SHORT-PAPER

GreenSpot: Improving Public Transport with GIS-Based AR and Cluster-GCN Recommendation

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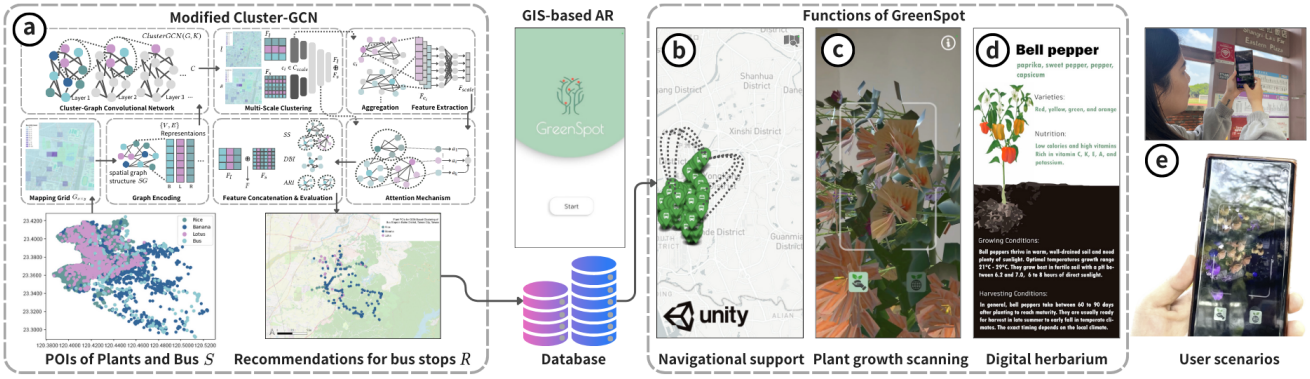

Figure 1: Our system is a GIS-based AR that revitalizes urban transportation by offering interactive bus commute experiences. It provides (a) tailored recommendations at bus stops from the database using Cluster-GCN, (b) navigational support, (c) plant growth scanning, (d) digital herbarium access, and (e) user scenarios at bus stations.

ABSTRACT

We introduce a GIS-based AR to promote public transport and environmental awareness. It transforms bus rides into gamified journeys of virtual plant cultivation at bus stops. Featuring AR scanning for plant growth, navigation aids, and a digital herbarium, it enriches user interaction with their surroundings. The system integrates nature-inspired virtual installations, supported by a database and species map for green education, utilizing Cluster-GCN for plant, flower, and crop information and mapping into bus stops to recommend travel sites for passengers. An immersive AR interface enables users to access plant information at nearby stations through a custom graph clustering pipeline. User tests showed no significant change in bus ridership interest, slightly fluctuating from **52%** to **43%**, attributed to bus punctuality and frequency issues. However, the app significantly increased user engagement with the environment and species knowledge from **54%** to **82%**, underscoring a positive relationship between public transport and environmental awareness.

CCS CONCEPTS

• **Information systems** → **Geographic information systems**; • **Computing methodologies** → **Artificial intelligence**; • **Human-centered computing** → **Mixed / augmented reality**.

KEYWORDS

Graph Convolutional Networks; Public Transport; Spatial Data Mining; Recommender System; Augmented Reality

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1 INTRODUCTION

The research on planning bus routes based on spatial feature heterogeneity is abundant [4, 7, 10], yet studies focusing on city-specific or local characteristics for service-oriented approaches are rare. This gap highlights the potential for integrating local distinctiveness into public transportation planning, aiming to enhance both service quality and user experience. This suggests that the transportation needs of passengers are divided into citizens and tourists in the demarcated group. Consequently, the experience of our system needs to be differentiated and customized, focusing on leveraging spatial heterogeneity of local experiences to effectively enhance the promotion and usage of different bus routes and stops.

Our initiative innovatively bridges cultural and natural heritage with digital technology, aiming to boost the city's cultural economy and encourage the use of public transport through location-aware and contextual computing. By integrating Geographic Information System (GIS) and Augmented Reality (AR), it transforms bus stations into interactive hubs for virtual plant cultivation, fostering a connection between tourists, locals, and the environment. This mobile reality game goes beyond traditional HCI by offering AR-driven experiences like plant growth scanning, navigational aids, and a digital herbarium, all supported by a detailed species database and Cluster-GCN [5] model for personalized recommendations (**Figure 1**). By embracing a user-friendly approach, our GIS-based AR system endeavors to engage urban dwellers and commuters in collecting valuable plant species, thus lowering the barriers to nature exploration and enhancing the interactive travel experience, nurturing a symbiotic relationship with the local ecological milieu. The system makes public transport more engaging and promotes sustainable urban living by nature-inspired digital interactions with the physical realm for commuters and travelers community.

In the demo, the system shows AR user interactions at bus stops for visualizing virtual plants. It highlights real-time plant growth scanning and flora access via the AR interface, demonstrating the GIS-based AR system's effectiveness in engaging users and enhancing environmental education through daily public transport. The demonstration can be found at **https://youtu.be/z8h73SGyPvw**.

2 SYSTEM IMPLEMENTATION

Overview. The database and regional species map serve as foundational elements in addressing the growing disconnect between urban residents and the natural world. Through the meticulous storage of Points of Interest (POIs) related to bus stations and plant species, and the deployment of a graph data clustering pipeline from a Cluster-GCN, our system dynamically outputs recommendations for bus stations and their associated plant species in nearby areas. This not only showcases the potential of recommendation systems but also integrates Augmented Reality (AR) to offer tailored recommendations at bus stops, directly utilizing the Cluster-GCN.

POIs Data, Species Map and Cluster-GCN. The government's active promotion of open data and ecological conservation initiatives and the digitization of urban and ecological databases create a rich backdrop for our work. Despite the wealth of information contained in thematic databases and field guides, there remains an underutilization in making these resources accessible to the general public. Notable among these are: (1) Bus Stop Information [3], (2) Agricultural and Fishery Production Map [9], (3) Distribution and production period of agricultural products [1], (4) Old Trees Maps and Database [2], to name a few. Despite the existence of these spatial databases, there is a notable gap in projects that integrate these diverse themes and make them accessible and appealing to the general public. Through sustained efforts involving the integration of various POIs databases and field guides, coupled with the spatial heterogeneity analysis of local features in each area, we can develop intricate regional species maps. Our initiative leverages these comprehensive databases, integrating them with the latest in AR technology and graph convolutional networks to not only provide practical information like bus routes but to also invite exploration and interaction with the rich biodiversity. Through this, we aim to transform the way residents interact with their environment, promoting a more intimate connection with nature and encouraging greater concern and action on environmental issues [8, 11]. It illustrates a novel pathway to making environmental conservation a tangible part of urban life, drawing on the intricate regional species maps, such as the one illustrated for the districts, as a tool for education and engagement.

Through the deployment of AR to provide personalized recommendations derived from the database using Cluster-GCN, we introduce an interactive dimension to urban conservation efforts. The personalized recommendation leveraged by the Cluster-GCN to impact mobility habits, which focuses on the most relevant features of green attractions information based on user queries. This targeted approach ensures that the recommendations are customized to the specific interests and needs of the users, thereby enhancing user satisfaction and engagement with the recommended green spaces. This method capitalizes on the wealth of information contained within the ecological databases and field guides, transforming them from static resources into dynamic tools for environmental education. By doing so, it encourages residents to explore and understand their local ecosystems, thus fostering a deeper appreciation for environmental conservation. This strategy complements the government's initiatives, enhancing the public's connection with nature and driving more informed environmental actions. Specifically, the AR system, powered by the enriched POIs database and regional species map with spatial heterogeneity, facilitates tailored recommendations at bus stops, directly addressing the urban disconnect by making local ecological knowledge accessible and engaging. This innovative approach not only leverages the government's efforts in the imbalance of traffic volume in central and non-central areas, ecological conservation, and digitization issues but also bridges the gap between existing thematic databases and the public's traffic convenience and environmental awareness.

GIS-based AR. The system is designed to encourage the use of public transportation, specifically buses, through an augmented reality (AR) plant cultivation experience. Developed with Unity 2021.3.11f1 and AR Foundation version 5.1.3 for plane detection, along with the Google ARCore XR Plug-in package version 1.31 for Android mobile devices. The Mapbox API in the Maps SDK for GPS location-based gaming, the app aims to gamify the commuting process. It enables users to collect various plant seeds and tools within the app for cultivation, thereby incentivizing the use of bus services. It integrates AR into the bus transportation system's network, enhancing it with features such as floral interactive

Figure 2: User flow and scenarios of AR application.

installations, bus route and map displays, and personalized recommendation information. This enables direct interaction with virtual plant cultivation at bus stops, shelters, and transfer stations via the app, allowing passengers to discover their location and engage in environmental enrichment activities.

They have the opportunity to collect seeds for planting, access detailed plant information, and utilize tools provided at bus shelters for greening the space. By scanning images on bus stop signs through the app, users can ascertain their location. This enables them to collect plant seeds and acquire tools to assist with planting or planting mature plants at bus shelters to green the shelters and stimulate other users' interest in the origins of the plants. Scanning at the bus shelters provides access to special tools that aid in planting to green the station. These interactions are designed to promote awareness of local flora and encourage sustainable commuting habits among users, merging the utility of navigation and station information with the appeal of interactive plant cultivation. The AR interface is divided into four main functionalities: Camera, Map, Inventory, and Compendium, the detailed user flow is demoed in **Figure 2**: (a) The start page showcases the AR logo; (b) "**Inventory**" function provides a space to store tools from bus shelter scans, crucial for plant growth, and "**Compendium**" function serves as a digital herbarium, showcases the seeds collected from bus stop signs, where users can select and start new plantings; (c) "**Map**" function aids navigation by highlighting bus stop locations for efficient collection journeys; (d) "**Camera**" activates an AR scanner with prompts for collecting seeds or tools, providing users with information about the nearest station to guide them. Additionally, (e) the interface presents scenarios designed for user interaction at bus stations, merging digital and physical collection experiences.

Through the utilization of AR technology, users can collect seeds at each bus station and also view others' plant achievements by scanning the AR codes at the bus stop signs, satisfying their curiosity about the origins of the plants. Scanning at bus shelters yields special tools to assist with planting. The UI in the Camera function has two buttons: the left one allows users to place their plant achievements as the floral interactive installation in AR to decorate and green the bus stop, while the right button enables users to tap each plant, showing the source seed from which bus stop and the transfer information. At bus transfer stations, users encounter physical installations integrated with AR technology, which allow them to display their grown plants in a virtual exhibition space. Our system offers an interactive and environmentally friendly approach to daily commuting, integrating a digital layer of engagement with the physical world to promote sustainable transportation habits.

3 USER EVALUATION AND RESULTS

Participants. A survey with app testing was conducted to assess the citizens' perspectives regarding their experiences with public bus transportation, their environmental awareness, and the impact of GIS-based AR software usage on bus riders' willingness to ride and environmental awareness. The sample comprises 51 residents who have resided in Taiwan for at least 3 months, consisting of 27 males and 24 females. The majority of participants fall within the 21-30 age group (**75%**) and the 11-20 age group (**15.4%**), with **63.5%** being undergraduates and **30.8%** graduate students. The graphical representation of the survey results is illustrated in **Figure 3**.

Results. In **Figure 3** (a), among the **70%** of individuals who infrequently utilize the bus service, a significant proportion indicates that the bus routes pass through their residences (**52.8%**) and workplaces (**58.3%**), with **75%** having considered using the bus. The primary reasons cited for not using buses are predominantly associated with issues concerning punctuality and frequency, as buses are frequently reported as being either late or inconsistent in their schedules. Conversely, regular bus users (**30%**) exhibit distinctions in their usage patterns, primarily for commuting purposes (to schools and workplaces), leisure activities (such as visits to parks, gyms, museums, etc.), and shopping endeavors (to markets, malls, etc.). The adoption of bus transportation remains unpopular. Our

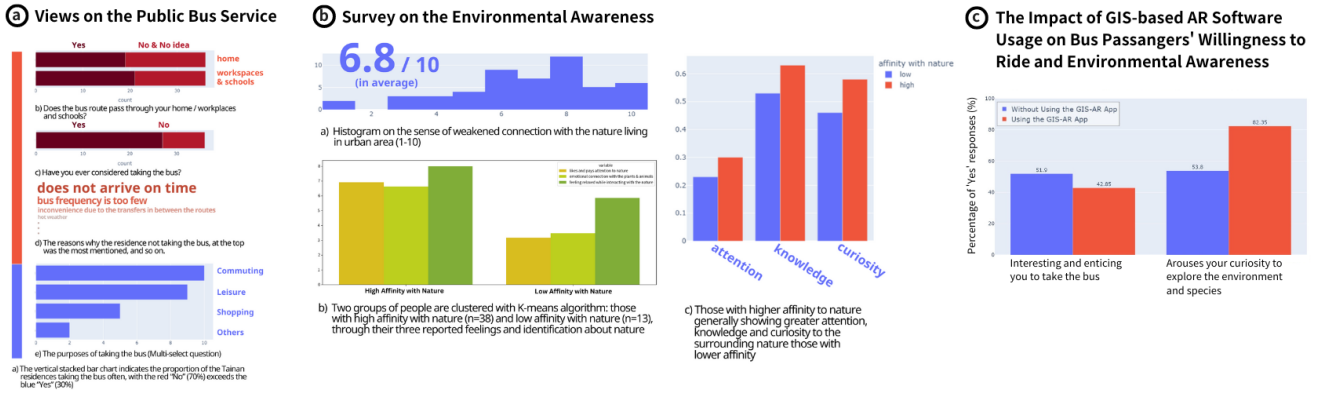

Figure 3: Survey with app test assessing (a) the user experiences with public bus transportation, (b) their environmental awareness, and (c) the impact of GIS-based AR software usage on bus riders' willingness to ride and environmental awareness.

system aims to improve the bus-riding experience, aligning with the overarching goal of promoting urban transportation.

In **Figure 3** (b), Urban residents exhibit an average perceived disconnection with nature of **6.8** out of **10**, indicating a moderate sense of diminished nature engagement in their urban living environments. Employing the K-means algorithm [6], we categorized participants into two distinct groups based on their reported feelings and identifications concerning nature, including preferences, attention, emotional connections with plants and animals, and relaxation during nature interaction. The high affinity to nature group (**n = 38**) demonstrates heightened levels of attention (noticing the changes in the local species), knowledge (recognizing local plant and animal species), and curiosity (actively seeking information about specific species) compared to the lower affinity group (**n = 13**). It supports a general demand for incorporating natural elements into urban lifestyles and highlights a positive correlation between an individual's affinity to nature and environmental awareness. It is evident that heightened environmental awareness is cultivated through increased exposure to and knowledge of nature.

Figure 3 (c) revealed that **51.90%** of residents were inclined to utilize the GIS-based AR application, citing its appeal in stimulating their interest to utilize public transportation. Surprisingly, this sentiment did not experience a discernible increase among individuals who experienced the application, with only **42.85%** expressing similar sentiments. Notably, a predominant reason cited for the reluctance to utilize public transportation pertained to concerns regarding bus frequency and punctuality mentioned above, suggesting underlying structural and administrative inadequacies within the public transit system. The evaluation succinctly demonstrates GIS-based AR's significant influence on increasing environmental curiosity among users—from only 53.8% of respondents feeling more curious without AR to a substantial rise to 82.35% with the AR application. This marked increase highlights the effectiveness of AR in fostering a deeper connection with the environment. Furthermore, it underscores the potential of GIS-based AR to not only alter urban travel habits but also enhance residents' engagement with their natural surroundings, emphasizing AR's capacity to enrich urban transport experiences and environmental awareness.

4 CONCLUSION

Our study presents GreenSpot, a mobile app that integrates AR with public transport to promote greener urban spaces and boost bus ridership. By turning bus stops into interactive hubs for virtual gardening, the app connects people with nature and enhances their travel experience. It features AR-based activities such as plant scanning and navigation, underpinned by a detailed species database and a Cluster-GCN for tailored plant recommendations during bus journeys. GreenSpot not only makes urban exploration engaging but also strengthens community bonds and environmental awareness, merging digital innovation with sustainable urban practices.

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