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“WALD DIGITAL” – A VIRTUAL LABORATORY FOR STUDIES IN (NOT ONLY) FOREST SCIENCE

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Abstract

At the Technical University of Munich (TUM), School of Life Sciences, the virtual lab “Wald Digital“ (Döllerer, 2021) was developed in order to enable students in forest science and related fields to study digital twins of a real forest of about 1.5 ha, and its augmented reality. Three areas were selected, following these criteria: relevance for student’s education, possibility to incorporate up-to-date research results, and accessibility.

Detailed single tree data are obtained and enriched with third party information such as digital elevation and surface models, digital ortho photos, drone data, and terrestrial laser scanned (TLS) data. Corresponding data are consolidated to a spatio-temporal database that serves as input for models, which are integrated in “Wald Digital”: Forest Growth Model, Climate Model, Survival Probability Model, and Disturbance Model. Further models can be included. Supported by a GIS database, students can investigate questions particularly related to forest growth dynamics and extreme biotic or abiotic impacts.

“Wald Digital” can be integrated in study courses of BSc and MSc curricula. Courses at TUM like Bachelorkolloquium, Controlling of Forest Enterprises or Forest Management Planning could benefit from it. In general, “Wald Digital” is open to any student and lecturer at TUM, both in reality with or without the help of augmented reality apps, and virtually: both at home and at the university campus in a computer room. With the evolution of study programmes in the forest sector environments like “Wald Digital” could gain importance.

Key words: “Wald Digital”, forest plots, digital twins, virtual reality, forest curricula, life science, Technische Universität München, Germany.

Introduction

The most exciting lab for any forest scientist is, of course, the forest itself. Furthermore, forests are subject of the general interest of natural and environmental sciences, and of broad public attention with respect to ecological, economic and social

benefits. “Wald Digital” is a virtual environment that manages digital twins of forest areas, which are relevant to education and research at the TUM School of Life Sciences in Weihenstephan.

“Wald Digital” allows the integration of third-party information such as digital elevation and surface models, digital ortho photos, stereo images, drone data, and terrestrial laser scanned (TLS) data. The resulting database can be integrated in a variety of investigations dealing for instance with forest dynamics in response to climate change and specific extreme events such as storm damage, drought, or biotic calamities. Such data are relevant for various educational purposes such as what-if-analyses and forecasting approaches. They may serve as criteria for forest management decisions, like tree species selection, rotation period optimisation etc. and can be utilized by forest enterprises, e.g. for risk assessment. Generally, the utilisation of augmented reality tools is expected to complete existing information via modelling, digital ortho photos, drone data, or terrestrial laser scan data.

“Wald Digital” allows to conduct what-if-analyses by the integration of simulation models like SILVA 2 (Pretzsch *et al.*, 2002), iLand (Seidl *et al.*, 2012) or BROOK90 (Federer *et al.* 2003). The implementation of innovative learning concepts via “serious gaming” like examination situations like in the Bachelorkolloquium can be simulated in the digital twin’s virtual landscape is also possible.

The target group of “Wald Digital” are the students in the field of forest sciences at the TUM School of Life Sciences. The major objective of “Wald Digital” is to assist in several study courses on both Bachelor and Master level, e. g. Bachelorkolloquium, Controlling of Forest Enterprises or Forest Management Planning.

“Wald Digital” should also serve as data pool and simulation environment for Bachelor’s or Master’s theses. Outstanding students could even extend “Wald Digital” as topic of their theses.

In general, “Wald Digital” is open not only to students of forest sciences, but also to other students and lecturers at TUM in the field of environmental sciences and beyond.

Material and methods

Experimental sites

Three sites ranging between 0.75 to 1.5 hectares were selected and tree attributes as well as supplemental data (e. g. micro habitats, soil layer) were assessed. These three “Wald Digital” sites are:

- The project site of the Kranzberg ROOF project (later referred to as “KROOF”, see Figure 1, left) which allowed to incorporate up-to-date research results.

- An area in the Kranzberger Forst (later referred to as “KRANZBERG”, see Figure 1, centre) because it is located in cycling-distance from the TUM campus in Freising Weihenstephan.
- An area in the “Stiftungswald” of the University of Munich (later referred to as “UNIWALD”, see Figure 1, right) because of its relevance for education as exams are held regularly in that forest.

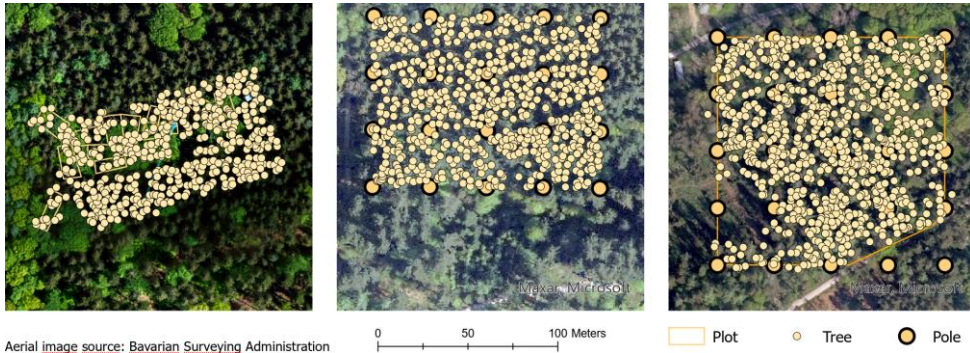


Figure 1: Position of trees, sub plots and staked out areas KROOF (left), KRANZBERG (centre), UNIWALD (right). For explanation see text.

Plot design and data acquisition

In all three areas, all trees with a diameter of at least 7 cm at breast height (dbh) were measured. In addition to dbh, tree species, position, height, crown length and special properties (e.g., trees with more than one stem) were assessed.

The KROOF area consists of twelve subplots, which are surrounded by fences. Poles (stakes) with a spacing of 31.60 m were installed in the other two areas. They form squares with an area of 1000 m² and help with orientation.

At the UNIWALD area, soil samples were taken in a 20 m by 20 m raster by means of a soil drill. In the KRANZBERG area, micro-habitats on trees such as lichens, mosses, bark damages, etc. were assessed. The Chair of Forest Yield Science provided data about the development of tree dimensions from 1994 through 2020 for the KROOF area.

All measured data were enriched with third party information such as publicly available geo information (aerial photographs, digital terrain models, digital surface models), data from unmanned airborne vehicles (UAVs) and laser scanning data (airborne as well as terrestrial).

All available data was imported in a spatio-temporal data base and published to an online GIS environment (Esri, 2021).

The GIS and the associated data are coupled with simulation models. These enable for example the study of interactions between forest structure, forest dynamics, climate change and extreme events. The way how the visualisation systems communicate with the simulation models is derived from Döllner (2008). It allows to couple basically any simulation model and handles communication as well as data transfer between the visualization software and the simulation model application.

Results

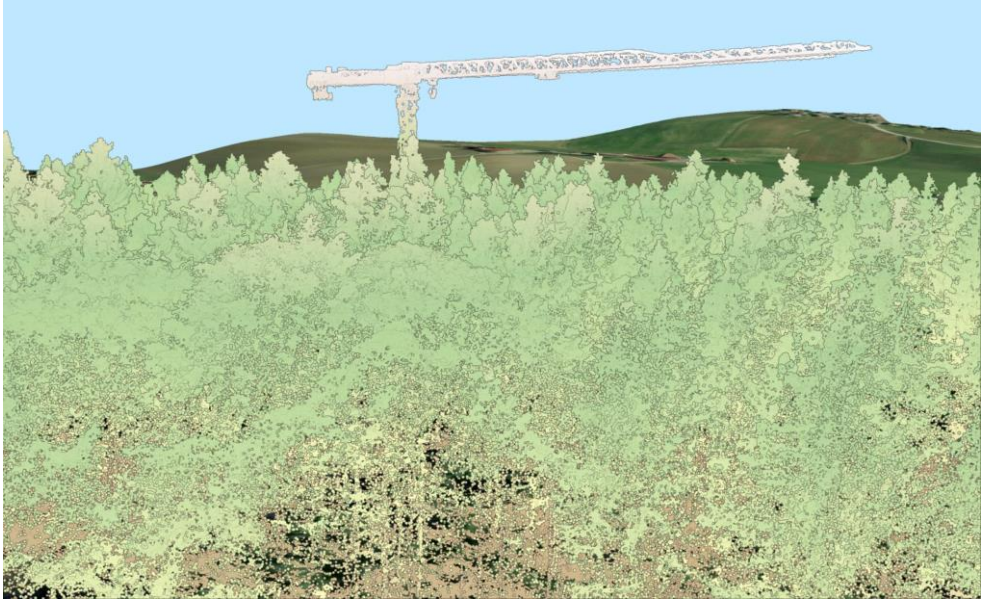


Figure 2: 3D GIS Visualisation of a LIDAR point cloud at the KROOF area.

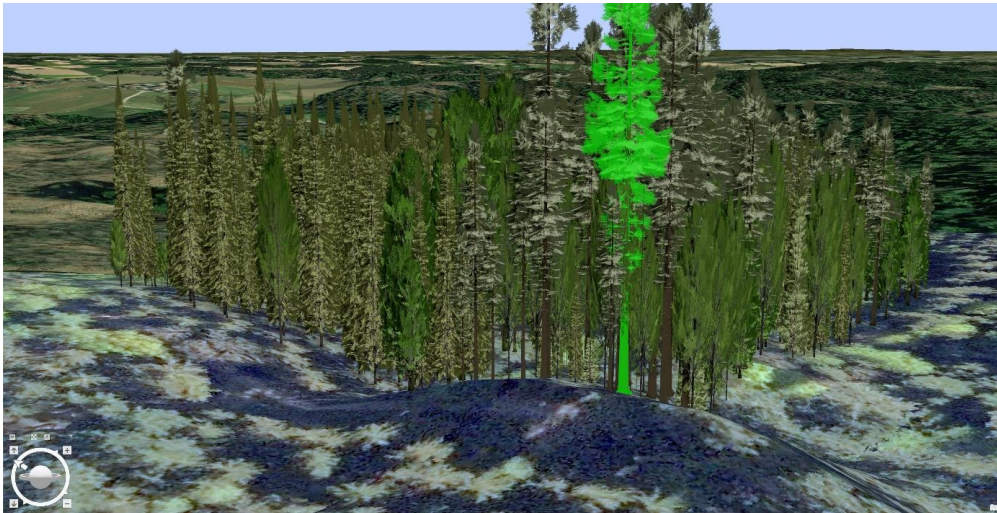


Figure 3: 3D GIS Visualisation of the KRANZBERG plot (Douglas Fir at the front selected, Navigation Tools bottom left).

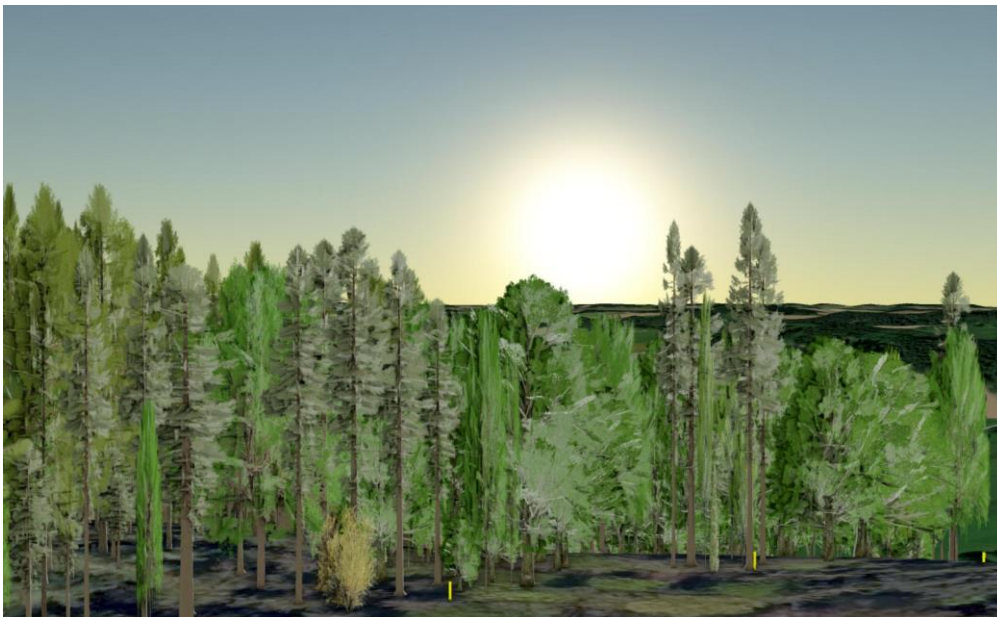


Figure 4: GIS Visualization of the UNIWALD plot at sunset.

Close to reality visualisation using computer game technology

So called game engines are used in the production process of computer games that allow the creation of the game environment interactively and intuitively. Modern computer games are able to visualize their game world in a very realistic way. A game engine was used to realize the graphically most sophisticated version of “Wald Digital”. We decided to use the Unreal Engine 4.27 by EPIC games (Epic Games,

2021). 3D models of different tree species were bought from the EPIC games store, distributed in the virtual landscape and scaled to the correct height. Two forest landscapes – the KROOF area and the UNIWALD area – were created by a group of talented students in the frame of a Bachelor project study.

To ease placement and scaling of the individual trees, a GIS layer was imported (see Figure 5) to visualise position, species and height of each tree. Three examples are presented in Figures 6, 7 and 8. Figure 9 proves that the virtual pictures approach the real sceneries pretty well.

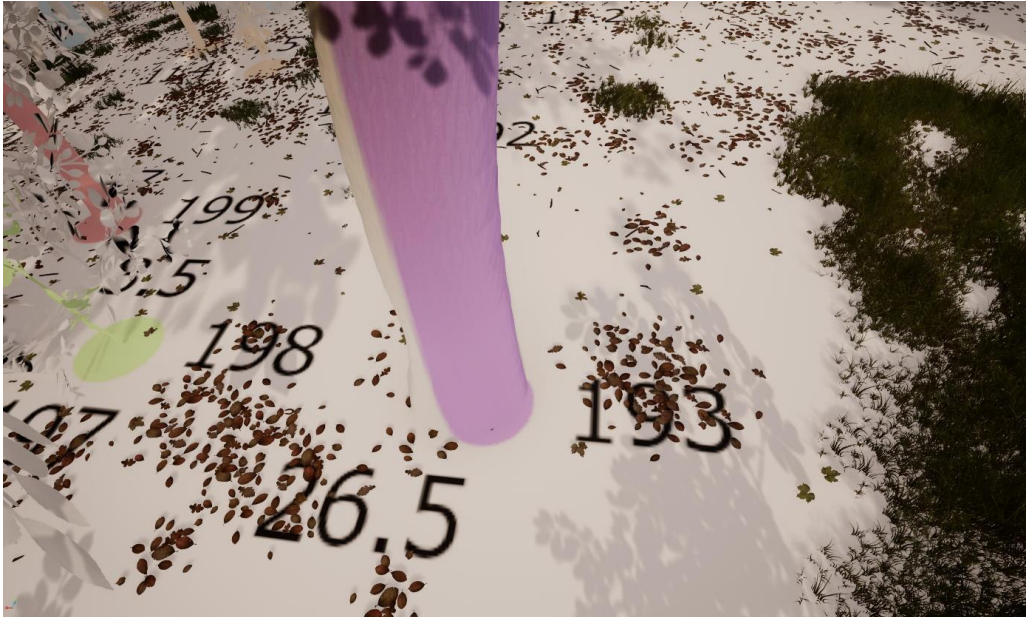


Figure 5: Imported GIS layer in the Game Engine Editor: The numbers indicate tree number (193) and height (26.5), the dot indicates position and species (purple: Oak).



Figure 6: Visualisation of the KROOF area.



Figure 7: Visualisation of the UNIWALD area.



Figure 8: Visualisation of a measurement facility at the KROOF area.



Figure 9: Photograph of the scene shown in Figure 8.

Integration of “Wald Digital” into curricula

“Wald Digital” is currently available as an early prototype. Simulation of forest growth dynamics with SILVA is already available.

There are numerous possibilities for integration of “Wald Digital” into current study programmes:

- Basic GIS courses (e. g.: Introduction to GIS);
- Forest management courses;
- Environmental management courses;
- Climate change courses;
- And many more.

Demonstrations have shown that environments like this are appreciated by both teaching staff and students. Advertisements of “Wald Digital” are currently ongoing, so are enhancements of the system.

Concluding remarks

Even with standardized three-dimensional tree models, it is possible to create notably realistic forest landscapes. Querying and selecting objects must be added by programming code. By identifying individual trees in the terrestrial laser scanning point clouds and converting them to wire frames, every tree could be modelled as it grew in reality. The search for methods to automatically create such wire frame models is at the moment subject to basic research.

Unlike e.g. Marteloscopes or visualisation-only approaches (Chandler *et al.*, 2022), “Wald Digital” allows both free navigation through the scene and flexible interaction with objects as well as the invocation of external applications that modify the scenery. All trees have to be placed and scaled manually in the two existing game environments. Although GIS data assist the process, this is a considerable workload: The UNIWALD area consists of 845 trees and there are 479 trees at the KROOF area. Virtual Reality (VR) visualisation is directly supported by the game engine, VR displays are available. The third forest landscape at the KRANZBERG area is under development. An approach to add a programme code that creates the trees automatically is tested.

Study programmes evolve and environments like “Wald Digital” most likely will gain importance. As an example, the module “forest simulation” (Waldsimulation) will be a compulsory module in the German master programme “Forst- und Holzwissenschaft” at TUM. As the KROOF area and the KRANZBERG area are located in a publicly owned forest in cycling distance from the University campus, participants of this module could benefit from “Wald Digital” being integrated.

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