

RESOURCE INVENTORY FOR CONVERSION MODELING

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ABSTRACT

FORESTERS ROUTINELY ESTIMATE THE economic potential of a standing forest resource as lumber. It is usual to consider the straightness and size of a tree to estimate gross recovery and the range of lumber products that might be produced. However, such estimates are usually subjective and depend on the knowledge and experience of the assessor. Several conversion modeling packages are available to assist with such appraisals, but these require an established library of log data, or require detailed and expensive log measurements. Fortunately, many tree attributes that influence lumber out-turn can be easily and objectively appraised, and these easy-to-measure attributes can be used to infer a larger suite of log characteristics.

This paper briefly describes a computer-based conversion modelling system that emulates components of a wood-processing system and enables users to create a custom wood-processing facility producing lumber, veneer, or other products. It examines the attributes of trees that need to be quantified for such simulation to proceed, describes how routine timber cruising can record these details, and discusses how a user may modify these attributes to reflect different silvicultural regimes. It also describes the accounting module which enables detailed financial analysis of conversion strategies, and of the whole value chain. The system challenges forest managers to examine silvicultural options in a broader context, focusing not on a “better log”, but on creating more value in the lumber marketplace.

INTRODUCTION

Wood production in Australasia has undergone considerable change over the last 30 years as the wood-using industries convert from native forest to plantation-grown wood. Change continues with pace now as hardwood plantation production emerges and native forests are conserved free of harvesting.

Sawmills are the primary wood users and are becoming more exposed to global markets; they are, consequently, reducing margins. The importance of management has never been so critical, nor the impact of wood quality more important to achieving commercial goals.

It is the goal of both producer and processors to optimize the profitability of the industry. Therefore, management is mainly about manipulating the character of wood, the design of processes, and as far as possible the price of products.

The problem that faces most managers is: How can resource quality be evaluated inexpensively so that different management scenarios can be compared?

The parameters contributing to this analysis are:

- Available processing options
- Market for products
- Average properties of clear wood and variation
- The presence and impact of defects

The important message from this discussion is that value, and therefore quality, is a “local” variable. That is, the resource produced in say Southeast Queensland needs to be different from wood grown in the Northwest of the United States.

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For sawn-wood processing, the primary process-efficiency parameters are the scope and *variation* of wood properties and defect distribution. The *average* values contribute most substantially to product price. Simulation is ideal for this kind of problem because the variety in the character of a wood resource can be accommodated sensibly.

Industrial optimization, in the context discussed here, requires a resource simulator and a process simulator. That is, a component that can create virtual stems and a component to convert these stems into virtual products.

The resource description component is the most difficult because of the level of detail required by product grading systems, and the apparently wide variation in the relevant quality parameters. Both these features need to be accommodated if simulation is to incorporate both finished-product value estimates as well as process-cost estimates.

Models and simulators of various types span the range of application from standing stems to finished product. For example:

- Yield models are used extensively to program wood flows
- MARVL (NZFRI 1987) is an example of a system that provides yield by log quality classes
- CAPSIS and WinEPFN (Meredieu et al. 1999) are examples of simulators that combine yield or growth models with conversion simulators to provide estimates of processed product yield by value
- AUTOSAW (Todoroki 1990) is an example of a complex conversion simulator enabling optimization of saw pattern and grade recoveries using virtual logs that include knot defect information. This system has also been combined with production models to provide stand management optimization like WinEPFN
- GRASP (Occena and Schmoltdt 1996) is a sawing simulator developed in the USA that uses sophisticated 3D solid-log representations with shape and defect derived from CT (computer tomography)
- SATECH (Saatech Systems Pty Ltd.) is a very simple saw pattern simulator that uses log sizes and minor variations in shape to optimize recovery
- WOODEYS SIM (Innovative Vision) is a docking simulator that can provide product yields by quality class from board character inputs collected by a scanner/docker system

In the view of the author, if these systems are considered in the context described above, potential problems exist that include:

- The localized nature of detailed resource character and process design inputs
- Limited breadth of resource characters that are supported by simple systems
- The high cost of detailed data such as provided by computer-aided tomography

Additionally, for many potential users, data and or models that describe stem features may not be available, e.g., growth and taper functions, knot models, density models, etc. For these users, inventory and general and known statements of correlation between stem characters are the only sources of input data.

In Queensland, the public wood producer has attempted to solve these problems by adapting WinEPFN to local parameters. This required a significant rebuild of the system to incorporate local models and grade rules which are “hard coded”.

What is needed is a broadly applicable software system that can be used to define or describe detailed stem characteristics for a virtual resource using whatever input data that can be assembled easily and/or cheaply. In particular, the use of standing resource inventory data offers the best opportunity to capture local resource character.

A software system such as this could be applied to a variety of problems; for example, resource valuation, strategic planning of merchandising processes, and process design optimization to name a few. The application of such a system may also be widened if data can be manipulated by “skilled” users to reflect novel stands that may be the objective of breeding or silviculture.

INVENTORY DATA

For the purpose of developing and now demonstrating the operation of the system, the following inventory data were gathered to describe stems.

- Diameter at breast height and total tree height
- Taper formed from height and diameter
- Stem form assessed by measuring the height of each bend in the measured stems, the direction of the bend measured by compass, and the deviation of the bend from straight estimated as a proportion of stem diameter at the bend node
- Crown assessed by locating points in the stem that correspond to the bottom of the growing crown (identified by the lowest dead branch) and the bottom

of the live crown (identified as the branch node above the lowest dead branch)

- o At each point on the stem, a collection of local branch nodes assessed—the number of branches, along with the size and the direction of each branch was recorded (branch size estimated by eye as a proportion or percent of stem diameter at the point of branch location)

While this format was implemented here, the system was designed to accommodate any format adopted by the user.

The important point to be made is that the nature of the inventory is not limited and, in practice, more detailed and expensive data collection can be accommodated with the obvious advantages of accuracy and detail that can be achieved through a more complex inventory.

A Resource Maker

The system described here attempts to meet the goal of generic application.

The system includes:

- An abstract data structure that describes a stem including all the characteristics that a user or application demands
- Tools to read data of various types
- Tools to display and manipulate data
- Tools to make new simulated data
- A tool to display the stems

An important concession is made in the design of the system in order to maintain reasonable cost and accessibility. A virtual stem of sufficient complexity to represent the characteristics that define product value is assumed to be resolved by a collection of 3D forms located in Cartesian space. These forms, in turn, are described by simple mathematical expressions.

The principle reason for making this concession is that any stem may be stored more efficiently within a computer as a collection of expressions rather than as a 3D-matrix or raster of point data values. The latter requiring large amounts of computer memory, e.g., 1m3 resolved to 1mm3 units equals 10⁹ bytes potentially.

Finally, a sawmill simulator is also under development that will convert virtual stems

to product grade by recovery data. It is the resource maker that is the focus of this document.

The Data Type “Stem”

At the center of the system is the abstract stem data type. This data type must be designed to accommodate all of the usual features of a stem that might impact either conversion cost or product grade and recovery. The design also needs to accommodate expansion so that other features may be accommodated as a given simulation context requires.

The user can define any additional variables to add to the data structure, and this feature is used to accommodate any wood-quality variable the user wishes to add. For example, microfibril angle or heart/sap wood.

The data structure includes the following types:

- values—single value data
- functions—a mathematical expression that solves to produce value of y for all x
- sequences—a sequence is a series of values or sequence members that describe characteristics that may be correlated between members; for example, the distances between branch nodes will be correlated to

Table 1—The stem data structure.

Attribute or Sub-attribute	Type of Entry
Age	single value
BHt	single value
DBH	single value
THt	single value
Growth = Function of age GHt [f (GAge)] GDia [f (GAge)] GAge	expression expression single value
Form = Sequence of Bends Bend = BndHt BndDir BndDev BndFrm	single value single value single value expression
HForm = Function of Direction Radius	expression
Taper = Function of height TprDia [f (TprHt)] TprHt	expression single value
Bark = Function of height and direction BrkHt BrkThk [f (BrkHt)]	single value expression
Crown = Probable sequence of Branch Nodes Branch Node = Node Ht, Array of Branches Branch = BrDia BrDir BrAng BrGnl BrDdl BrFrm	single value single value single value single value single value expression
Wood Properties = Array of Wood Property Wood Property = f (Age)	expression

- the distance between previous branch nodes
- probable sequences—similar to a sequence except that the input data relating to a sequence is a census for any single tree while data for a probable sequence are in samples; these types vary the manner in which the system treats them during resource design

During run time, two data structures are formed and utilized by the system. One structure is formed for input, and a second is formed as the simulated stems. In practice, the user enters data via the input structure, and then uses tools to create the simulated structure.

Data Input Tools

Data that can be utilized by the system include both numeric values and expressions. To accommodate the input of numeric data, the system includes an input file format designer, and a reader. The capacity to design input files enables the reading of any data file for any feature of the stem.

Input is assumed to be hierarchical. For example, for the following data structure,

```
VarA, ArrayA
    ArrayA = VarB, ArrayB
        ArrayB = VarC, VarD
```

the input file will be arranged as a series of values as follows:

```
VarA1.
    VarB11
        VarC111, VarD111
        VarC112, VarD112
        VarC113, VarD113;
    VarB12
        VarC121, VarD121
        VarC122, VarD122
        VarC123, VarD123;;
VarA2.
    VarB21
        VarC211, VarD211
        VarC212, VarD212
        VarC213, VarD213;
    VarB12
        VarC221, VarD221
        VarC222, VarD222
        VarC223, VarD223;;;;
```

The system interface is shown in the following figures. The upper dialog window in Figure 1 shows the data form through which the user defines DBH and total height, then opens a new form (lower dialog window) to enter data for the bend height, bend size, and bend direction of each bend within the stem.

The Function Design Tool

To accommodate input of functions, an interpreter is included within the system that can read and interpret functions (input as typed text) that may then be attached to data items. An analogy may be drawn with “macros” used in numerical analysis software such as spreadsheets. Figure 2 shows the function panel and an example expression defining growth in diameter at breast height as a function of age. This function has been formed by fitting a curve provided by the system of input data, by least squares. This approach or an external user-defined function may be used.

The Chart Tool

A data-charting module provides the user with data display capacity to view the manner in which variables are related. The chart tool also provides the interface for the “make” tools mentioned below.

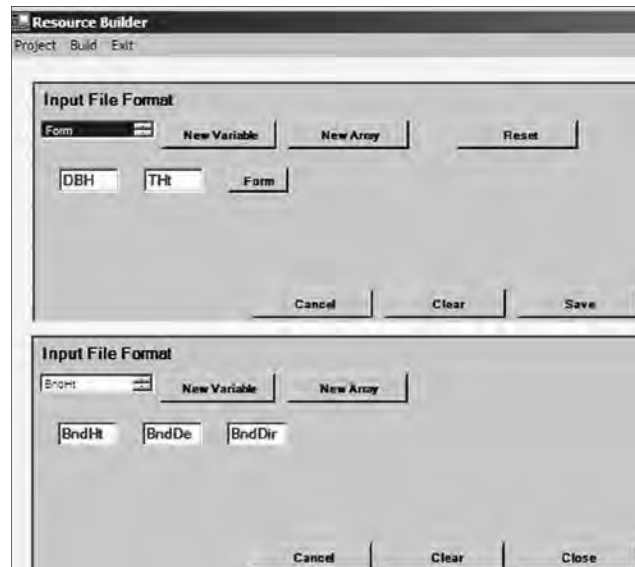


Figure 1: The input format definition panel. At level 1 (upper dialog window), diameter at breast height (DBH) and total height (THt) are defined. Then, the user accesses level 2 by clicking the “Form” button. This opens the lower dialog window through which the stem form is defined by entering, for each bend in the stem, the bend height (BndHt), bend deviation (BndDe), and bend direction (BndDir).

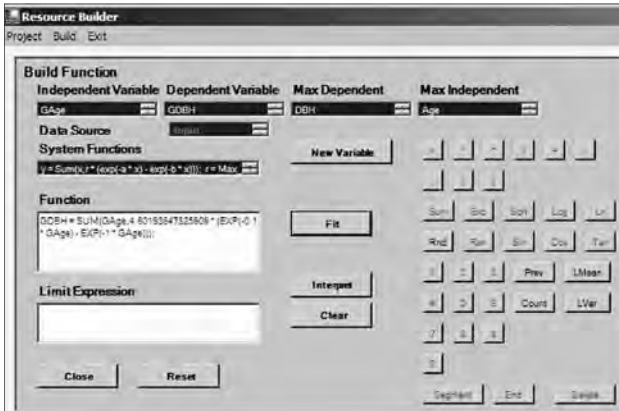


Figure 2. The function input panel.

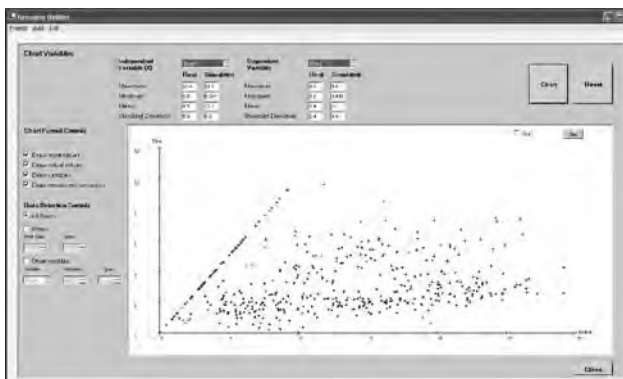


Figure 3: The data-charting panel showing input and simulated data values for inter-bend distance versus height in the stem.

“Make” Tools

At the core of the system is a set of tools that are designed to “make” data values or functions for simulated stems from input data or functions generated from real stems. The make tools include:

- Making single values
- Making functions
- Making sequences and
- Making probable sequences

Each uses the same general approach which is:

- Input data values are used to determine variability around an average value.
- This variation is used to select a simulated value either at random or biased to reflect a normal distribution in the input data. A further bias is applied to cause the make process to tend toward producing the same variability in the simulated data as is displayed by input data, i.e., the next value made will be selected to maintain the variance described by the input.
- Sequences are made from individual member data sets in sequence.

- Probable sequences use the average and variance of samples taken from the range of an independent variable to make simulated values.

Figures 4 and 5 illustrate the use of the “make” tools. Figure 4 shows the process through which one of the tools is used to define growth curves that display the development of simulated tree stems over time. Figure 5 illustrates the result of the “make” process for a specific example. The input values are shown by curves connecting light-colored points and the simulated growth curves are those connecting the black points.

The Display

Finally, a display tool is provided within the resource maker to visualise virtual stems. In Figure 6, profiles are displayed of a simulated stem showing the stem surface (upper image) and a cross section of wood density (lower image). Note that

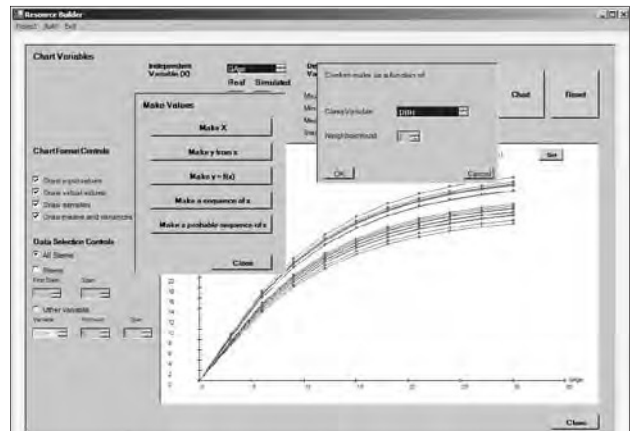


Figure 4. Using the “make” tools to form growth curves for simulated stems.

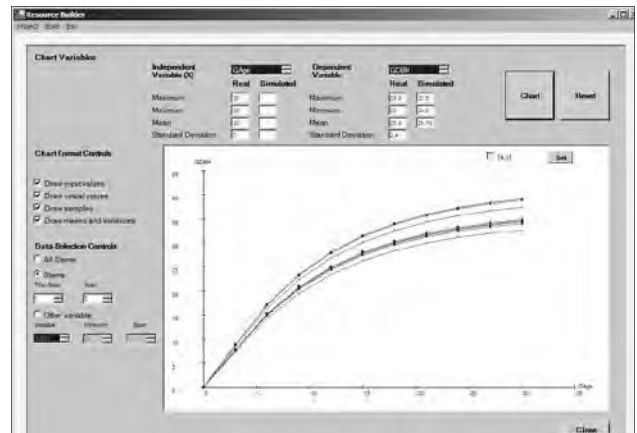


Figure 5: A display of input (curves connecting the light-colored points) and simulated (curves connecting the black points) growth curves for the first five stems of the input and simulated data sets.

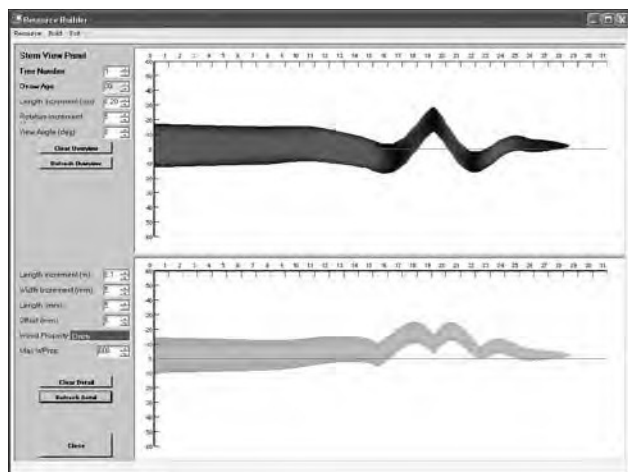


Figure 6: The display tool showing stem surface over bark (upper image) and cross-sectional variation in wood density (lower image).

in the stem-surface image, darker shading denotes bending into the image, giving information in the third dimension. For the wood-density image a simple relationship with diameter is displayed in only two dimensions.

Concluding Remarks

This discussion and demonstration have shown how the system may be applied to almost any application context that might arise. The system offers capacity for any user to exploit any form of input to create virtual 3D representations of tree stems that can be manipulated in Cartesian space by a conversion simulator.

While the system is fundamentally complete, minor developments continue to build a more robust system. In the next stages, the distribution of knots will be added to the system and display.

The system remains untested in any practical sense, however, and this is the subject of work that will go on over the next 3 years, using eucalypt hardwood plantations as the test environment.

The sawing simulator that is required to partner with the resource maker is also under development. The design of this system is similar to the resource maker in that it attempts to provide a design platform which would enable the user to design both saw patterns and the sequence of process stations that comprise process design. In this way, the system will attempt both to define product-grade volumes that form output and to estimate material flow rates and machine productivity.

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