustainable urban planning.

Key words: *Urban Green Space, Augmented Reality, Environmental Ecosystem Services, Participatory Urban Planning, Environmental Awareness, Geospatial*

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1. INTRODUCTION

The interrelated themes of urbanization and climate change are among the greatest challenges facing humanity on a global scale. The anticipated impacts of climate change include an increase in the average global temperature, a decrease in average rainfall, and a rise in sea levels, potentially coupled with an increase in extreme storm events [1]. In this context, urban areas are recognized as the greatest contributors to all global energy-related carbon emissions [1]. In recognition of these trends, the three core priorities for sustainable urban development are recognized: the improvement of urban life, the minimization of ecological footprints, and the improvement of urban resilience to climate change [2,3].

UGS—parks, tree-lined avenues, urban forests, green roofs, and walls—have the potential to enhance the ecological balance within cities and also improve the quality of life among citizens. Besides cultural and social ecosystem services, UGS performs many important ecosystem functions like carbon sequestration, pollutant filtration, mitigation of the urban heat island effect, and preservation of biodiversity [4]. UGS are of much more significance in a changing climate environment, as they contribute to the resilience of urban areas from severe weather events [5]. Because of evidence that nature improves human well-being [6,7], UGS research is being pushed by an increasing interest in the environmental, social, and economic advantages of its use in urban areas, while the demand for more UGS is high on the political agendas of cities all over the world.

It has become more and more important that, in this new age of rapid urbanization and the relentless whirlwind of climate change and environmental degradation, people have a better understanding of their relationship with their habitat. These contorted challenges should be tackled through sustainable governance of natural resources and the conservation of the ecological balance [8,9]. The aforementioned goals do not come easily, as they require much human energy and systemic change, especially in how urban spaces are planned and managed. Increasing environmental awareness among citizens, coupled with their active participation in participatory planning processes, is increasingly recognized as a prerequisite for cities that are more disaster resilient and at the same time more efficient, inclusive, and sustainable [10,11]. Thus, a future-proof city is one with inclusive governance structures that empower communities against social and ecological disaster.

Environmental awareness is defined as the ability of an individual to recognize and understand the significance of natural processes as well as ecosystem services and their dependence on people's activities. In urban settings, this increasing population severity distance from the natural values has caused a growing danger of the separation of the urban population from natural values [12]. This fact affects the population's inactivity concerning issues of spatial planning and environmental preservation. Research from the studies shows that knowledge about environmental ecosystem services like air filtration, microclimate control, and permeable water surfaces contributes to more environmental care by urban citizens and participation in the planning process [13,14].

Participatory planning is the process of involving citizens in the entire phases of urban planning, from problem identification to implementation and evaluation. This has made it possible to mainstream citizens' needs and aspirations in spatial policy, thereby improving acceptance of, and thus effectiveness in, implementation of plans [15,16]. However, without proper information, public decisions cannot be made, and meaningful critiques and recommendations should not arise.

Technology brings about the aspect, especially AR, which very well suffices as a tool used for education through visualization. In this context, AR can be a solution to the gap between abstract planning and designing concepts and the effective perception of space by the citizens. This technology can enable users to visualize complex environmental data at the given location in real time, including air quality data, the degree of green coverage, species types, and their role in the ecosystem. In that way, users can directly experience the role of UGS in real space and time.

As an interactive technology, augmented reality can provide quick contextual information about environmental awareness in urban spaces. Using hardware such as a mobile device, users can engage interactively with their surroundings while virtual information overlays the physical environment through the device's display. This effect is possible through various techniques for recognizing and tracking the environment. Image tracking enables the recognition of flat image objects, achieving high precision under stable lighting conditions. However, since this technique is sensitive to lighting variations, it is best suited for indoor environments. Similarly, object tracking is used for recognizing physical 3D objects and is best performed indoors. This technology is precise but requires effort to generate 3D models or scan objects. For outdoor environments, location-based tracking utilizes GPS coordinates to position virtual materials. A limitation of this technology is that the precision of aligning virtual objects depends on the GPS signal and hardware quality.

2. MATERIALS AND METHODS

2.1. Data visualization method: Geospatial AR

In our work, we used a hybrid type of geospatial tracking to achieve higher precision in an outdoor environment. This type of tracking combines solutions such as Global Positioning System (GPS) and Visual Positioning System (VPS). The sensor of the device and the GPS are used for location-based tracking to detect the user's environment. VPS is used to improve the precision of tracking based on computer vision algorithms. These algorithms are used to match visual features with previously stored images in the database.

We use AR Core Geospatial API to determine the precise location of the user's device and anchor virtual content. Device sensors and GPS data are used to detect the visitor's device location, while Google's VPS is used to determine a more precise location. The VPS detects the device location by comparing the data captured by the camera with feature points from the VPS localization model. This VPS localization model is realized as a 3D model point cloud generated using Street View images from Google Maps. Therefore, this tracking solution does require the creation of additional markers in contrast to other tracking solutions. Also, ARCore Geospatial API can be used in any outdoor environment where the location of the device can be determined.

2.2. Data

The assessment of ecosystem services provided by green areas, specifically trees within schoolyards, comprised a point of interest during this study via the i-Tree tool [17].. Seven urban elementary schools are selected for this study (Table 1, Figure 1). Average tree circumference was measured per dominant species; the total number of trees was estimated per site; and the overall tree condition was evaluated based on variables defined for the i-Tree tool (Table 1). Carbon sequestration, stormwater runoff interception, and air purification were determined from the i-Tree assessments of the major tree species in each site. The results were extrapolated to simulate possible green infrastructure improvement scenarios, wherein calculated values were increased by either 30, 50, or 100 percent, thereby portraying possible scenarios of increased green coverage. It is emphasized that ecological service valuations obtained from i-Tree for a certain stand are for a 20-year projection period and thereby offer some pointers regarding the long-term benefits of the concerned tree and shrub cover that may need recognition for management improvements.

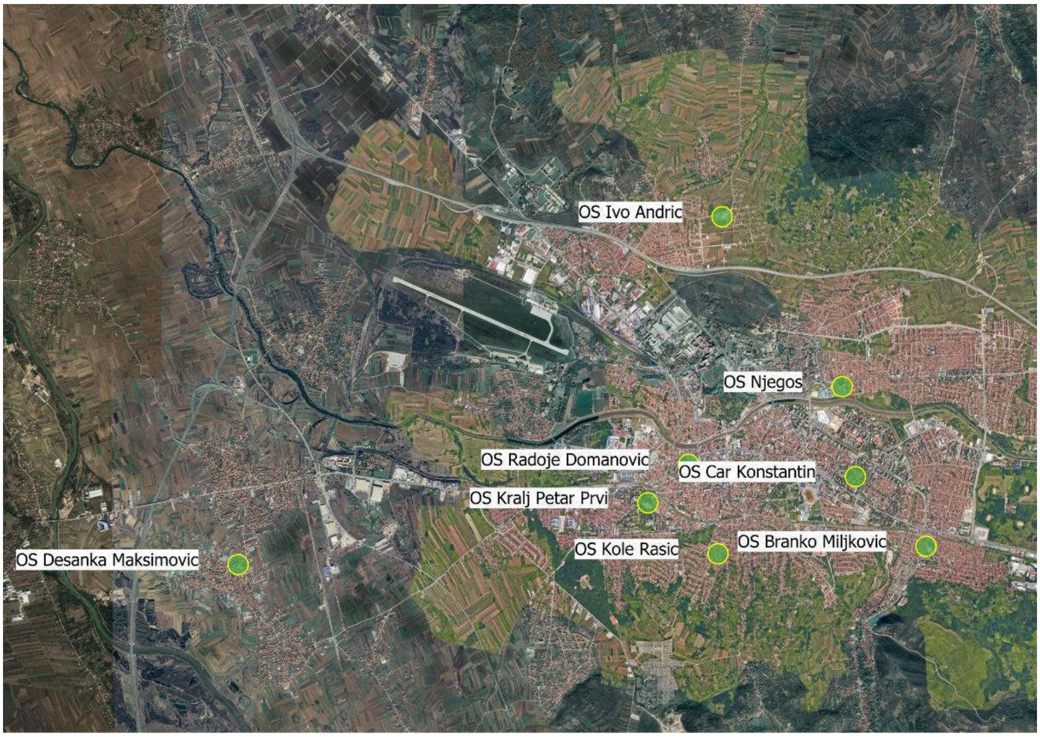

Figure 1. Selected elementary schools

The i-Tree tool is a software developed by the USDA Forest Service to estimate, in terms of dollars and cents, the environmental and economic benefits offered by trees and urban forests. It operates through a field-based data collection procedure that includes species of trees, tree size (for instance, circumference at standard height), tree health, and local environmental conditions. Carbon storage and sequestration, stormwater attenuation, and air quality improvement are some key services and benefits assessed by i-Tree by applying scientifically proven models and extensive databases. The i-Tree uses basic tree inventory data and translates this into much more detailed output on ecosystem services involving ecological valuation and monetary estimates. This makes the i-Tree an important tool in urban green-space management and planning with regard to evidence.

Table 1. Entry data for selected elementary schools

Name	Spices	Number of trees	Condition	Circumference
Radoje Domanovic	Betula pendula	27	11-25%	112
Kole Rasic	Acer sp.	15	11-25%	100
Kralj Petar Prvi	Tilia sp.	145	1-10%	135
Car Konstantin	Betula pendula	78	1-10%	135
Ivo Andric	Betula sp.	69	1%	90
Njegoš	Pinus nigra	65	11-25%	99
Branko Miljkovic	Abies alba	67	11-25%	88

3. RESULTS: REALIZATION OF THE AR APPLICATION

The aim was to develop an interactive application based on geospatial AR that will provide environmental data directly at the location of the user.

The application is realized using the Unity engine as a multimedia cross-platform tool for developing interactive solutions [18]. Using this tool application can be published on various mobile devices based on platforms such as Android and iOS. Also, Unity integrates AR Foundation [19] as a framework for developing augmented reality applications for multiple platforms and devices. For using AR Foundation, various package extensions are available that depend on the platform. For the development of the application, we used the ARCore [20] package, which has various tracking features. The ARCore Geospatial API [21] tracking feature is used to develop an application that visualizes data in an outdoor environment. This tracking technology, based on GPS and VPS, is used to anchor virtual content at the location of the primary schools. This virtual content is based on the environmental data given in Table 1.

When a user is at the location of the primary school, he opens the application and points the camera of the mobile device toward the garden. The augmented reality application using GPS and VPS determines the position of the user device. Then, on the mobile device screen, show the virtual overlay over the image captured by the camera. This virtual overlay shows the environmental data about the schoolyard in the user's surroundings. For this exercise we presented results for two elementary schools. Figure 2 shows the usage of an AR application that provides environmental ecosystem services information about the park in the primary school Kole Rasic. The information’s presented are calculated using iTree tool. The resulted information about ecosystem services involving ecological valuation and monetary estimates is presented in Table 2.

Table 2. Ecosystem services ecological valuation and monetary estimates for elementary school Kole Rasic

	Current Value	30% increase	50% increase	100% increase
Amount of stored carbon dioxide equivalent expressed in RSD per tree over a 20-year period.	8132	10571.6	15857.4	31714.8
Benefit of absorbed pollutants expressed in RSD per tree over a 20-year period.	8346	10849.8	16274.7	32549.4
Benefit of flood prevention expressed in RSD per tree over a 20-year period.	3	3.9	5.85	11.7
Total benefit expressed in RSD for all trees over a 20-year period.	249417	324242.1	486363.15	972726.3

Figure 2. AR application shocase environmental ecosystem services information about the trees in the elementary school Kole Rasic

Also, the visualization of environmental data about the park in the primary school Radoje Domanovic is given in Figure 3, and output iTree information in Table 3.

Table 3. Ecosystem services ecological valuation and monetary estimates for elementary school Radoje Domanovic

	Current Value	30% increase	50% increase	100% increase
Amount of stored carbon dioxide equivalent expressed in RSD per tree over a 20-year period.	10058	13075	19613	39226
Benefit of absorbed pollutants expressed in RSD per tree over a 20-year period.	9368	12178	18267.6	36535
Benefit of flood prevention expressed in RSD per tree over a 20-year period.	3	4	6	12
Total benefit expressed in RSD for all trees over a 20-year period.	525156	682702	1024054	2048108

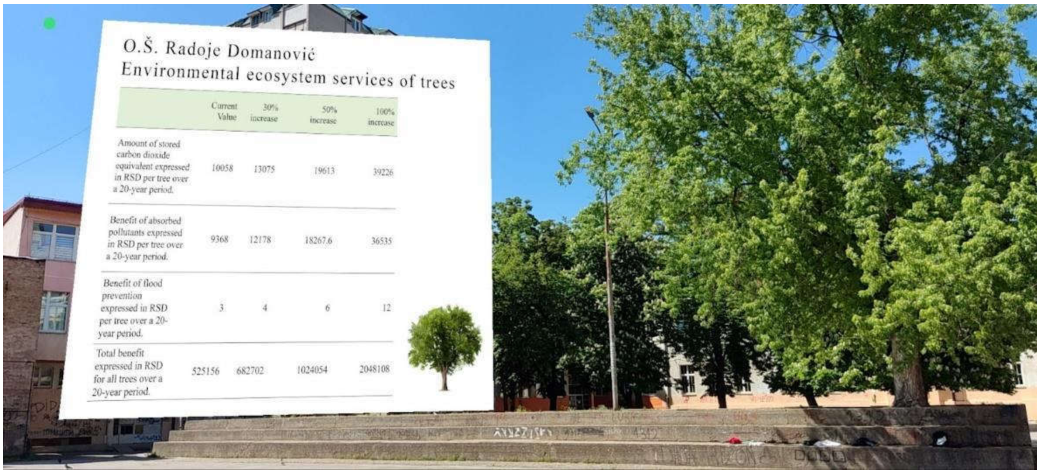

Figure 3. AR application shocase environmental ecosystem services information about the trees in the elementary school Radoje Domanovic

The finding comparison between elementary school Radoje Domanovicand Kole Rasic portrays a very important impact of the number and type of species of trees, as well as its condition towards the value of the ecosystem services they generate. With 27 Betula pendula trees, elementary school Radoje Domanovicoffers very high ecological and monetary benefits compared to those of Kole Rasic, which is equipped with 15 Acer sp. trees. Although both share similar conditions of health for their trees (11-25%), the greater number of trees at Radoje Domanovic directly contributes to the total benefit amounting to 525,156 RSD compared with 249,417 RSD for a 20-year period. Also, other species differences and size or circumference of the trees affect rates of carbon stored and pollutants absorbed: the Betula pendula, despite its condition and circumference not being very impressive, seems to do better than Acer sp. regarding total services delivered.

Seeing such a comparison in an AR setting is one way for users to understand the impacts that different trees and conditions have on their lives. With AR, learners would interact with overlays of ecosystem service values right on the schoolyards, enabling intuitive comparisons and active learning. Observing the variations in carbon, pollution, and flood prevention, among other things, truly lets users internalize the characteristics and quantity of trees in place and how these lead to certain environmental outcomes. This, at scale, could enhence participatory city planning, empowering citizens—especially young ones—to directly learn about the ecological values of urban greenery and make informed decisions and proposals for the future urbanization based on real, localized data.

4. CONCLUSION

Increasingly, UGS are showing their influence on environmental resilience in sustainable urban living within the pressing challenges of climate change and urbanization. This study introduced a novel and accessible means of communicating the ecological value of UGS through the combination of ecosystem service evaluation using the i-Tree tool with the creation of an AR application. The i-Tree assessment quantified key ecosystem services as carbon sequestration, air purification, and stormwater management, demonstrating the direct environment benefits from urban trees. The AR application allowed users to interactively "receive" such data within real-world urban settings and in such a manner rendered more complex ecological processes clear and relatable.

In fact, this approach narrows the gap between the scientific information and the citizenry by converting much of the solid data into public awareness and highly stimulating participation in urban planning. The study highlights the modalities that should be adopted in future integrative frameworks to align data-driven environmental management with citizen-centered technological tools in empowering the urban population and provide adaptability for cities to future-proof their planning.

It must be pointed out that several limitations exist. The ecological service valuations provided by iTree are based on model projections and assumptions that sometimes do not represent the on-the-ground realities of local environmental dynamics, especially on horizons spanning a number of years. The other constraint of the study is that it has focused only on several elementary school sites, which limits the generalization of the results across wider urban contexts. Although the AR application makes one aware, it does not necessarily induce behavior change or active civic participation without supplementary curricula and policy initiatives.

Broadening the application of the approach to diverse urban locations with diverse ecological, social, and spatial characteristics would be an appropriate extension of this methodology for further validation and refinement. Advances in AR technology, especially in improving outdoor tracking accuracy and user interface design, would also enhance the user experience and educational impacts. Likewise, linking AR visualizations with participatory workshops and some feedback mechanisms would further fortify citizen engagement and create a sense of environmental ownership. Finally, it is hoped that policy-makers and urban planners will include such technology in wider sustainability education campaigns and participative planning processes.

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