An Educational Approach for Mixed Reality Visualization of Agro-meteorological Parameters

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***Abstract*—This paper proposes an innovative system to visualize real-time agro-meteorological parameters on real trees in a mixed reality (MR) environment. It uses Vuforia area targets which are identified and tracked using the Microsoft Hololens 2 MR headset and geographic coordinates to precisely track and place virtual content on the trees. The proposed system provides an immersive and interactive way to visualize weather station data in a natural environment, using real trees as markers to display real-time data. This allows users to quickly identify changes in weather conditions, making informed decisions in real-time. We evaluated the system by developing a proof-of-concept MR application that showcases the potential of using trees as Vuforia Area Targets (VATs) with geographic coordinates for displaying weather station parameters. The application allows users to explore an urban park and learn about real trees and their environmental conditions in an interactive and engaging manner. The proposed system is a serious game supporting living labs and educational purposes.**

***Index Terms*—Mixed Reality, Precision Agriculture, Plants, Sensors, Serious Game**

I. Introduction

The use of augmented and MR technologies has seen significant growth in recent years, with a range of applications in various fields such as education [1], [2], entertainment [3]–[5], and marketing [6]. In this paper, we propose a novel approach to utilizing MR technology for visualizing weather station parameters in real-time on real trees. The visualization of weather data is of critical importance in various fields such as agriculture, environmental monitoring, and urban planning. However, traditional methods of displaying weather data such as charts and graphs can be difficult to interpret and understand for non-experts. Through the MR technology, we aim to provide an intuitive and visually appealing way of displaying the data, making it accessible to a wide range of users [7], [8]. Since MR and precision agriculture are both enabling technologies of industry 4.0, their synergy takes an innovative focus on data visualization [9]. Our proposed system uses VATs and geographic coordinates to identify and track the real trees as targets for the MR application. It was developed for the Microsoft HoloLens 2, a wearable MR device that allows users to interact with digital content overlaid in the physical environment. This approach allows for the accurate placement of virtual content relative to the physical tree in the MR environment, providing an immersive and interactive way of visualizing the agro-meteorological parameters. The system displays weather station data such as temperature, rain, humidity, wind speed, wind direction, solar radiation, and UV radiation on the trees in real-time. This allows users to quickly identify changes in weather conditions, enabling them to make informed decisions in real-time. We evaluate the proposed system by developing a proof-of-concept MR application that showcases the potential of using plants as VATs with geographic coordinates. This feature enables the user to track augmented areas and spaces, by using 3D scan to generate an accurate model of the space and create an area target device database. It is possible to use this database to provide augmented/mixed information on stationary objects such as trees in the scanned environment. In this way, it is possible to use spatial information as interactive and trigger elements in data visualization.

The application allows users to explore a park and learn about weather conditions and their effects on the surrounding environment. Our plant scenario consists of an olive tree (*Olea Europea*) placed in the experimental garden located in the "Sassi of Matera", specifically in the garden of the municipal building intended as House of Emerging Technologies of Matera, a center for technology transfer at the forefront in Italy. The garden contains a set of sensors integrated into a weather station named Davis Wireless Vantage Pro2 Plus. The sensors are configured and integrated through wireless sensors that consist of a soil moisture sensor placed on the ground and a leaf wetness sensor placed on the olive tree. We proposed this system as a serious game considering the following benefits:

- Interactive and engaging learning: The MR application provides an immersive and interactive way for students to learn about weather data and its effects on trees.
- Real-time data visualization: The system provides real-time visualization of weather data on a tree, allowing students to see the effects of different weather conditions

on the tree.

- Accessible to a wider range of learners: The MR application is visually appealing and easy to use, making it accessible to a wider range of learners.
- Living lab tool: The proposed system can be used as a living lab tool for the visualization of weather data, providing an opportunity for students to conduct experiments and collect data in a real-world setting.

The results of this research demonstrate the potential of using MR technology to visualize weather station parameters in real-time on a plant. The system provides an intuitive and visually appealing way of displaying weather data, making it accessible to a wider range of users. The system's serious game application offers an engaging and interactive way for users to learn about weather data and its effects on plant growth, while the educational tool application offers a living lab tool for the visualization of weather data.

II. Related Work

The advent of Industry 4.0 has produced significant technological developments in various sectors, including agriculture. Precision agriculture and mixed reality technologies are two such developments that are transforming the way agro-meteorological data is visualized and utilized.

Precision agriculture is a data-driven approach to agriculture that involves the use of advanced technologies such as GPS, sensors, and drones to monitor and analyze various agricultural parameters with the aim of identifying and applying management strategies that are highly effective in terms of both economic and productive aspects, as well as environmental sustainability [10]. In the last years, due to the recent developments in the field of Information and Communication Technologies, precision agriculture has been supported by MR technologies, which have been used to visualize and analyze various agricultural parameters due to their ability to blend real and virtual worlds to create a new environment where physical and digital objects coexist and interact in real-time. These applications are generally related to the recognition and identification of parasites [11], [12], the observation of soil and vegetation [13], and environmental monitoring [14]. For example, Zhao et al. [15] proposed an Augmented Reality (AR) application to help dairy farmers identify and locate animals with large herds while grazing. Ponnusamy and Natarajan [16] identified five use cases of AR in precision agriculture, including access to meteorological, soil, and vegetation information. Alj et al. [17] proposed a mixed reality intelligent agriculture application capable of monitoring plant moisture and weather conditions to create an intelligent irrigation system, useful both agronomically and for training activities. In general, regardless of the operation to be performed, the ability to visualize information in a more intuitive way makes the work of farmers and technicians/researchers more efficient. The availability of interactive monitoring and decision support systems can generate various benefits, both in terms of production and environmental optimization, optimizing the relationship between crop inputs and output. To determine the greatest benefit in the agricultural sector, AR technologies must be coupled with other technologies such as sensors [18], artificial intelligence systems [19], next-generation radio mobile systems [20], GIS systems [21], etc. Currently, from the systematic review conducted in this study, scientific production in the sector still appears to be limited. However, the greatest difficulties in the diffusion of these systems appear to be related to strong cultural resistance - production traditions, entrepreneurs' habits, excessive simplification of agriculture, limits related to production regulations, etc. - and the limited skills of operators in the sector. Therefore, it is essential to develop educational systems for information and training [22], [23]. One of the greatest limits to the spread of new technologies for agriculture and urban greenery lies in the poor education of various stakeholders [24]. From a pedagogical point of view, research has shown that project-based team learning (collaborative) is one of the best systems to respond to the educational challenges of new generations [25], [26]. With the continuous progress of technology, AR systems have become increasingly popular in education and training, thanks to their ability to offer an immersive and engaging experience for students. Agriculture and urban greenery are two areas of particular interest for the application of AR systems in education. D. Loukatos et al. [27] propose a mixed reality approach capable of enriching the education paradigm in the field of agricultural engineering by prototyping a robotic arm for fruit picking. Tangworakitthaworn et al. [28] propose two serious games for advanced learning in agricultural engineering. Students are asked to complete the different levels of the game by monitoring plants and their health status and establishing care methods. The completion of each level is linked to the monitoring of the plant's growth rate through the comparison of photographic shots taken at different times. In 2021, Wang et al. [29] proposed a somatosensory interactive system based on computer vision and AR techniques for food education and agriculture. In this field, the use of AR systems can allow students to interactively explore concepts and techniques related to crop cultivation and management. Thanks to AR, students can visualize in real-time the variations in environmental conditions and assess their effects on crops. In general, AR makes it possible to offer an immersive and engaging experience that can enhance the educational process.

III. Materials and Methods

Our proposed MR system is based on VATs to track and use a real environment as a marker to recognize and integrate virtual components. VATs is a feature based on a 3D scan of a static environment, called Area Target Database (ATD), used as a marker that can be utilized for tracking and augmenting the real space. The ATD comprises a collection of dataset files, textures, materials, and meshes, that are necessary for the tracking of the area target. Furthermore, the files are packaged in a Unity game engine package to simplify their import into its editor. The simplest and fastest approach to make good quality scans is to employ ARKit-enabled devices featuring built-in LiDAR sensors (*e.g.,* Apple iPad Pro) with the Vuforia Creator App installed. It is a robust application that simplifies the process of scanning the environment, creating the ATD, and verifying the accuracy of the scan in relation to the real environment. With this method the quality of the scan is low, but its features and spatial characteristics are still trackable and crucial for rendering virtual objects within the real environment. The Unity package of the ATD created can be loaded in a Unity editor project with Vuforia package pre-imported. After the creation of the areaTarget gameObject that contains the ATD imported, a model preview is shown in the Unity 3D scene. The other 3D content to track in the app, can be added as a child to the areaTarget gameObject and can be positioned and sized in relation to the preview model.

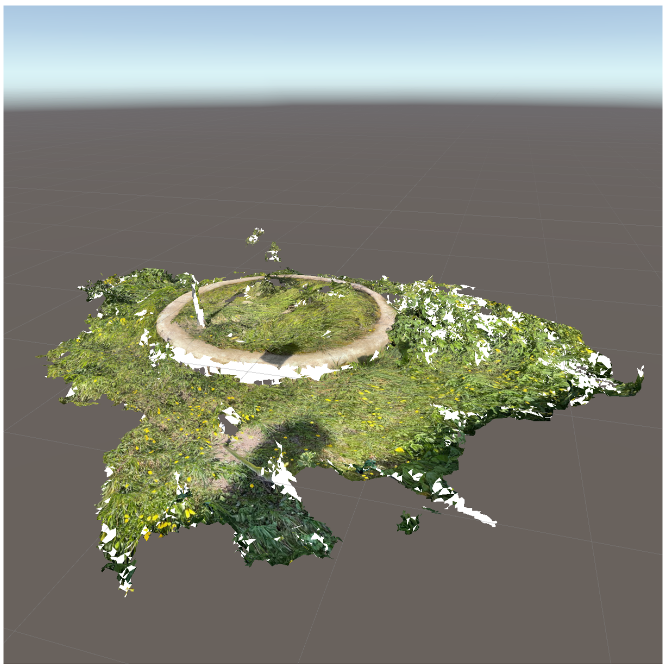

Fig. 1: The model preview of the generated Area Target Database in Unity Editor.

As mentioned in Section I, an olive tree in the experimental garden in the House of Emerging Technologies of Matera (see Figure 4) was selected for this purpose. Figure 1 shows the model preview of the generated area target. The absence of the olive tree is notable, due to its small size. This was resolved by reconstructing with photogrammetry and integrating it as virtual content in the area target. In this context, creating a detectable and trackable area target of an outdoor environment is a challenge due to various external factors, such as daylight and seasonal changes, shadows, and vegetation growth. Vuforia recommends georeferencing the area target, using the geolocation provided by GPS as an external prior to enhancing environment detection and tracking. Another problem was the Hololens 2 has no GPS sensors built-in because it was thought to be employed in indoor environments. To georeference the Hololens 2, one option is establishing a bluetooth connection with external devices (such as smartphones) and retrieving location information. Another option is connecting the Hololens 2 to a WiFi router to estimate its latitude and longitude without utilizing bluetooth communication. The UWP *Windows.Devices.Geolocation Namespace* is the library that provides this feature. Furthermore, Microsoft's *Mixed Reality Feature Tool* is an essential component for developing in Unity for Hololens 2, as it contains all the required functionalities for this purpose.

Figure 2 shows the architecture of our system based on three essential parts: a sensor side which consists of the weather station, its sensors, and an edge device; the cloud server and storage side, and the application side. The weather station collects data every minute from its sensors using a nearby connected edge device. This edge device can be a data logger or a PC connected via WiFi within a radius of no more than 300 meters from the weather station. Data are stored in a cloud server using a simple database and through a properly configured webserver that allows data access through HTTP requests based on the RESTFUL architectural style. The application side consists of an edge device which is a simple smartphone (Samsung Galaxy S22 plus) with a mobile data connection used as a hotspot and the Hololens 2 as a WiFi-connected device. Our MR application is installed and executed on the Hololens 2 which retrieves data from the cloud server using the connection shared by the edge device. Since Hololens 2 is not equipped with a GPS sensor, we used the coordinates provided by the edge device to improve the tracking of the VAT and obtain a more accurate overlapping of the virtual objects on the area target represented by the olive tree. To arrange the HTTP requests we used the *UnityWebRequest* plugin and query the server cloud to retrieve weather station data in JSON messages format. These latter were parsed using the *JsonUtility* of the Unity game engine. To ensure a high level of accuracy in the overlapping of virtual objects on the area target, we scanned the trunk of the olive tree using the camera of the earlier-mentioned smartphone as a set of unsorted photos. In this way, we reconstructed a 3D representation of the olive trunk using photogrammetry through the Reality Capture software (Figure 3). The reconstructed trunk was placed at the corresponding olive tree location of the ATD. In subsequent steps, we refined the position, orientation, and size of the 3D trunk to make it perfectly match the real trunk of the olive tree. Furthermore, as explained in Section IV, the trunk is also affected by some agro-meteorological parameters, and for this reason, we change the color of the diffuse material according to the values of these parameters.

IV. The Mixed Reality System

To visualize and interact with the virtual mixed with the real environment, the proposed application must be used close to the olive tree location (see Figure 4). The GPS location of the edge device shared with the Holoens 2 worn by the user triggers virtual objects visualization. The ATD allows Hololens 2 to recognize spatial features through the Vuforia engine and allows our application to adjust the virtual object according to them. The MR scene comprises a legend displaying symbols associated with parameters and their respective meanings, 4

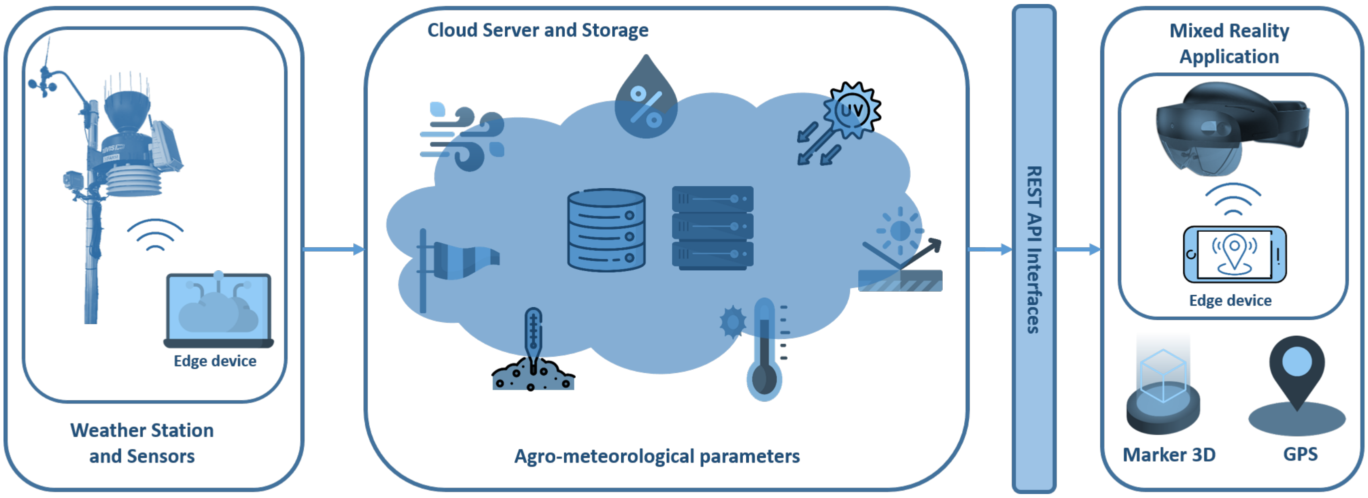

Fig. 2: The proposed system architecture is characterized by three essential parts - a sensor side, a cloud server and storage side, and an application side. The sensor side includes a weather station, its sensors, and an edge device (*e.g.,* datalogger or PC connected via WiFi), while the cloud side manages the storage and processing of data retrieval, and the application side provides an interface for end-users to interact with the system.

Fig. 3: The point cloud and the mesh of the trunk reconstructed using Reality Capture. It was placed in the corresponding tree location of the ATD.

billboards, and 3 main virtual objects overlaid on specific parts of the olive tree. Virtual elements can be toggled on and off by the user through a menu accessible within the scene, activated by holding the hand open in front of the user's head for at least 5 seconds. The billboards show data correlated with one another. Specifically, one billboard displays parameters associated with humidity and temperature, another displays parameters associated with wind (direction in degrees and velocity in $\frac{km}{h}$), another displays parameters associated with soil (moisture and radiation in $\frac{W}{m^2}$), while the last billboard displays parameters associated with UV radiation dose ($MEDs$ [1]). As shown in Figure 5, to provide the user with an understanding of the values obtained from the weather station sensors, we have proposed a semantic relationship through the intensity and opacity of the color of the main virtual objects integrated into the MR scene. In this way, the user can make an immediate decision to address any critical issues highlighted by the parameter values. The object at the base of the tree is a cylinder, representing a scale of colors ranging from light orange to dark orange according to changes (from low to high values) in soil radiation. The object corresponding to the trunk is the actual reconstructed tree trunk obtained through photogrammetry, as described in Section III. The intensity of its blue color varies according to the UV radiation dose parameter, while the opacity highlights the variation in humidity. Lastly, wind velocity and temperature parameters respectively influence the intensity and opacity of a cloud-shaped virtual object that encapsulates the tree's foliage.

A. Agro-meteorological Parameters

We have chosen the above parameters for specific reasons described below: *(i) Humidity* represents the ratio between the density of water vapor contained in the air and the maximum density that can be accommodated at a given temperature. It is a fundamental parameter that influences vegetation vigor [30], specific evapotranspiration [31], soil water content, organic matter content [32], and the possibility of parasitic attacks [33]. *(ii) Temperature* is a physical quantity that measures the degree of air heat and directly affects vegetation vigor, specific evapotranspiration, soil water content, and organic matter degradation processes [34]. *(iii) Wind direction and speed* are directly related to evapotranspiration phenomena and can cause problems such as lodging or

[1]Minimal Erythema Dose

Fig. 4: Our real study case consists of an olive tree located in the experimental garden in the House of Emerging Technologies of Matera.

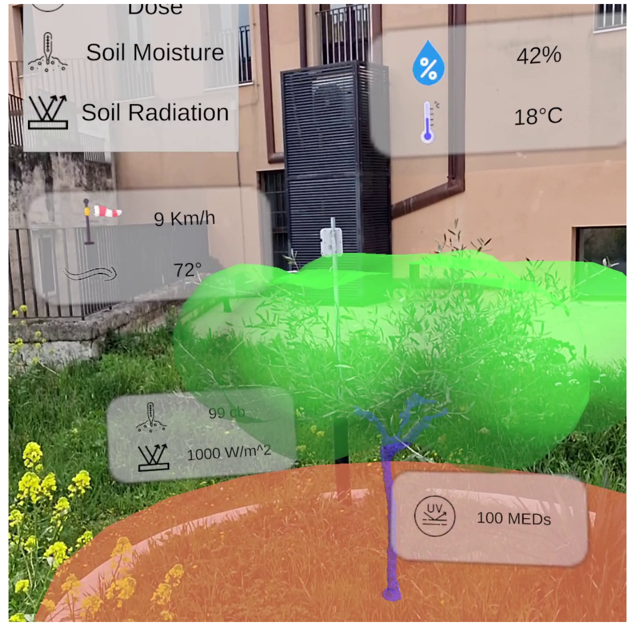

Fig. 5: The visualization of MR information on the Olive Tree located in the experimental garden of House of Emerging Technologies of Matera.

uprooting of plants [35]. *(iv) UV radiation* high exposure can limit photosynthesis and cause visible damage to crops, but it can also have beneficial effects, such as improving the color of ornamental plants and increasing their resistance to diseases and pests. *(v) Soil moisture* is a vital parameter for vegetation, and its threshold values vary considerably depending on the plant species and water retention characteristics of the organic matrix. Olive trees, for example, require well-drained soil, as excessive moisture and stagnation can compromise their health [36]. *(vi) Soil Radiation* is a crucial parameter for remote and proximal sensing systems and for crop growth. Sensors use the relationship between the incident, emitted, and backscattered energy from vegetation to estimate important characteristics and dynamics [37].

V. Conclusions

This research proposes a novel MR-based system that combines VATs, geographic coordinates, and weather station data to visualize real-time changes in environmental conditions and their effects on trees, using the olive tree as a case study. The serious game application of this system offers an interactive and engaging learning experience for students to learn about weather data and its effects on plant growth. The system's educational tool application provides a living lab tool for the visualization of weather data in real-world settings, enabling students to conduct experiments and collect data. The research also highlights the potential of using MR technology in precision agriculture and urban green spaces, where it can simulate various irrigation strategies and test fertilization methods, allowing students to explore different design options and evaluate the environmental and visual impact of their choices. Furthermore, the choice of the olive tree as the case study offers important didactic and informative potential, given its agronomic and physiological characteristics and its significance in Southern Italy's olive oil production. Overall, the proposed system has the potential to simplify the application of MR and precision agriculture in real-world contexts, bridging the gap between theory and practice and providing students with practical knowledge and a greater understanding of environmental management and protection.

In the future, there are several potential areas for improvement and research in this field. One such area is the improvement of overlapping between virtual and real plant components, which can be achieved through procedural modeling and deep learning techniques [38]. This would enhance the visual realism of the MR application, providing an even more immersive and engaging experience for students. Another important area for future work is the evaluation of the usability, user experience, sentiment, and didactic effectiveness of the MR application with students of different ages and educational backgrounds. This would provide valuable insights into how the system can be further improved to meet the needs and preferences of different users. By conducting further research and experimentation, we can continue to explore the potential of MR and serious games in agriculture and environmental education, providing innovative and effective tools for learning and experimentation.

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REFERENCES

[1] M. Glowatz, E. Mangina, and D. Holland, "Virtual, augmented and mixed reality technology based simulations in higher education: Opportunities for alternative assessment strategies," ser. SIMUTOOLS '17. New York, NY, USA: Association for Computing Machinery, 2017, p. 72–76.

[2] H. Zhang, Y. Cui, H. Shan, Z. Qu, W. Zhang, L. Tu, and Y. Wang, "Hotspots and trends of virtual reality, augmented reality and mixed reality in education field," in *2020 6th International Conference of the Immersive Learning Research Network (iLRN)*, 2020, pp. 215–219.

[3] C. Stapleton, C. Hughes, M. Moshell, P. Micikevicius, and M. Altman, "Applying mixed reality to entertainment," *Computer*, vol. 35, no. 12, pp. 122–124, 2002.

[4] N. Capece, G. Manfredi, V. Macellaro, and P. Carratù, "An easy hand gesture recognition system for xr-based collaborative purposes," in *2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE)*, 2022, pp. 121–126.

[5] U. Erra and N. Capece, "Engineering an advanced geo-location augmented reality framework for smart mobile devices," *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, pp. 255–265, 2019.

[6] P. A. Rauschnabel, B. J. Babin, M. C. tom Dieck, N. Krey, and T. Jung, "What is augmented reality marketing? its definition, complexity, and future," *Journal of Business Research*, vol. 142, pp. 1140–1150, 2022.

[7] E. Olshannikova, A. Ometov, Y. Koucheryavy, and T. Olsson, "Visualizing big data with augmented and virtual reality: challenges and research agenda," *Journal of Big Data*, vol. 2, no. 1, pp. 1–27, 2015.

[8] C. Fiorentino, M. Crimaldi, P. Libergoli, P. D'Antonio, and V. Scalcione, "Farm management information systems: Digital register of farm management in southern italy," in *Safety, Health and Welfare in Agriculture and Agro-food Systems*, M. Biocca, E. Cavallo, M. Cecchini, S. Failla, and E. Romano, Eds. Cham: Springer International Publishing, 2022, pp. 337–354.

[9] M. Zheng and A. G. Campbell, "Location-based augmented reality in-situ visualization applied for agricultural fieldwork navigation," in *2019 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, 2019, pp. 93–97.

[10] R. Bongiovanni and J. Lowenberg-DeBoer, "Precision agriculture and sustainability," *Precision agriculture*, vol. 5, pp. 359–387, 2004.

[11] A. Nigam, P. Kabra, and P. Doke, "Augmented reality in agriculture," in *2011 IEEE 7th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*. IEEE, 2011, pp. 445–448.

[12] M. de Castro Neto and P. Cardoso, "Augmented reality greenhouse," in *Proceedings of the EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy*, 2013, pp. 24–27.

[13] J. Huuskonen and T. Oksanen, "Soil sampling with drones and augmented reality in precision agriculture," *Computers and electronics in agriculture*, vol. 154, pp. 25–35, 2018.

[14] E. Veas, R. Grasset, I. Ferencik, T. Grünewald, and D. Schmalstieg, "Mobile augmented reality for environmental monitoring," *Personal and ubiquitous computing*, vol. 17, pp. 1515–1531, 2013.

[15] Z. Zhao, W. Yang, W. Chinthammit, R. Rawnsley, P. Neumeyer, and S. Cahoon, "A new approach to utilize augmented reality on precision livestock farming." in *ICAT-EGVE*, 2017, pp. 185–188.

[16] V. Ponnusamy and S. Natarajan, "Precision agriculture using advanced technology of iot, unmanned aerial vehicle, augmented reality, and machine learning," *Smart Sensors for Industrial Internet of Things: Challenges, Solutions and Applications*, pp. 207–229, 2021.

[17] Y. Alj, A. Dadda, H. Fahmani, and Y. Tace, "Towards an approach integrating mixed reality and iot for smart agriculture," in *2022 International Conference on Microelectronics (ICM)*. IEEE, 2022, pp. 229–232.

[18] S. A. Kumar and P. Ilango, "The impact of wireless sensor network in the field of precision agriculture: A review," *Wireless Personal Communications*, vol. 98, pp. 685–698, 2018.

[19] K. Jha, A. Doshi, P. Patel, and M. Shah, "A comprehensive review on automation in agriculture using artificial intelligence," *Artificial Intelligence in Agriculture*, vol. 2, pp. 1–12, 2019.

[20] L. Tomaszewski, R. Kołakowski, and M. Zagórda, "Application of mobile networks (5g and beyond) in precision agriculture," in *Artificial Intelligence Applications and Innovations. AIAI 2022 IFIP WG 12.5 International Workshops: MHDW 2022, 5G-PINE 2022, AIBMG 2022, ML@ HC 2022, and AIBEI 2022, Hersonissos, Crete, Greece, June 17–20, 2022, Proceedings*. Springer, 2022, pp. 71–86.

[21] M. M. Elsharkawy, A. E. A. S. Sheta, P. D'Antonio, M. S. Abdelwahed, and A. Scopa, "Tool for the establishment of agro-management zones using gis techniques for precision farming in egypt," *Sustainability*, vol. 14, no. 9, p. 5437, 2022.

[22] G. Manfredi, G. Gilio, V. Baldi, H. Youssef, and U. Erra, "Vico-dr: A collaborative virtual dressing room for image consulting," *Journal of Imaging*, vol. 9, no. 4, p. 76, 2023.

[23] N. Capece, M. Gruosso, U. Erra, R. Catena, and G. Manfredi, "A preliminary investigation on a multimodal controller and freehand based interaction in virtual reality," in *Augmented Reality, Virtual Reality, and Computer Graphics: 8th International Conference, AVR 2021, Virtual Event, September 7–10, 2021, Proceedings 8*. Springer, 2021, pp. 53–65.

[24] G. D. Stone, "Towards a general theory of agricultural knowledge production: environmental, social, and didactic learning," *Culture, Agriculture, Food and Environment*, vol. 38, no. 1, pp. 5–17, 2016.

[25] E. Salas, D. DiazGranados, C. Klein, C. S. Burke, K. C. Stagl, G. F. Goodwin, and S. M. Halpin, "Does team training improve team performance? a meta-analysis," *Human factors*, vol. 50, no. 6, pp. 903–933, 2008.

[26] S. Decuyper, F. Dochy, and P. Van den Bossche, "Grasping the dynamic complexity of team learning: An integrative model for effective team learning in organisations," *Educational Research Review*, vol. 5, no. 2, pp. 111–133, 2010.

[27] D. Loukatos, E. Zoulias, E. Chondrogiannis, K. G. Arvanitis *et al.*, "A mixed reality approach enriching the agricultural engineering education paradigm, against the covid-19 constraints," in *2021 IEEE Global Engineering Education Conference (EDUCON)*. IEEE, 2021, pp. 1587–1592.

[28] P. Tangworakitthaworn, V. Tengchaisri, and P. Sudjaidee, "Serious game enhanced learning for agricultural engineering education: Two games development based on iot technology," in *2020-5th International Conference on Information Technology (InCIT)*. IEEE, 2020, pp. 82–86.

[29] C.-M. Wang, Y.-H. Lin, and Y. Lin, "Construction of a somatosensory interactive system based on computer vision and augmented reality techniques using the kinect device for food and agricultural education," *International Journal of Engineering Science Technologies*, vol. 5, no. 2, pp. 1–37, 2021.

[30] G. C. Mbofung, A. S. Goggi, L. F. Leandro, and R. E. Mullen, "Effects of storage temperature and relative humidity on viability and vigor of treated soybean seeds," *Crop Science*, vol. 53, no. 3, pp. 1086–1095, 2013.

[31] M. Valipour, "Importance of solar radiation, temperature, relative humidity, and wind speed for calculation of reference evapotranspiration," *Archives of Agronomy and Soil Science*, vol. 61, no. 2, pp. 239–255, 2015.

[32] D. Leelamanie *et al.*, "Changes in soil water content with ambient relative humidity in relation to the organic matter and clay," *Tropical Agricultural Research and Extension*, vol. 13, no. 1, pp. 6–10, 2010.

[33] G. Bonanomi, N. Salvatori, M. Zotti, A. Stinca, R. Motti, M. Idbella, F. Cartenì, S. Mazzoleni, and F. Giannino, "Parasitic plant causes an ephemeral "rainbow" pattern in a reservoir bank," *Journal of Vegetation Science*, vol. 32, no. 1, p. e12931, 2021.

[34] M. S. Jin and T. Mullens, "A study of the relations between soil moisture, soil temperatures and surface temperatures using arm observations and offline clm4 simulations," *Climate*, vol. 2, no. 4, pp. 279–295, 2014.

[35] F. J. Méndez, I. J. Losada, and M. A. Losada, "Hydrodynamics induced by wind waves in a vegetation field," *Journal of Geophysical Research: Oceans*, vol. 104, no. C8, pp. 18 383–18 396, 1999.

[36] A. J. Espejo-Pérez, L. Brocca, T. Moramarco, J. V. Giráldez, J. Triantafilis, and K. Vanderlinden, "Analysis of soil moisture dynamics beneath olive trees," *Hydrological Processes*, vol. 30, no. 23, pp. 4339–4352, 2016.

[37] O. Panferov, Y. Knyazikhin, R. Myneni, J. Szarzynski, S. Engwald, K. Schnitzler, and G. Gravenhorst, "The role of canopy structure in the spectral variation of transmission and absorption of solar radiation in vegetation canopies," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 39, no. 2, pp. 241–253, 2001.

[38] G. Manfredi, N. Capece, U. Erra, and M. Gruosso, "Treesketchnet: From sketch to 3d tree parameters generation," *ACM Transactions on Intelligent Systems and Technology*, vol. 14, no. 3, pp. 1–29, 2023.