Pine Crown and Trunk Diameter Dependence Research

Alexey S. Pyataev[1,2], Andrey A. Vais[1]

[1]Reshetnev Siberian State University of Science and Technology, Krasnoyarsky Rabochy Av 31, Krasnoyarsk, Russia, 660037
[2]Branch of FBI «Russian Centre of Forest Health» – «Centre of Forest Health of Krasnoyarsk Krai», Akademgorodok 50A building 2, Krasnoyarsk, Russia, 660036

Abstract. In this paper, we propose a method for estimating crown diameters from the trunk diameters of Scots pine in high-full stands. In such conditions, computer vision methods are not able to clearly distinguish the boundaries of the tree crown under study due to the significant mutual penetration of the crowns of trees. For this approximating functions based on the diameters of the crowns of the steps in the thickness of the tree trunk are built.

Keywords: tree crown, approximation, Pinus sylvestris.

1   Introduction

The tree crown plays a very important role in the various characteristics of forest stands determining process. Such crown parameters as density and color characterize the health state of the tree, crown density affects species competition between trees [1-3], canopy density influences on woodland canopy characteristics and crown fire potential [4], even wood quality can depend on crown characteristics [5]. The crown of the tree is formed under the influence of various indicators and factors, such as distance between crowns and degree of their mutual penetration, crown illumination degree[6], winds speed and force [7,8], etc.

One of the automatic crown estimation problem solving variant is the analysis of visual data, for example, when determining the category of a tree's sanitary condition. Using computer vision methods, it is often difficult to identify the crown boundaries of a particular tree in high-density plantation, as the crowns of trees penetrate significantly into each other. Nowadays the tree crown evaluation and conclusions could be made empirically by using a human resource, therefore, the task of automatically evaluating the shape of a crown is relevant. Evaluation of the characteristic diameters of the crown projections, for certain conditions of the growing areas of forest areas, can be performed using static data depending on the diameter of the trunk [9]. A similar problem for Larix principis-rupprechtii was solved in [10]. The proposed methods establish changes of the tree crown width and heights and tree trunk size dependence of age and dominance of the tree in the plantation. In addition, in this work, a rough tree model was constructed, represented by geometric primitives: two cones and a cylinder (Fig. 1)
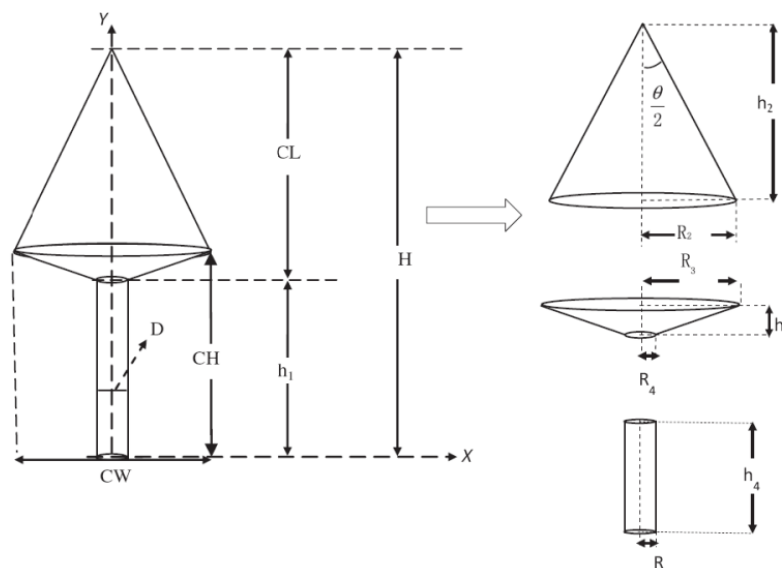

Figure 1. Representation of Larix principis-rupprechtii model.

Parameters in Figure 1: H - tree height; D is the diameter of the tree trunk at chest level; CW - maximum crown width; CL - total crown height; CH - height to the widest part of the crown; h1 is the height of the lower part of the barrel; h2 is the height of the upper cone; h3 is the height of the lower cone; h4 is the height of the cylinder; R2 is the radius of the base of the upper cone; R3 and R4 are the radii of the bases of the lower cone. In [11], researchers searched for an allometric relationship between trunk diameter at chest height and crown diameter of healthy trees from young to aged stages of their growth. In this study the authors included only detached urban trees, that allows to obtain data of the species growth potential in typical urban conditions, linking them with the estimated age of the trees. In [12], the inverse problem is considered. The authors predict the diameter of the tree trunk, depending of its crown size, by the materials obtained using aerial vehicle laser scanning. The authors of [13] evaluated models for predicting tree heights depending on their diameters.

Thus, the crown diameters due to trunk diameters dependence assessment , specific for a certain completeness of a plantation, will help to increase the reliability of determining the crown boundaries using computer vision methods from images in high-density plantations.

2   Pine crown dependence due to trunk

In paper [14] an fuzzy logic based approach was proposed to determine the category of tree state. Such an approach allows to formalize the subjective representations of a specialist, on the basis of which decisions are made. The following variables such as the degree of density of the crown, growth, the degree of drying of the branches, the decay of the bark, and the color of the needles were used as linguistic variables. A spline approximation of piecewise linear membership functions using Gauss functions was performed at work [15]. The crown state determination by specialist is rather difficult in a wild because of complication of the crown boundaries visual determination for a particular tree due to the high density of the forest canopy (Fig. 2).

Figure 2. High-density pine plantations.

As well, for the one health state category it could be large variability of crown density within the class: the crown density difference can reach 30%. Therefore, the paper proposed using methods for assessing the dependence of the size of the tree's crown on the diameter of its trunk to estimate crown density and form. This will increase the accuracy of living trees differentiation by categories of health state, especially since measuring trunk diameters is one of the mandatory requirements when forest taxation or forest pathological surveys are conducted.

The close proximity of the growing trees affects the mutual crowns penetration, that affects their diameter, it will be different from the average crown diameter of free-standing trees. The scientists of the Reshetnev Siberian State University of Science and Technology measured the diameters of crowns and trunks in forest stands with high density from plantations growing near the Kuragino in the Krasnoyarsk Krai. The data measurements were obtained about 400 pine trees of different diameters, ages, and health conditions.

Using a statistical analysis of the data measurements, the average dimensions of the pine crowns were derived, grouped by the thickness steps of the trunks. In addition, statistical indicators were calculated, such as standard deviation and standard error, showing a measure of the difference between the average crown diameters and the crown diameters of the sample. Table 1 presents the calculated statistical indicators, grouped by trunk diameters, as well as the number of trees in the calculations involved.

Table 1. The pine crowns average diameters distribution

Trunk diameter step,cm	Crown avg diameter	Standard deviation	Standard error	Trees count

4	1,08	0,24	0,08	10
8	1,44	0,48	0,12	17
12	1,88	0,64	0,1	39
16	2,95	1,48	0,26	32
20	3,44	0,9	0,22	17
24	4,16	1,58	0,25	41
28	4,45	1,78	0,32	30
32	4,64	1,96	0,41	23
36	4,86	2,04	0,33	38
40	6,02	2,13	0,39	30
44	5,95	2,28	0,72	10
56	6,38	1,03	0,52	4

Figure 3 shows the original and averaged statistic data. A function based on averaged statistic data and describing the dependence the pine crown diameter from the trunk diameter is piecewise linear.
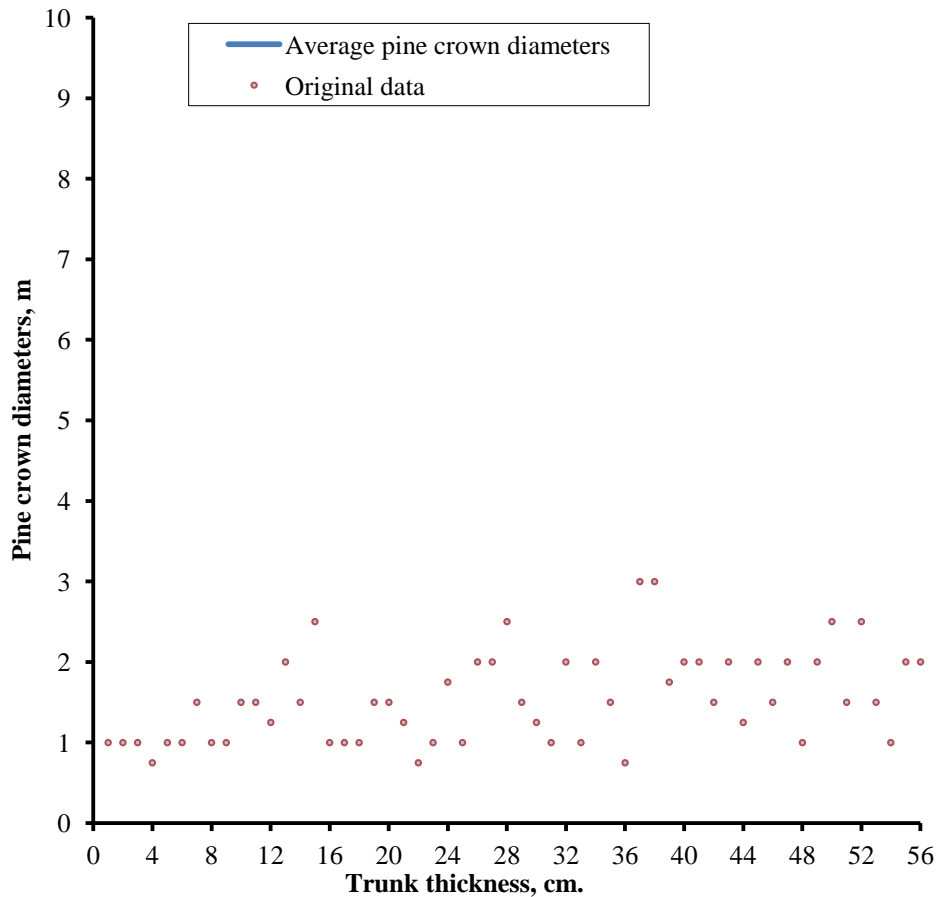

Figure 3. Regression line reflects crown diameter and thickness stage dependence.

3 Approximation by Gauss functions

For the convenience of calculations, the constructed piecewise linear function was approximated by Gauss functions. Two approaches were considered: approximation by one function and approximation by several Gauss functions. The first approach is presented by formula 1.

$$g(x) = 11e^{\frac{-(x-80)^2}{2380}} + 0.5, x \leq 52 \tag{1}$$

Comparative graphs of the initial and approximated functions are presented in Figure 4.
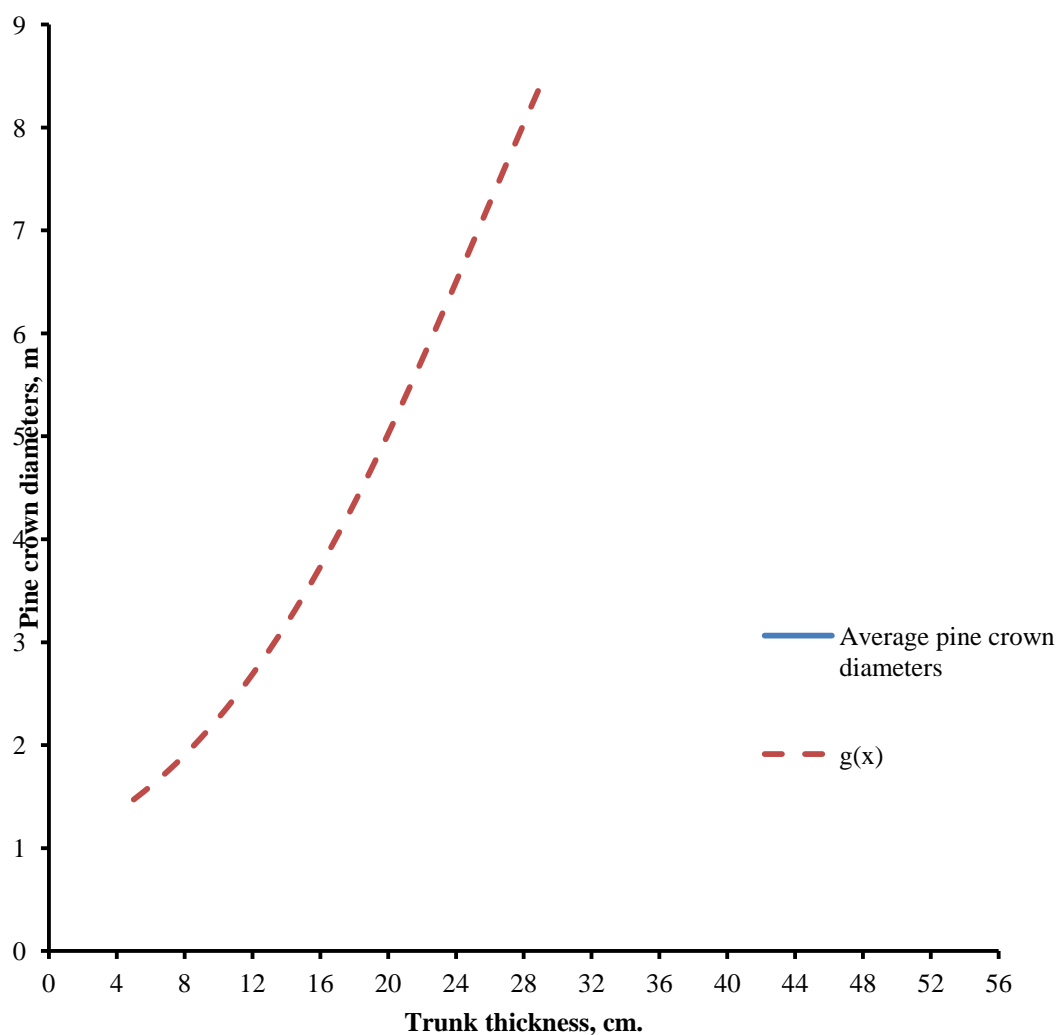

Figure 4. The average crown diameters function by the Gauss function approximation.

Despite the visual difference, the calculations show that the average approximation error is 13%, which fits into the acceptable limits.

Table 2. Approximation error of one function used.

Trunk diameter step,cm	Crown avg diameter	g(x)	Error, %	Avg error, %
4	1,08	1,47	36,29	
8	1,44	1,75	21,27	
12	1,88	2,08	10,47	
16	2,95	2,47	16,32	
20	3,44	2,92	14,99	
24	4,16	3,45	17,16	13,11
28	4,45	4,03	9,38	
32	4,64	4,68	0,84	
36	4,86	5,38	10,65	
40	6,02	6,12	1,61	

44	5,95	6,88	15,67	
52	8,19	8,41	2,73	

The second variant of approximation by several Gauss functions is represented by formula 2.

$$g(x) = \begin{cases} 3{,}9e^{\frac{-(x-30)^2}{327{,}68}} + 0{,}6, x \le 28 \\ 3.7e^{\frac{-(x-52)^2}{112{,}5}} + 4{,}5, x \in (28{,}52] \end{cases} \tag{2}$$

The graphs of these functions are presented in Figure 5.
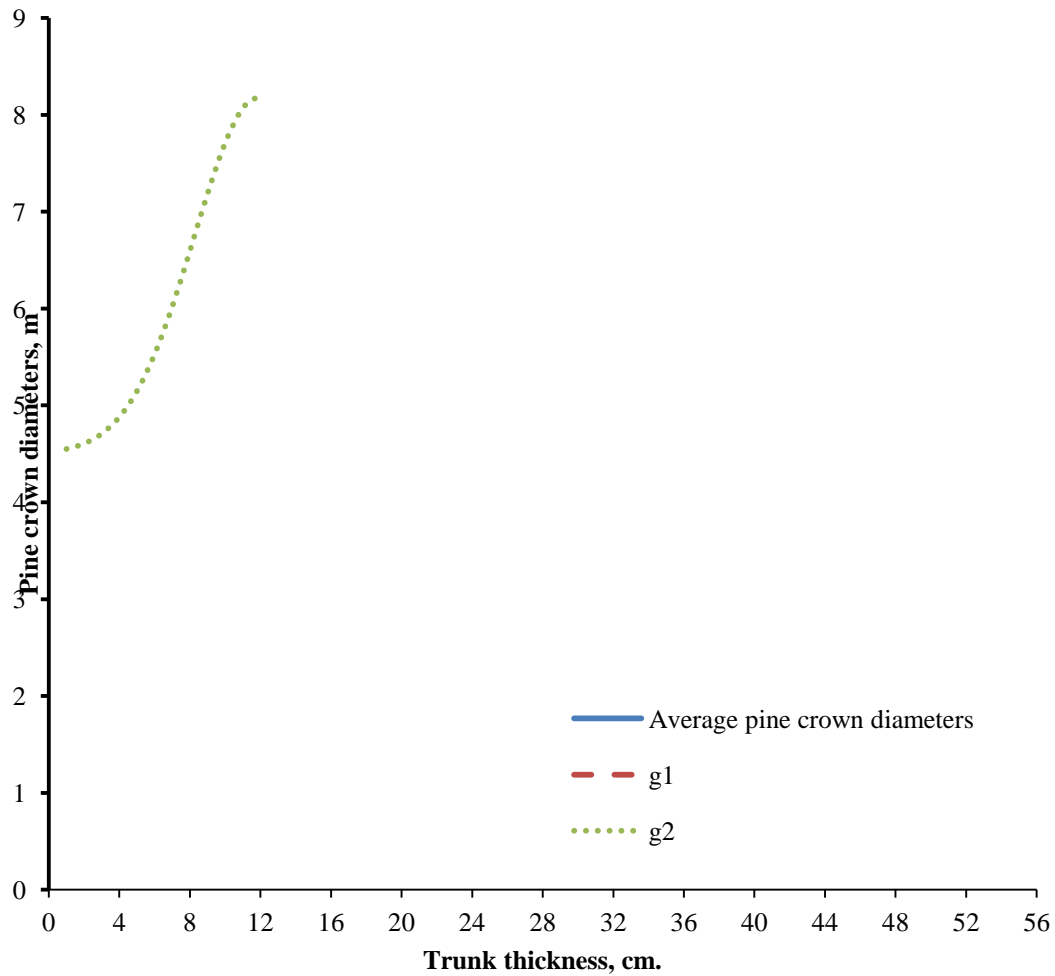

Figure 5. The average crown diameters function by the two Gauss function approximation.

The graphs show that the discrepancy between the values of the initial and approximated functions is insignificant. This is confirmed by the calculations of approximation errors, which are shown in table 3. The average error value indicates well-chosen approximating functions.

Table 3. Approximation error of two function used.

Trunk diameter step,cm	Crown avg diameter	g(x)	Error, %	Avg error, %
4	1,08	1,1	1,44	
8	1,44	1,49	3,5	3,38
12	1,88	2,05	9,09	

16	2,95	2,74	6,97	
20	3,44	3,47	1	
24	4,16	4,09	1,58	
28	4,45	4,45	0,06	
32	4,64	4,61	0,74	
36	4,86	4,88	0,41	
40	6,02	5,53	8,16	4,05
44	5,95	6,59	10,84	
52	8,19	8,2	0,12	

Thus, using one-function approximation of the function describing the dependence the pine crown diameter from the trunk diameter shows an average approximation error of 13%, at the same time using of two-function approximation gives an average error of 4%.

Table 4 shows the scattering of the pine crown diameters in steps of trunk thickness relative to the average value and the values obtained by approximation.

Table 4. Comparative deviations of calculated pine crown diameters from the real ones.

Trunk diameter step,cm	Standard deviation	Deviation from 1 function	Deviation from 2 functions
4	0,2372	0,4805	0,2382
8	0,4803	0,5738	0,483
12	0,6435	0,674	0,6668
16	1,4817	1,5616	1,4968
20	0,8993	1,0456	0,9
24	1,5789	1,7362	1,5803
28	1,778	1,8282	1,778
32	1,9581	1,9585	1,9585
36	2,0398	2,1071	2,04
40	2,1273	2,1297	2,1845
44	2,2785	2,481	2,3777
52	4,13	4,1382	4,1301

By the results presented in tables 3 and 4, we can see that the two function approximation is most preferable, since it is the most accurate.

4 Conclusion

In the study of high-density plantations using computer vision methods, difficulties arises in pine crown boundaries determination, therefore, the approache proposed in this paper could be a pine crown parameters correcting factor in case of contentious situations.

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