Interactive Virtual Planning Tools for Sustainable Forest Production in Mountain Areas

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Abstract. Forest wood harvesting in mountain areas needs a deep and accurate planning to avoid possible failures and criticalities due to the complex morphology of the terrain. Steepness, difficult accessibility and on the field manual work are cost effective factors to reckon, but not always taken into account on all phases, due to the heterogeneity of competences and instruments adopted by the involved actors. Geographical information systems planning tools, demonstrated their usefulness to analyze spatial data in such conditions, but their specificity makes their adoption difficult among operators especially in a conservative industry like forestry. This document introduces an interactive web 3D planning tool based on an accurate virtual forest environment reconstruction, to support the entire wood processing chain in mountain areas, from tree marking to timber production within sawmills, accommodating the needs of all the involved actors bringing novel simulation, planning and monitoring tools at their disposal.

Keywords: Forest planning · Forest monitoring · GIS · 3D virtual globe · WebGL

1 Introduction

In the last decades, the wood market has been subject to a constant global growth in production and consumption of wood products. Projections suggest that this trend will not change before 2030 with the major production growth in Europe, Russian Federation, Eastern Europe and South America and highest consumption in Africa, Asia and the Pacific. This growth involves all the major wood sectors like wood-based panels, paper, industrial round wood and bioenergy and is caused by increasing energy resource needs combined with a rediscovery of wood in the building sector [1]. Modern timber buildings require low operating energy with performances orders of magnitude better than steel and concrete, emitting half of the solid waste, 18 % less air emissions and requiring 13 % less energy [2]. In this context, the adoption of effective planning techniques and on-the-field harvesting solutions becomes crucial to optimize production, reduce costs and respond to growing market demands. In Europe, one of the major wood producers with 45 % of forest surface [3] this becomes even more critical

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considering that a large portion of wood resides in mountainous areas and many operations are still manual. The main goal of this study performed in the context of the European project SLOPE, is the improvement of the forest supply chain in mountain areas through the integration of a variegated set of services under the same platform, developing human machine interfaces to meet the specific user requirements of several mountain forest actors. After a first review of the state of the art of visualization interfaces for forest information systems (FIS) and an overview of the followed design process, a detail of the designed human machine interface for the final implementation is provided, describing its look and feel and technological solutions.

2 State of the Art

In forestry, the first decision support tools appeared in the 70 s as linear-programming software for the estimation of the forest areas harvesting levels [3]. Later on, with the advent of space based remote sensing, FIS evolved as extension of GIS software containing, in addition to geo-referenced data, thematic and non-formatted data with a temporal relation [4]. Being it stored in a central location or distributed as a remote service as in the current trends, georeferenced data can be classified under two main categories: imageries and vector. The former includes aerial colored and multispectral pictures [5] useful to recognize vegetation areas, roads and other visual objects. The latter including data derived from point clouds obtained through light detection and ranging (LIDAR) technology. Compared with conventional data acquisition techniques, LIDAR works at night, has very high vertical accuracy and resolution per meter and can be used to measure forest canopy heights [5] as well as count and delineate trees stand [6, 7]. In the 80 s, FIS started to be used as decision support tools, with a first application for the federal administration and industry of forest in US, demonstrating many advantages between the past technology, providing tracing maps, more clear data visualization with advanced computing calculation and data update. Further integration with enterprise-resource-planning (ERP) systems have been reported in [6] to manage operations while maintaining certification documentation and applications for fire control and road planning have been reported in [8].

In the last decade, FIS interfaces evolved from simple mapping into sophisticated systems characterized by 3D navigation, interaction and visualization. For a forest landscape planning perspective, understanding spatial patterns and temporal dynamics can take advantage from 3D visualization. Finnish researchers highlight the possibility of computer-generated images for environmental landscape planning, in particular to understand the visual impact of determined decisions in management procedures, while in [9], researchers studied its use as a deploying simulation and modelling of ecological model for environmental evolution. These applications are strengthen by [10] who illustrated the effectiveness of map exploration against map visualization. Several techniques for real-time rendering of terrain and forests have been studied in the past [11], going from planar tree billboards to more complex 3D models with lighting techniques [12] and new representation of canopy reflectance on steep terrains [13]. From the current overview, it clearly appears how FIS with advanced visualization capabilities are ideal candidates for today's forest production needs. However, until now R&D focused only on specific aspects of the wood chain like surveying, visualization or monitoring, without considering the whole process and their actors.

3 Human Computer Interface Design Process

The design process leading to the definition of the interactive interface of the virtual planning tool has started with an analysis of the actors involved inside an enhanced forest production process and their main use cases through a set of questionnaires. This workflow, developed in the context of the SLOPE project (Integrated processing and Control Systems for Sustainable Production in Farms and Forests) is summarized in Fig. 1. It differs from the classical ones introducing advanced forest surveys for digital reconstruction of a forest model used for planning and simulation, the adoption of RFID tags for trees and logs tracking and for the real-time analysis of wood quality during cutting and debranching phases. The most important actors are the following:

- Forest operator (FO): involved directly on field forest operation, like the coordinator of on-field operations or the one in charge of the digital surveys;
- Forest planner (FP): involved in the decision making processes for harvesting;

This list does not include actors like cableway and truck operators as well as forestry experts, which are mainly involved on the field and are subject to other studies more focused on mobile interfaces on rough and in-vehicle conditions. For these two main actors, four main categories of tools at their daily disposal have been recognized:

- Forest resource planning systems: featuring personnel, hardware and wood management tools through 2D maps and table interfaces;
- Forest analysis and monitoring: including built-in software to handle laser scan, ad hoc proprietary software to program UAVs flights and post-process the acquired data;
- Intelligent harvesting tools: like head processors controlling software to dynamically define cutting log length according to wood quality index computed in real-time by sensors mounted on the head;
- GIS tools: like well-known proprietary software and 3D free virtual globes;

This analysis, together with the complete scenario of Fig. 1 contributed to the definition of the following main use cases:

- 3D Forest navigation with the ability to switch datasets and maps;
- Forest data model visualization: including tree properties and terrain profiling;
- Real-time operations visualization: including harvesting and transport;
- Information hub access: with climate data, wood pricing, certifications, etc.
- Resource inspection: including staff, machineries, wood and storage area;

Fig. 1. Enhanced forest production flow

- Supply management: including plot, logs and stock storage;
- Business analytics: for income and outcome estimation;
- Wood selling: through direct selling and online auctions;

The forest operator is usually focusing on the first four points while the planner daily work, as an extension of the operator actor, performs all the above use cases. The described analysis has been used as a starting point for the definition of the interactive toolset for monitoring and planning described in the next section.

4 The Slope System

Considering the definition given by [14, 15], different parts compose a system for forest management: an input interface for data management (editing, update), an underlying database, an analytical engine for statistical and/or numerical analysis, tools for estimation and prediction to be adopted for future developments, a decision-support system and a set of visualization tools. Not all of these elements require a user interface but a forest management system should be able to wrap them under the same seamless toolset involving data acquisition and processing, decision support and 3D visualization. At the same time, particular attention should be paid to avoid redesigning an entire interface model from scratch, since novelty usually constitutes an entry barrier and a learning burden. With this principle of least astonishment in mind, and the assumption to rely on an integrated forest information model as a data source, a desktop graphical user interface layout has been designed as shown in Fig. 2.

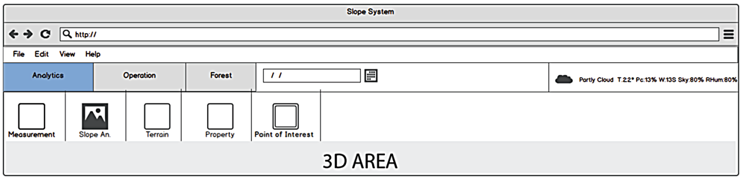

Fig. 2. Main layout

Running inside all the modern web browsers to ensure portability and with an interface which can adapt to mobile browsers, the interface has three levels of menus. The first one is a classical toolbar for saving and loading project plans, print plans, handle tools history and help. The second one includes three main buttons to switch between the three main working modes that have been identified accordingly with the use cases: planning, deployment and monitoring together with a calendar, essential for operations history and an information hub including weather conditions.

The third level includes a set of buttons specific for the selected operational mode while the 3D interactive model of the forest covers the main area. Second and third level menu buttons are medium sized in order to be easily selectable on tablets and smartphones with small screens or from operators wearing gloves. The following list provides additional details about each operation mode:

- The **planning mode**, shown in Fig. 2, provides a set of tools to retrieve geometrical and geophysical information (like slope and soil components), about the real estate to be processed. The 3D map can be viewed and inspected with the use of keyboard, mouse and touch gestures and can be enriched with specific imageries and terrain data (UAVs orthophotos and digital surface model). It allows viewing a huge amount of trees typical of forest scenario correctly georeferenced thanks to UAV data processing as well as performing terrain analysis, like distance and surface estimation or slope trend along a path.
- The **deployment mode**, shown in Fig. 3a is related to the operational phase, with tools for planning forestry operation for specific days, going from harvesting related ones like felling and processing, to more logistical or general planning ones like creating street or assigning resources and machineries. One of the most crucial functionalities on steep terrain is the optimal placement of a cable line to transport logs from the forest to the processing area. This mode enables a what-if analysis in which forestry experts can place a cable line, specifying the pillars heights and rope tension, visualize the catenary trend of the cable and inspect the covered harvesting area which depends on the height of the cable from the terrain. Additionally, this mode allows an estimate of the cable line setup costs, landing zone recognition and planning of roads to be used for logs transport to the sawmills.
- The **monitoring mode**, shown in Fig. 3b, contains all the tools to inspect information concerning forest inventory such as tree physical properties (i.e. height, diameter, and species), logs quality, parcels economical value as well as marked and tagged trees within the forest or placed on storage areas. This information can then be used for direct selling and auction of the available wood to sawmill and other customers.

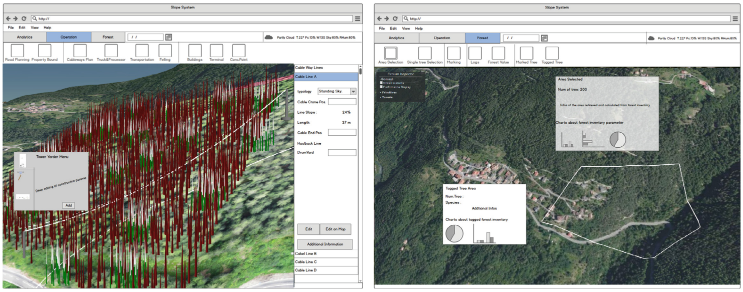

Fig. 3. Deployment (a) and monitoring (b) mode

5 Conclusions and Future Work

A user-friendly framework is essential when dealing with mapping applications, such as those in the forestry sector and the latest generation of 3D interactive applications are the ideal candidates for this task. This paper has shown a work in progress interface developed from real use case scenarios and feedbacks from field experts, as an attempt to build a new user friendly integrate system to cover the entire wood processing chain in mountainous areas. Future works will include an interface refinement, especially concerning the mobile usage, integration with the underlying forest data model and testing on the field with real experts having different levels of technological expertise. The goal is to shape the prototype around on-the-field experts' needs to build a toolset that can really be adopted in the daily business.

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References

1. Global demand for wood products. FAO report. (2009)
2. Evaluating the Environmental Performance of Wood Building Materials. http://www.esf.edu/ecenter/eis/woodmaterials.htm
3. Global Forest resource assessment. FAO report (2010)
4. Wing, M., Bettinger, P.: Geographic Information Systems: Applications in Natural Resource Management. Oxford University Press, Oxford (2008)
5. Lillesand, T., Kiefer, R.W.: Remote Sensing and Image Interpretation. J. Wiley & Sons Ltd, Chichester (2004)
6. Hetemäki, N.: Information Technology and The Forest Sector. IUFRO World Series, vol. 18. IUFRO, Vienna (2005)
7. Tao, W., Jian-hua, G.: Forest reconstruction using point cloud data of airborne LIDAR. In: International Conference on Management and Service Science, pp. 1–4. IEEE Press Computer Society Press, Wuhan (2009)
8. Lewis, J.L., Sheppard, R., Sutherland, K.: Computer-based visualization of forest management: A primer for resource managers, communities, and educators. J. Ecosyst. Manag. **5**(2), 5–13 (2005)
9. Zyda, M., Sheehan, J.: Modeling and Simulation: Linking Entertainment and Defense. National Research Council, Washington, DC (1997)
10. Thorndyke Perry, W., Hayes-Roth, B.: Differences in spatial knowledge acquired from maps and navigation. Cogn. psychol. **14**(4), 560–589 (1982)
11. Hoppe, H.: Smooth view-dependent level-of-detail control and its application to terrain rendering. In: Proceedings of the Conference on Visualization 1998, pp. 5–42. IEEE Computer Society Press (1998)
12. Bruneton, E., Neyret, F.: Real-time realistic rendering and lighting of forests. Comput. Graph. Forum **31**(2.1), 373–382 (2012)
13. Fan, W., Chen, J.M., Ju, W., Zhu, G.: GOST: a geometric-optical model for sloping terrains. IEEE Trans. Geosci. Remote Sens. **52**(9), 5469–5482 (2014)
14. McCloy, R.K.: Resource Management Information Systems: Process and Practices. CRC Press, Boca Raton (1995)
15. Günther, O.: Environmental information systems. Newsl. ACM SIGMOD Record **26**(1), 3–4 (1997)