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Context

Agroforestry systems (AFS) are farming systems that associate trees, crops and animals. They cover a variety of management options and spatial arrangement [Dupraz et al, 2011]. Therefore, co-design workshops are an efficient way to design AFS. To design the spatial arrangement of species, participants often interact with a physical mockup [Chieze et al, 2021], locating plants to define the system structure. But despite the numerous exchanges between participants, the resulting ecosystem functions are difficult to perceive [Potschin et al, 2011].

Building models for agroforestry is a growing concern [Burgess et al, 2019]. However, agroforestry models seldom express both structural and functional representations. Some, such as Hi-safe [Dupraz et al, 2019], focus on functional aspects, extending crop model approaches. Others, such as EcoAF [Liagre et al, 2019], focus on the structural descriptions of the system, applying pattern grammars to describe the spatial arrangement of species. These approaches are difficult to mobilize in co-design workshops, facing in the first case the lack of visualization supports and complex parametrization, and, in the second case, the lack of interactions between elements of the modeled system and the scarcity of ecosystem services that are considered.

In the review of Sereno et al. (2022), Augmented Reality (AR) is shown to be efficient for collaborative work. This technology could allow the co-design workshop participants to share a common vision of the AFS and its functioning. Using traditional functional – structural plant model (FSPM) with AR during design workshop is promising to link scientific knowledge, visualization, interaction and collaboration.

Our proposal

Our proposal is composed of 3 steps: (1) acquiring and digitizing an AFS mockup such as those that are commonly used in co-design workshops, (2) automatic building of a model of the AFS using graph theory [Lemière et al, 2022] and, (3) visualizing the system and the associated ecosystem services using AR. We can integrate functional-structural models at two scales: at the plant scale, i.e. FSPM, and at the agroecosystem scale, leading to a new concept of Functional-Structural Agroecosystem Model (FSAM) as detailed hereunder.

Using FSPM at the plant scale

In step 2, each mockup element becomes a node of the graph and is edge-connected to others depending of their relation (such as adjacency). The element can then be attached to a FSPM. FSPMs offer a realistic and/or volumetric visual representation that can be projected in AR. Depending on their assumptions, models can be integrated into a tool and mobilized for decision making [Surový et al, 2013], or dynamics understanding, as shown for light interception [Streit et al, 2016].

Mobilizing a FSPM approach at the system scale

The graph modelling form enables us to expand the FSPM principles at the scale of the whole AFS, building so-called FSAM. In FSAM, functions are based on the AFS pattern and are linked to ecosystem services. With graph structural descriptions, we can search for or identify patterns (such as tree alignments) within the system; we can also design a system by combining existing patterns with desired functions.

Implementation

We are currently implementing a prototype application using these concepts. In particular, steps 2 and 3 (which include function–structure aspects) can be detailed as:

- From the captured mockup, a raster model and a graph model are built
- Tree alignment (a simple pattern) is recognized
- AFS designers are able to interactively visualize, with AR, the 3D virtual plants (built from FSPM simulations) corresponding to the mockup elements
- AFS designers are able to visualize the virtual mockup in situ
- AFS designers can visualize the tree growth over the time

Conclusion

With the structural information in graph form, some ecosystem functions can be considered during co-design workshops. Using FSPM at the plant and system scale combined to AR, the current prototype keeps interactivity during co-design workshops while improving visualization and understanding of the system thanks to the system simulation. To do this, we developed a new model (FSAM) using the structures and functions of the AFS.

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