Baraton Interdisciplinary Research Journal (2025), 11 (2), pp 1-16
www.birj.ueab.ac.ke
ISSN:2789-3995
(Online)

Integrating GIS Into Teaching and Learning in Tertiary Institutions: Opportunities and Challenges

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Abstract

Geographic Information Systems (GIS) have transformed numerous professional fields, including urban planning, environmental management, public health, and disaster risk reduction, by enabling users to visualize, analyze, and interpret spatial data. In the context of higher education, GIS holds similar transformative potential, offering tools that can enhance teaching and learning across a wide range of disciplines. However, despite its increasing recognition as a powerful educational resource, the integration of GIS into teaching and learning in tertiary institutions remains limited. This study investigates the current extent of GIS integration into academic programs, examines faculty and student perceptions of its educational value, and identifies the opportunities and challenges faced in its implementation. The problem underpinning this research is the underutilization of GIS in higher education curricula, despite its proven ability to develop critical spatial thinking and interdisciplinary analytical skills. Many tertiary institutions face constraints such as inadequate infrastructure, limited access to software and data, insufficient faculty training, and a general lack of awareness regarding the pedagogical benefits of GIS. As a result, students often graduate with minimal exposure to spatial tools that are increasingly essential in today's data-driven and geospatially interconnected world. The justification for this study stems from the growing need to align higher education with the digital and spatial competencies required in the contemporary workforce. Integrating GIS into university curricula will not only enhance students' technical and analytical abilities but also foster inquiry-based and problem-solving approaches to learning. Moreover, such integration will support interdisciplinary teaching by bridging gaps between the natural and social sciences, thereby enriching academic programs and broadening students' career readiness. To address these concerns, the study pursues four key objectives: to explore (1) the concept of GIS (2) scalable models of GIS integration in instruction (3) opportunities and challenges in GIS adoption. (4) develop a prototype of GIS integration.

Key Words: Geographic Information Systems (GIS); Spatial Thinking; Interdisciplinary Learning, Curriculum Integration; Educational Technology; Higher education; Artificial Intelligence

ISSN:2789-3995
(Online)

Introduction

Geographic Information Systems (GIS) are emerging as transformative tools across a variety of disciplines including urban planning, public health, environmental science, and disaster risk management because of their ability to collect, visualize, and analyze spatial data (Goodchild, 2006; Sui, 2015). In the context of higher education, GIS unravels vast pedagogical opportunities, which foster an interactive and interdisciplinary approach that promotes spatial thinking, problem-solving, and digital literacy among students (Mekonnen & Zhao, 2020). Through dynamic visualizations and spatial data interpretation, GIS facilitates deeper understanding of, otherwise, complex concepts, making it a valuable asset in curriculum development across disciplines. However, in spite of the growing global awareness of its educational value, integration of GIS into tertiary institution, especially in developing countries, remains uneven and often marginalized within traditional teaching frameworks with stress on theoretical jargons. This study, therefore, explores the extent, opportunities, and challenges of integrating GIS into teaching and learning in tertiary institutions, with an attempt to develop a scalable prototype for effective curriculum integration.

Problem Statement

The concept of GIS has received wide recognition in university education through advancements of inquiry based and blended learning, and has proved to be effective in enhancing analytical and critical thinking through spatial problem-solving (Mekonnen & Zhao, 2020; Yeboah, 2022). In particular, the combined approaches to GIS, "teaching with GIS" and teaching about GIS, would potentially improve the education process, content and learning conditions, yet the integration of these approaches into higher education curricula remains low (Jakab, Ševčík & Grežo, 2017). Many universities, especially in the Global South, face systemic barriers such as lack of access to GIS infrastructure, inadequate software and datasets, limited expertise and awareness of GIS as a pedagogical tool (Oyatayo & Adeyemo, 2021). As a result, the majority of graduates in academic programs such as Environmental Science often rate below average in spatial literacy and technological skills required for related jobs and professions. This study seeks to address this educational gap by investigating the current level of GIS adoption in tertiary institutions and the structural and pedagogical constraints that hinder its effective integration into teaching and learning processes.

Justification of the Study

According to UNESCO (2022) There is a growing demand for education systems that respond to 21st-century challenges that require the integration of digital and spatial competencies into learning. As labor markets continue to prioritize data analysis, geospatial literacy, and interdisciplinary collaboration, integrating GIS into university curricula is definitely a strategic imperative (Baker et al.,

Baraton Interdisciplinary Research Journal (2025), 11 (2), pp 1-16
www.birj.ueab.ac.ke
ISSN:2789-3995 (Online)

2015). Furthermore, there is need to align higher education with these workforce demands and to create engaging, inquiry-based learning environments that promote student-centered learning. The integration of GIS in the curriculum helps students to solve authentic problems using professional systems (such as GIS, GPS, WMS, DBMS) and real data. These modern methods of processing and analyzing data are in demand in real work situations. There is need for graduates who have acquired disciplinary subject knowledge and skills that are market driven. As such, the insights gained from this research will help stakeholders to understand the pedagogical value of GIS and inform policies that support its broader integration into academic programs.

Significance of Study

The findings of this study will be significant to multiple stakeholders. For educators and curriculum developers, it will provide actionable insights into best practices for GIS integration and interdisciplinary teaching. For higher education institutions, the study will highlight the infrastructural, pedagogical, and technological investments needed to realize the potential of GIS in enhancing student learning outcomes. Moreover, students stand to benefit directly from improved exposure to spatial technologies, which are vital for careers in urban planning, environmental studies, public health, and beyond (Goodchild, 2006). As observed by Griffins (cited by Jakab, Ševčík, & Grežo, 2017); the integration of GIS will empower students to learn as researchers, involved in inquiry-based activities. Additionally, policymakers can utilize the results to support digital transformation initiatives in education, thus, fostering innovation and capacity building in tertiary institutions.

Theoretical Framework

This study is grounded in the Constructivist Learning Theory, which posits that learning is not a passive absorption of information. Learners construct knowledge through their daily experiences and reflection as they interact with their environments (Piaget, 1971; Vygotsky, 1978). GIS tools support this paradigm by offering interactive, real-world scenarios that stimulate exploration, hypothesis testing, and problem-solving. Experiential Learning Theory (Kolb, 1984) also helps to explain how GIS transforms the educational process, making it more practical. The emphasis in this theoretical framework is learning by doing, a pedagogical approach that GIS technologies naturally support. Together, these theories provide a robust foundation for examining how GIS can transform learning experiences and foster deep, interdisciplinary engagement in tertiary education.

Literature Review

The Concept, History, Development, and Educational Relevance of GIS

Geographic Information System (GIS) is a coordinated combination of specialized software, computer hardware, geographic data, and skilled personnel that enables the collection, manipulation, analysis, and presentation of location-based information

Baraton Interdisciplinary Research Journal (2025), 11 (2), pp 1-16
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ISSN:2789-3995 (Online)

tied to specific points on Earth's surface. This integrated system comprises of software, hardware, data, and the skilled people operating it, make it realistic to transform raw spatial data into meaningful insights. As a result, the origin of GIS can be traced back to 1854 when Dr. John Snow mapped and analyzed the spread of cholera outbreak in London, England, establishing the foundation for the use of spatial analysis to address public health challenges. He carried out a spatial mapping of outbreak locations, roads, and property boundaries; and discovered that the affected areas were along the water lines. Paper maps dominated until the 1964-1975 era, when there was a shift to computer mapping marked by utilization of mainframes, minicomputers; and proprietary software and data structures. Between 1980s to 1990s additional features such as Geo-relational data structures, Graphical users' interface and new data acquisition technologies like GPS, and Remote sensing emerged. From mid 1990s to the present the GIS technical environment is more complex with emergence of workstations and PCs, network/Internet, open system design, multimedia, data Integration components, enterprise Computing and object relational data model. Its' major applications areas are in resource management, census, surveying and mapping, facilities management, market analysis, utilities, and geographic data browsing (Ali, 2020).

Geographic Information Systems (GIS) have increasingly become essential tools in understanding spatial phenomena and decision-making across various domains. In the context of education, GIS fosters spatial thinking, inquiry-based learning, and multidisciplinary exploration (Bednarz, 2020). Educators have acknowledged that the integration of GIS into the curriculum enhances learners' ability to visualize, analyze, and interpret spatial data (Lee & Bednarz, 2019). As students engage with geospatial technologies, they build as well as strengthen their problem-solving and analytical abilities hence enabling them to better comprehend complex and complicated issues at both global and local, (Fargher, 2021). The growing focus on geoliteracy has motivated curriculum developers to incorporate GIS as a connection between theoretical learning and practical, real-world applications, (Favier & Van der Schee, 2020). In urban planning, GIS is frequently used to visualize zoning laws, model transportation systems, forecast patterns of urban growth as well as in architecture as it supports site analysis and urban design by combining physical, social, and environmental data layers, (Al-Kodmany, 2012). In the medical and health sciences, GIS plays a key role in tracking disease outbreaks, planning healthcare delivery, and assessing environmental health related risks. For instance, students might use GIS to examine the spatial spread of malaria or to map vaccination coverage in rural areas of Kenya, (Mwaniki & Makokha, 2018).

Scalable Models of GIS Integration into Instruction

The ability to scale GIS integration in education largely depends on the availability of intuitive platforms and level of institutional support. Cloud based platforms such as

Baraton Interdisciplinary Research Journal (2025), 11 (2), pp 1-16
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ISSN:2789-3995 (Online)

ArcGIS online, along with open-source option like QGIS, have made it possible to implement GIS effectively and efficiently a cross a wide range of learning environments, (Sinton, 2021). Educators have adopted different instructional models such as project-based learning, flipped classrooms featuring GIS activities, and embedded modules within geography and science curricula, (Milson & Kerski, 2020). Adaptable component-based GIS tools which combines mobile GPS devices with spatial data platform, offers versatile pathways for incorporating GIS into various teaching contexts, (Wikle & Fraizer, 2022). These scalable strategies enable GIS education to thrive even in institutions with limited technical resources which makes GIS to be well-established particularly in geography and environmental science programs, where students use it to map ecosystem, track land-use changes evaluate environmental impacts, and analyze climate change trends. For instance, GIS can be employed to monitor deforestation in the Congo Basin or to study patterns of urban expansion in Nairobi, (Nyakundi et al., 2021).

Opportunities and Challenges in GIS Adoption within Tertiary Institutions

The adoption of Geographic Information Systems (GIS) in tertiary education opens up valuable opportunities, such as fostering spatial literacy, promoting interdisciplinary learning, and enhancing graduates' employability as it allows universities to design innovative programs that align with labor market demands in areas like urban planning, environmental science, and analytics, (Yin, 2021).It allows universities to design innovative programs that align with labor market demands in areas such as urban planning, environmental science, and data analytics. Despite these benefits, uptake remains limited due to barriers like high licensing costs, shortage of skilled personnel, and low awareness of educational values of GIS, (Demirci, 2019). Research further points to infrastructure deficits and the absence of localized teaching materials as ongoing challenges, (Jo Hong & Verma, 2022). Addressing these issues requires targeted investment in professional training, curriculum development, and affordable access to software. In Tanzania, for example, poor infrastructure, restricted software availability, and lack of qualified personnels hinders widespread of GIS adoption; however, supportive national ICT policies and the expansion of mobile technologies offer promising avenues for growth, (Sumari et al., 2017). Likewise, in South Africa and Zimbabwe, GIS is increasingly incorporated into urban planning, education, and municipal operations, but challenges such as inadequate funding, outdated course content, and weak institutional coordination continues to slow down progress, (Musakwa, 2017). These regional experiences illustrate the interplay between opportunities and challenges in implementing GIS in universities education.

Prototype Model Development for GIS Integration

Creating a prototype model for GIS integration involves the integration of technology, pedagogy, and content. Research has shown that effective prototypes include intuitive GIS interfaces, real-time data

ISSN:2789-3995
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sources, and problem-based learning modules that reflect local contexts (Gilmartin & Hall, 2021). A successful model is recursive, built upon user feedback, and adaptable across disciplines. For instance, configurable GIS integration tools incorporating mobile GPS, ArcGIS dashboards, and open-source datasets have demonstrated improved student engagement and comprehension in earth science and geography education (Wikle & Frazier, 2022). Designing such prototypes also supports long-term institutional capacity building and sustainable GIS instruction. San Diego State University has a center for Human Dynamics for the Mobile Age. Within this center, the University hosts the Metabolism of Cities Living Lab. The MOC-LLAB "represents a collaboration between instructors, students, and other partners to bring sustainable development to vulnerable communities. GIS tools such as ArcGIS Dashboards and ArcGIS Survey123 are often critical to these projects, allowing students and project leaders to understand the communities they're working with. The goal is to create targeted solutions to local problems through a global lens". In Finland, the national mobile learning innovation PaikkaOppi offers a browser-based GIS environment accessible via Android and iOS. It enables students across primary to upper secondary levels to collect, analyze, and share spatial data collaboratively, promoting inquiry-based, problem-based learning tied to national curricula. The platform integrates mobile GPS, open GIS datasets, and intuitive interfaces in real-time, enabling teachers to design discipline-spanning activities (e.g. geography, environmental science). The model is recursive and feedback-oriented: educators adjust the design over multiple cycles, adapting modules to local contexts (e.g. mapping school gardens, environmental issues), supporting both learner engagement and long-term institutional capacity building (M-learning Finland, 2025).

Methodology

Research methodology is the *systematic and theoretical framework* that guides a study's overall approach, including how data is collected, analyzed, and interpreted, and why specific methods are chosen over others (Grad Coach, 2025). This study will employ an experimental design, specifically, quasi-experimental.

Ethical Considerations

As the proposed GIS-integrated AI model is still under development, the research anticipates several key ethical considerations that will be addressed proactively before the tool is piloted or deployed. First, any future engagement with students, educators, or institutions will require formal ethical clearance from an accredited ethics review board. Informed consent will be a foundational requirement, ensuring that all participants are fully aware of the research objectives, data collection procedures, and their right to withdraw without any negative consequence.

Another key consideration in developing the model is the safeguard of data privacy and security where student behavior, location details, or video interaction logs are involved, and robust measures will be in place to anonymize sensitive information and to

ISSN:2789-3995
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protect individual identities. Any geolocation or live video data will be encrypted and stored in full compliance with both institutional guidelines and national data protection regulations. The incorporation of AI-driven insights will also demand strong oversight to prevent bias, misrepresentation, or the reinforcement of educational inequalities. To address this, the research team will ensure that all AI-driven outputs remain transparent, interpretable, and subject to human evaluation before informing teaching pedagogies. Participants will also be informed that the system may adapt over time as the algorithm learns, making continuous monitoring and refinement as essential part of its development cycle.

The GIS Integrated Technology Prototype

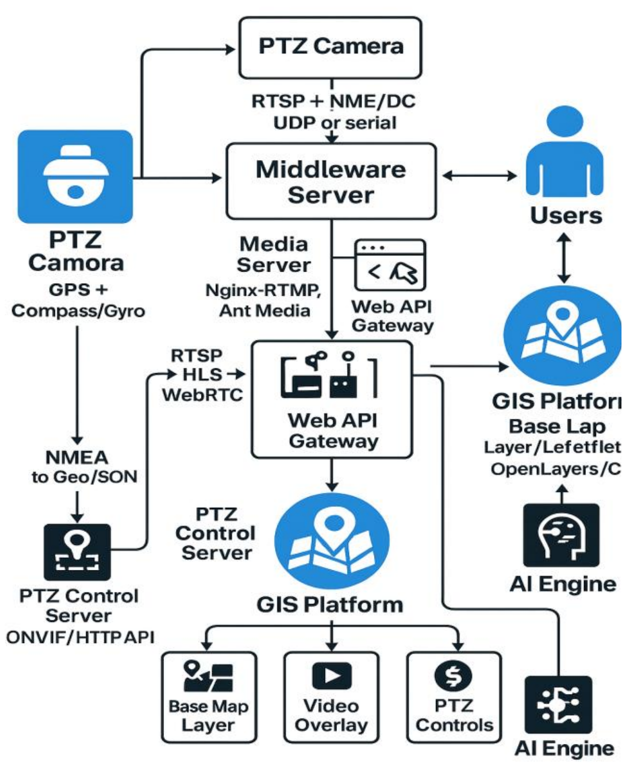

Figure 1: The GIS Integrated Technology Prototype

Each component of the prototype performs a specific and essential function in delivering real-time GIS enabled video analysis. The PTZ (Pan-Tilt-Zoom) camera serves as the central device for capturing both video and spatial data. Its ability to adjust direction remotely and zoom optically makes it well suited for applications such as environmental surveillance and interactive teaching, (Qiu et al., 2023). This camera also produces NMEA GPS data hence providing live geographic coordinates and orientation that are important for accurate location-based interpretation, (Rao & Li, 2022). The network server operates as a middleware layer, managing the transfer of data, organizing video streams, and handling multiple client requests which is a key requirement for real-time delivery and scalability, (Chen et al., 2023). A media server such as Ffmpeg or NGIN, transforms the camera's RTSP (Real-Time Steaming Protocol) feeds into HLS (HTTP Live Streaming) or WebRTC (Web Real-Time Communication) format which works smoothly across most web browsers and mobile platforms, ensuring broad accessibility and low delay, or low latency (Wang et al., 2024). The GeoJSON, process reformats GPS data into structure that GIS mapping system can easily read hence allowing for seamless integration with spatial visualization tool, (Esri, 2023). Finally, the perse-to-browser-format module, often implemented through python-based GPS parsers which converts unprocessed data into organized formats that are essential for synchronized display and clear visualization, (Kumar & Singh, 2023).

At the frontend, the GIS Platform displays video overlays, map data, and camera controls, allowing users to interactively explore real-world locations in educational or surveillance contexts (Goodchild et al., 2022). The subcomponents Base Map, Video Overlay, and PTZ Controls support spatial awareness, real-time visual feedback, and interactivity, fostering an immersive learning experience. These integrated tools reflect the need for scalable, modular, and real-time educational GIS technologies.

Components of the Integrated GIS Technology Prototype and how it Works/Functions

The PTZ Camera (Pan-Tilt-Zoom Camera) serves as the foundational hardware of the system, capable of capturing high-resolution live video while physically rotating (pan), adjusting its vertical view (tilt), and zooming in or out to focus on objects of interest. This camera is typically mounted at a strategic vantage point (e.g., on a rooftop or pole) and is powered either through PoE (Power over Ethernet) or a power adapter. Along with video, the camera continuously emits NMEA GPS Data (National Marine Electronics Association Global Positioning System Data), which includes live information about the camera's latitude, longitude, speed, direction (heading/yaw), and sometimes compass orientation, all of which are essential for spatial referencing. The camera streams its video using RTSP (Real-Time Streaming Protocol), a standard used for low-latency video transmission across IP networks. This stream, along with the GPS output, is received by a Network Server, which functions as the central middleware and processing hub that facilitates communication between the camera and other system components.

On the Network Server, two processes begin simultaneously. First, the RTSP (Real-Time Streaming Protocol) feeds are directed to a media server such as Ffmpeg or NGINX with the RTMP module (Real-Time Messaging Protocol) which converts the raw video into format that work seamlessly in modern browsers, specifically HLS (HTTP Live Streaming) and WebRTC (Web Real-Time Communication). HLS divides the video into small segments and delivers them over HTTP, making it widely compatible with browsers and mobile devices, while WebRTC enables low-latency, real-time video transmission, which is ideal for interactive applications like live teaching or surveillance. Meanwhile, the NMEA (National Marine Electronic Association) GPS data is processed by GIS parser, often implemented in python with libraries such as pynmea2. This parser extracts key geospatial details such as latitude, longitude, timestamp, and heading from the raw GPS strings and converts them into GeoJSON (Geographic JavaScript Object Notation), a widely accepted format for representing geographic data that can be displayed in mapping and GIS platform.

The processed video which is now in HLS (HTTP Live Streaming) or WebRTC (Web Real-Time Communication) format, and the converted location data in GeoJSON (Geographic JavaScript Object Notation) are then sent to the GIS (Geographic Information System) platform, which acts as the main interface for users which is often developed

Baraton Interdisciplinary Research Journal (2025), 11 (2), pp 1-16
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ISSN:2789-3995 (Online)

with mapping libraries such as Leaflet, OpenLayers, or CesiumJS, incorporates multiple interactive layers. At its foundation is the base map, which offers the geographic environment, displaying elements like satellite imagery, terrain features, or street-level views to provide spatial context. Next, a Video Overlay is embedded into the GIS interface using standard HTML5 or WebRTC video components, allowing users to view the live feed directly on the map. The exact position of the camera, based on the incoming GPS data, is pinpointed dynamically on the map and updated in real-time. Users can also interact with PTZ Controls embedded in the GIS interface, which send ONVIF (Open Network Video Interface Forum) commands or HTTP API calls back to the PTZ camera via the network server, allowing remote manipulation of the camera's position and zoom level based on map inputs (e.g., clicking on a feature to zoom in).

These controls make the system highly interactive and exploratory users can explore real-world geographic features, zoom into specific locations, and track changes visually in real time. The "Parse to Browser Format" module (which includes both media transcoding and GPS data parsing) ensures all outputs from the hardware are compatible with the GIS frontend. Importantly, the modular design of the prototype ensures each component the camera, media server, GPS parser, GIS frontend, and PTZ controller can be upgraded, replaced, or scaled independently without affecting the entire system. This makes it ideal for education, research, smart monitoring, and fieldwork. Additionally, for scalability and user access, the prototype includes User Authentication, Firewall Security, and optional Cloud Storage or Archiving Modules to store footage and geolocation logs for future analysis. Every component in this prototype connects in a logical and functional workflow, forming a complete, real-time geospatial visualization and learning tool.

Model Considered and Features Adopted

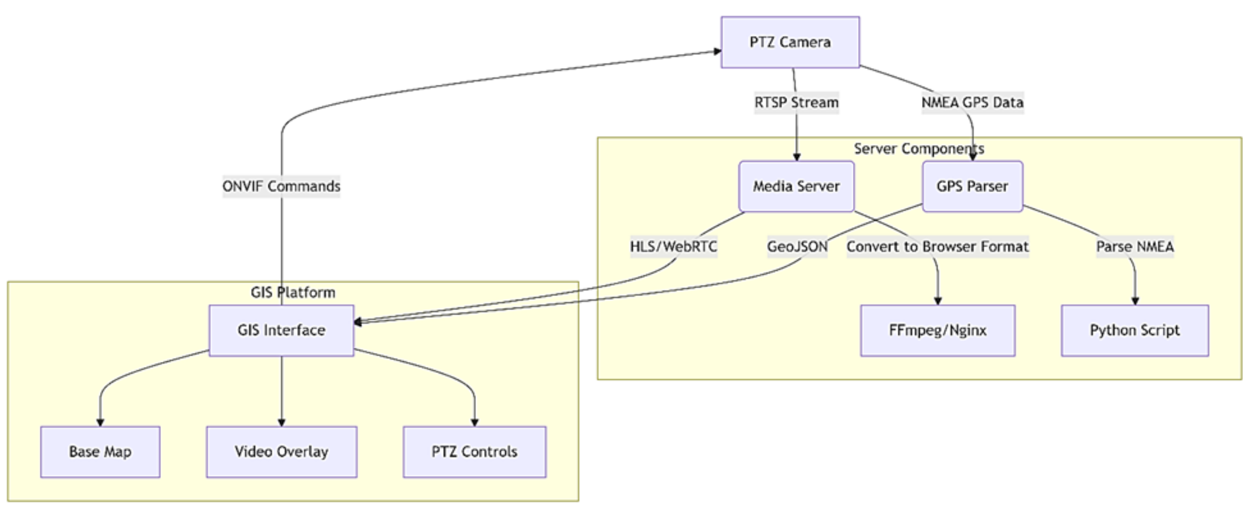

Figure 2: GIS Integration Technology Flowchart Model

Based on the architecture illustrated in the flowchart, the integrated GIS model incorporates several key features that enable real-time, interactive, and location-aware learning or surveillance. These features align well with modern GIS and smart video applications, particularly in education, environmental monitoring, and campus management.

Key Features Adopted in the Model

This integrated system supports real-time video streaming, enabled by a PTZ (Pan-Tilt-Zoom) camera and a media server, where live video is captured via RTSP (Real-Time Streaming Protocol) and converted into browser-friendly formats like HLS (HTTP Live Streaming) or WebRTC (Web Real-Time Communication) for seamless visualization on the GIS platform allowing real-world observation directly on a digital map interface. The PTZ camera control is managed through ONVIF (Open Network Video Interface Forum) commands sent from the GIS interface, enabling users to remotely pan, tilt, and zoom the camera interactively, supporting exploratory learning or centralized monitoring. GIS- based location integration works by using NMEA (National Electronic Association) GPS data, which is processed through a GPS parser which is often implemented as a Python script and then converted into GeoJSON (Geographic JavaScript Object Notation). This formatted data updates the camera's live position on the map, providing precise spatial accuracy and enabling automated, real-time tracking. The GIS interface includes three main components: a base map for geographic context, video overlay for embedding the live feed, and PTZ controls as a user interface element for camera manipulation forming a powerful spatial dashboard. The server-side middleware incorporates tools like Ffmpeg of Nginx to convert RTSP streams into HLS (HTTP Live Streaming) or WebRTC (Web Real-Time Communication) formats, along with Python-based scripts that process GPS data into map-compatible formats. This approach ensures scalability, broad compatibility, and secure data transmission. By standardizing format conversion, that is, from RTSP to HLS/WebRTC for video and NMEA to GeoJSON for location data, the system remains platform-independent and accessible on modern devices. Its modular, scalable architecture allows each component, from the camera to the GIS platform to operate independently while seamlessly integrating through APIs and standardized data protocols, making upgrades and maintenance straight forward. Beyond its technical strengths, the system is versatile enough for use in environmental field research, interactive classroom teaching, campus security, and urban planning simulations, highlighting its adaptability and value in educational and professional settings.

How the Model Functions

The system follows a clear, step-by-step process that begins with video and GPS capture, where the PTZ (Pan-Tilt-Zoom) camera records live video while

ISSN:2789-3995
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simultaneously transmitting NMEA (National Marine Electronic Association) GPS data. In the streaming and parsing phase, the video feed is sent via RTSP (Real-Time Streaming Protocol) to a media server, which converts it into browser-friendly formats such as HLS (HTTP Live Streaming) or Web RTC (Web Real-Time Communication). At the same time, the NMEA GPS data is directed to a GPS parser, which processes it into a GIS-compatible format like GeoJSON (Geographic JavaScript Object Notation). During the data routing to the GIS platform stage, the converted location data and the processed video stream are combined within the GIS platform, enabling the live camera feed to be precisely positioned on the digital map. In the user interaction phase, viewers can navigate different areas through the map, and any PTZ commands such as pan, tilt, or zoom, are sent from the GIS platform back to the camera using ONVIF (Open Network Video Interface Forum) protocol, creating a smooth, interactive feedback loop between the user and the system.

Educational Relevance

This integrated model directly supports the objectives of the article by enabling real-time spatial learning, where students can observe and engage with live environments mapped geographically, enhancing their understanding of spatial relationships. It offers an interactive GIS-based prototype that merges real-time video and GPS data into a map interface, making it highly suitable for both field-based and remote instruction scenarios. The model's modular design comprising independent components like the PTZ camera, middleware server, and GIS platform ensures scalability and adaptability for classroom or institutional deployment. Moreover, by combining GPS geolocation, digital mapping, and live video streaming, the system significantly enhances learners' geospatial reasoning and deepens their ability to analyze and interpret spatial data in real-world contexts.

"Integrating GIS into Teaching and Learning in Tertiary Institutions: Opportunities and Challenges"

Opportunities

Integrating PTZ (Pan-Tilt-Zoom) cameras, live GPS data, and interactive GIS platforms greatly enriches real-time learning by promoting spatial awareness and a deeper understanding of real-world settings. At the centre of this setup are middleware servers namely media servers for converting video streams and GPS parsers for processing geolocation data which ensure cross-platform compatibility and support scalability across various devices. The prototype modular design with standalone components for video processing, GPS data handling, and GIS-based visualization, offers flexibility, simplified maintenance, and room for future upgrades. Embedding interactive PTZ controls within the GIS interface enables both students and educators to actively explore, observe, and participate in inquiry-driven learning, making it especially valuable in fields like geography, disaster response, and urban development. Nonetheless, the successful integration of this technology in higher education depends largely on institutional preparedness, including robust infrastructure, reliable

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www.birj.ueab.ac.ke
ISSN:2789-3995 (Online)

technical support, and thorough training for instructors.

Challenges

Implementing this prototype that integrate GIS with PTZ (Pan-Tilt-Zoom) camera system for live video capture, brings a range of challenges spanning from technical, operational, and educational aspects. Technically, streaming real-time video can be affected by network delays and bandwidth constraints while compatibility issues may arise when converting NMEA (National Marine Electronics Association) GPS data into GeoJSON, as formatting can differ between camera models. The integration process is complex, requiring the coordination of multiple components such as ONVIF-based PTZ controls, GPS parsers, media servers, and GIS platforms. Hardware-related challenges, including inconsistent GPS precision or limited ONVIF support, can reduce system capabilities, and achieving perfect synchronization between video streams and location tracking in real time is an elaborate task. Security and privacy vulnerabilities also surface if video feeds or control mechanisms lack proper authentication, or if live geolocation data is mismanaged. From operational perspective, the system must be capable of scaling for multiple concurrent users, which demands powerful servers or content delivery network (CDNs), while ongoing maintenance, updates, and stable connectivity particularly in remote settings, it require skilled technical support and reliable infrastructure. Educationally, adoption may be slowed by limited digital skills among educators and students, budget constraints for advanced GIS and camera technologies, and ethical considerations when leveraging AI for content interpretation, as this can inadvertently introduce bias or deepen existing inequalities in access to learning tools.

Conclusions and Recommendations

Integrating Geographic Information Systems (GIS) into higher education offers considerable potential, especially in strengthening spatial literacy, encouraging cross-disciplinary learning, and ensuring that academic programs equip graduates with the digital and analytical skills sought in today's job market. GIS enables creative, inquiry-driven teaching methods that enhances student engagement and critical problem-solving. Despite these advantages, adoption on a broader scale is still limited by notable obstacles. Common barriers include poor infrastructure, such as insufficient access to reliable software, hardware, and internet services; a lack of trained educators and technical specialists; and the high licensing costs of commercial GIS platforms. Moreover, limited awareness of GIS's instructional benefits and the absence of locally relevant teaching materials continue to slow effective use. Unlocking the full potential of GIS in higher education will require deliberate investment in faculty training, the adoption of open-source tools, the development of context-specific curricula, and stronger institutional support system.

For successful and effective adoption of a GIS- integrated PTZ system, institutions should first roll it out in field-oriented programs such as geography and urban planning, where its impact can be most immediate. Building capacity among educators and technical staff through targeted training is vital for developing competence in GIS operation a-nd data analysis. Leveraging open-source or cloud-based solutions like QGIS can help lower upfront expenses, while launching pilot projects offers a practical way to test the system and make improvements before full deployment. A dedicated team should manage system upkeep and infrastructure reliability, and GIS-related content should be embedded directly into coursework to ensure its practical value. To secure the system's long-term viability, institutions should incorporate it into budget forecasts, establishing clear policies, and align it with broader digital transformation strategies.

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