Computers and Electronics in Agriculture 136 (2017) 97–110

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Robust learning-based prediction for timber-volume of living trees

Dong Zhang [a], Liyan Zhang [b], Qiaolin Ye [c,*], Honghua Ruan [d]

[a] School of Computer Science and Engineering, Nanjing University of Science and Technology, Nanjing 210094, China
[b] College of Computer Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China
[c] College of Information Science and Technology, Nanjing Forestry University, Nanjing 210037, China
[d] College of Biological and Environmental, Nanjing Forestry University, Nanjing 210037, China

ARTICLE INFO

Article history:
Received 18 August 2016
Received in revised form 29 December 2016
Accepted 24 February 2017
Available online 14 March 2017

Keywords:
Timber volume
Forest inventory
LSSVM
Virtual trees
Algorithm

ABSTRACT

Many existing timber volume calculating applications are applied by solving a single or multi-variables formulation, while most of those methods are based on the felled trees, which lead to a number of living trees is cut down yearly in different areas. In this paper, a novel learning-based nonlinear timber volume predicted model is proposed, which based on the least squares support vector machine (LSSVM) algorithm, and a modified particle swarm optimization (MPSO) algorithm is used to optimize the parameters involved in the LSSVM. Specifically, the initial weight coefficient in classical particle swarm optimization (PSO) is modified, such that the global optimal solution can be obtained more fleetly and accurately, meanwhile, the timber volume predicted model is established based on the modified algorithm. The experiments are carried out on our collected data, which are obtained from Xiashu plantation of Jurong in Jiangsu Province of China. Three kinds of trees, named Populus, Liriodendron and Soapberry, are selected as the experiment samples. The historical timber volume data of the same kinds, used as the training set in the proposed MPSO-LSSVM model, are obtained from the management of Xiashu plantation. The two properties from the manually measured data, including tree height and diameter at breast height (DBH), are used as the input parameters in the testing set of MPSO-LSSVM. Furthermore, the virtual trees, generated by computers, provide a novel approach to estimate the predicted accuracy of the learning-based model in forest inventory. The experiment results in comparisons with the solutions from volume equation, taper function, felled trees and the virtual trees demonstrate the availability and efficiency of the proposed model in prediction of timber volume.

1. Introduction

Nowadays, inspired by the problems about carbon sequestration and bioenergy resources, an accurate and detailed description to the living trees is a key object in forest inventory (Blackard et al., 2008). Especially, timber volume, which provides a crucial approach to calculate the volume of the forest, has became one of the most important research focuses (Maltamo et al., 2004). However, an intractable limitation to calculate timber volume is that the lack of an efficient but objective methodology.

In general, there exists three kinds of methods to calculate timber volume of living trees: experience-based one, terrestrial laser scanner TLS-based one and the hybrid one (Emery et al., 2014). The classical experience-based method mainly consists of three parts: volume table, volume equation and taper function, which is developed through the analyzes of DBH, tree height, felled down trees and the measured diameters at a regular interval along the stem (Jiang et al., 2005). Since different kinds of trees have different features, which resulting the experience-based method in a poorly generalized ability. Moreover, this kind of method often requires considerable time and large samples, then may can obtain an expected performance (West, 2009). Therefore, a mass of living trees needing to be felled down yearly for establishing the volume equations, volume tables and taper functions in different areas all over the world. Especially, each sample area has a limited number of species in the forest in practice. The method based on felled trees is very destructive to our fragile ecosystems (Navar et al., 2013). In order to overcome the weaknesses caused by the classical experience-based methods, researchers begin to focus on the non-contact method (Halabe et al., 2009). Specifically, the TLS-based method has been recently attracted much attention and applied to a wide range of areas (Riggio et al., 2014). During the past decades, the major part of the studies on TLS in forest inventory focused on developing intelligent methods for measuring DBH

* Corresponding author.
E-mail addresses: zhangd927@gmail.com (D. Zhang), zhangliyan@nuaa.edu.cn (L. Zhang), yeqiaolincom@163.com (Q. Ye), hhruan@njfu.edu.cn (H. Ruan).

http://dx.doi.org/10.1016/j.compag.2017.02.025
0168-1699/

and tree height (Ziegler et al., 2000). Although researches still need to put more attentions to data collecting, the potential for TLS on forest inventory has been demonstrated powerfully in practice. Since many studies require a more accurate parameterized description of the forest, some of the researches begin to focus on modeling living trees, and indicate that the most useful algorithms are based on sphere fitting, cylinder fitting and tree meshing (Rahlf et al., 2014; Latip et al., 2013; Dassot et al., 2012). However, due to the imperfection of the existing modeling algorithms, most of those studies just focused on the main stems and the major branches of the living trees. There are no or too few methods put attention to the fine branches, which may contribute large errors in calculating timber volume. In addition, the TLS has many extreme operating limitations, such as a flat ground surface and a wide forest interval. Those conditions are not always meet in the field. The exorbitant price of TLS and complicated procedures are also two major restrictions to the generalization of the TLS-based methods. Combined with advantages of the experience-based methods and the TLS-based methods, in recent years, some researches begin to focus on the hybrid method (Sun et al., 2016; Baltsavias et al., 2001; Määttä and Pesonen, 2000). Specifically, TLS is firstly used to measure the DBH and height of the living trees, and a volume equation or taper function is selected as the volume calculating model. Then, we need to manually select some representative samples in the study area and the felled trees, which are used to establish the coefficients involved in the volume model. After that, as the input parameters, the DBH and tree height are used to calculate the timber volume of the investigative forest. Although the hybrid method can avoid intensive labor, the felled trees are still required.

In order to overcome the disadvantages in previous methods. In this paper, we propose a novel learning-based nonlinear timber volume predicted model in forest inventory. Least Squares Support Vector Machine, based on the structural risk minimization (SRM) principle, is selected as the infrastructure in the predicted model. SRM minimizes the upper bound of the generalized errors instead of empirical risk minimization (REM) principles. Therefore, the solution of LSSVM may tend to a global optimum, and over fitting is unlikely to occur in LSSVM. A modified evolutionary computation (EC) stochastic technique, named as modified particle swarm optimization (MPSO), is used to optimize the parameters in LSSVM. The timber volume predicted model is established based on the modified PSO-LSSVM (MPSO-LSSVM), as show in Fig. 1 the proposed volume predicted model based on the MPSO-LSSVM mainly consists of four parts, which are data collection, data normalization, predicted model initialization and model application. Firstly, the related parameters involved in the LSSVM are determined by the MPSO method via the training set. Then, the timber volume of living trees is predicted by the testing set.

1.1. Contributions

We now state several highlights of our proposed model as follows:

(a) Applied innovation. It is the first time that the evolutionary algorithm and the learning-based technique are used to predict timber volume of living trees, an accurate but nondestructive approach is discovered. Moreover, a new idea is presented by applying the MPSO-LSSVM model to predict timber volume, researchers therefore just need to pay more attentions to more intelligent algorithms rather than data collecting.

(b) MPSO is an interesting modification of PSO, but with the injection of the self-adapted coefficient μ that makes the optimization problem intractable. In order to obtain a satisfactory solution, an "iterative procedure" is adopted to solve the proposed problem, which is common used in the fields of pattern recognition. The inertia weight coefficient μ in MPSO can be self-adapted under the changing of the fitness-function, such that the global searching performance can be improved effectively and the exploration ability can be coordinated preferably.

(c) As an important part in this study, a novel method based on the virtual trees is firstly used to estimate the accuracy of the timber volume predicted model. We generate a number of virtual trees that we have known the attributive parameters of every single tree, including tree height, DBH and timber volume. Then the proposed MPSO-LSSVM model is used to re-predict the timber volume of virtual trees. Through the comparisons between the "known" volume and the predicted results, we can obtain the predicted accuracy of our proposed method.

1.2. Organizations

The remainder of this paper is organized as follows. In Section 2, the basic condition of the study area and the existing timber volume predicted methods are introduced briefly, and our proposed timber volume predicted model based on the learning algorithm is introduced in detail. The data analysis process, experiment setting and experiment results are presented in Section 3, the discussion is given in Section 4. Finally, the paper is concluded in Section 5.

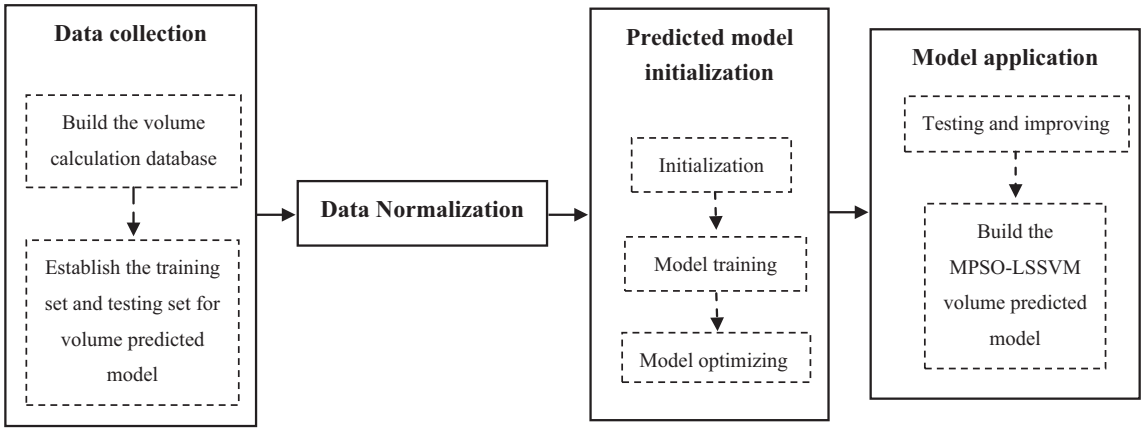

Fig. 1. The procedure of the proposed timber-volume predicted model.