World Academy of Science, Engineering and Technology
International Journal of Educational and Pedagogical Sciences
Vol:15, No:04, 2021

Augmented Reality to Support the Design of Innovative Agroforestry Systems

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Abstract : Agroforestry is recognized as a way of developing sustainable and resilient agriculture that can fight against climate change. However, the number of species combinations, spatial configurations, and management options for trees and crops is vast. These choices must be adapted to the pedoclimatic and socio-economic contexts and to the objectives of the farmer, who therefore needs support in designing his system. Participative design workshops are a good way to integrate the knowledge of several experts in order to design such complex systems. The design of agroforestry systems should take into account both spatial aspects (e.g., spacing of trees within the lines and between lines, tree line orientation, tree-crop distance, species spatial patterns) and temporal aspects (e.g., crop rotations, tree thinning and pruning, tree planting in the case of successional agroforestry). Furthermore, the interactions between trees and crops evolve as the trees grow. However, agroforestry design workshops generally emphasize the spatial aspect only through the use of static tokens to represent the different species when designing the spatial configuration of the system. Augmented reality (AR) may overcome this limitation, allowing to visualize dynamic representations of trees and crops, and also their interactions, while at the same time retaining the possibility to physically interact with the system being designed (i.e., move trees, add or remove species, etc.). We propose an ergonomic digital solution capable of assisting a group of agroforestry experts to design an agroforestry system and to represent it. We investigated the use of web-based marker-based AR that does not require specific hardware and does not require specific installation so that all users could use their own smartphones right out of the pocket. We developed a prototype mobilizing the AR.js, ArToolKit.js, and Three.js open source libraries. In our implementation, we gradually build a virtual agroforestry system pattern scene from the users' interactions. A specific set of markers initialize the scene properties, and the various plant species are added and located during the workshop design session. The full virtual scene, including the trees positions with their neighborhood, are saved for further uses, such as virtual, augmented instantiation in the farmer fields. The number of tree species available in the application is gradually increasing; we mobilize 3D digital models for walnut, poplar, wild cherry, and other popular species used in agroforestry systems. The prototype allows shadow computations and the representation of trees at various growth stages, as well as different tree generations, and is thus able to visualize the dynamics of the system over time. Future work will focus on i) the design of complex patterns mobilizing several tree/shrub organizations, not restricted to lines; ii) the design of interfaces related to cultural practices, such as clearing or pruning; iii) the representation of tree-crop interactions. Beside tree shade (light competition), our objective is to represent also below-ground competitions (water, nitrogen) or other variables of interest for the design of agroforestry systems (e.g., predicted crop yield).

Keywords : agroforestry system design, augmented reality, marker-based AR, participative design, web-based AR
Conference Title : ICE 2021 : International Conference on Edutainment
Conference Location : Boston, United States
Conference Dates : April 22-23, 2021