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Use of forest inventory data as a new method for cadastral valuation of forestlands in North-West Russia

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Abstract. Cadastral valuation of forestlands is poorly developed in Russia. Current methods of evaluation either depend on the probability of harvesting or do not differentiate forest areas by forest stand properties. In this study authors propose to use forest inventory data as a basis for cadastral evaluation of forestlands. At first, forest inventory data is reviewed and variables making the largest contribution to evaluation are determined using correlation matrix. Second, forest inventory data is brought to common comparison year using regression equations of stand development. After that, graphic presentation of cadastral value dependence on inventory data is visually analysed. Results of analysis allow calculating of relative value of forestland and get to absolute value using average regional cost index. Evaluation results correlate with Faustmann method.

Key words: correlation matrix, gradient vector, Faustmann's formula.

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Introduction

Russian forestlands occupy 1.144 billion hectares or 64% of the total land area of the country (Federal Forestry Agency, 2012). According to Russian legislation all forest land is state owned and private forest holdings are not allowed (Forest Code, 2006). Agricultural land can not be used for planting of private forests, either (Land Code, 2001). States provides forest management by itself and allows renting forestlands for procurement of forest and non-forest resources. Charge for the forest using can be collected as a rent or as the payment under the procurement contract for standing timber (Forest Code, 2006). These revenues are expected to compensate state expenses for forest management and reforestation. For rent calculation forest site cadastral value should be known. Also, cadastral value is helpful for state land management – knowing the value helps local government to correctly allocate the land for different purposes, e.g. for pipe line construction. But nowadays methods of forestland cadastral evaluation develop very slow.

Currently there are two forestland cadastral valuation methods in Russia. The first is the method of Roszemkadastr (it is the short name of Federal Land Cadaster Service of Russia) of year 2002 (Federal Land Cadaster Service of Russia, 2002), which specifies the methodology of the Federal Forestry Agency of year 2000 (Fed-

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eral Forestry Agency, 2000). The second is method of determining the value using the specific indicators of cadastral value (UPKS, in Russian: УПКС).

Roszemkadastr method is based on the profit that can be reached from forestland, using the formula proposed by the German forester Faustmann in 1849 (Amacher *et al.*, 2009). Input variables are rotation age, current age, harvesting revenue, standing volume, forest management expenses, discount rate. Output variable is cadastral value of 1 hectare of forestland. This method is economically convenient, but it can be applied only if profit can be derived from the forest area. After the financial crisis in 2008, harvesting in Russia became unprofitable, so cadastral value calculated using this method goes negative or close to zero (Cairns, 2012). It makes the use of this method meaningless, thus, it was canceled by the Russian Government in the year 2010.

Alternatively, there is the UPKS method based on a specific index that relates to the value of one hectare of forestland. UPKS is defined for every region of Russia. It is easy to use, but we can't speak about any differentiation in terms of forestland cost.

So, there is no working method for forestland valuation in Russia now: Roszemkadastr method is difficult to use under the conditions of forestry depression; UPKS method uses one unit cost for whole region. That is very rough for such a big forest territories of North-West Russia. For example, area of forestlands in Saint-Petersburg region is twice more than in Estonia (Food and Agriculture Organization of the United Nations, 2011), so identical cadastral value obviously is not enough for full evaluation.

The purpose of study is to develop the alternative method, that would not directly take into account the profitability of harvesting, but let assessor to consider different quality of varied forest sites.

Material and Methods

Obtaining data

Inventory data of forest stand, which is available in each forest district, is an important part of forest management in Russia. We decided to statistically analyze the contribution of each stand variable in the value of forestland.

Inventory data of forest stands in Russia is valid for 10 years and is needed to be updated within the given time (Kovyazin, 2013). Forest inventory data is the basis for the calculation of forestland cadastral value. It is represented in stand inventory papers in an uncomfortable form for statistical purposes. Therefore, on the preparatory stage we digitalized them into the appropriate representation. For the study, the data set of 100 sites from Saint-Petersburg Kurortny forest district (Figure 1) is presented. 8 sites are occupied by pure broadleaved stands, 30 sites are occupied by pure conifer stands. 21 sites are occupied by mixed stands with predominance of broadleaved species, and 41 sites – by stands with predominance of conifers.

Table 1 shows main information about investigation object. We use some inventory data, which can directly influence the value of the forestlands (Minayev, 2010). Spatial data (distance to the nearest road or loading point) is important too, but it's not included in the scope of investigation due to lack of appropriate information. Spatial data is useful for freight charges calculation. So, if we have enough material, we will add it to results as correction coefficient.

Selection of significant variables

These variables are: part in wood composition; age, average height and diameter of forest stand; growing stock. The set of variables for each site is presented in Table 2.

The review of Table 2 shows that there are too many variables and using them in full makes the model very complicated. So we switched to using the weighted average

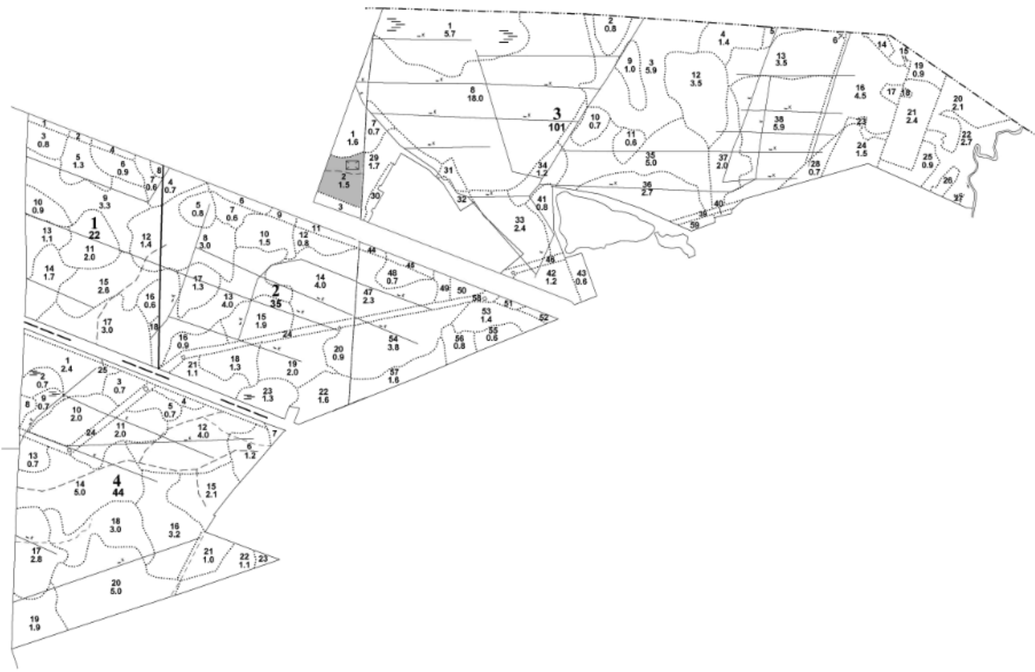

Figure 1. Investigation object.

Table 1. Information about investigation object.

Parameter	Value				
Number of sites	100				
Average site area	1.7 ha				
Average site standing volume	182 m³/ha				
Tree species	Whitewood (E)	Redwood (C)	Birch (Б)	Alder (Ол)	Aspen (Oc)
Average composition	20%	50%	20%	< 10%	< 10%
Average age, years	62	61	49	55	46

values of age and diameter accordingly to tree species composition (Table 3).

After selecting of the variables that can be used in a mathematical model for determining of the cadastral value, we should find the correlation ratio between them, because the presence of the variable-to-variable correlation significantly reduces the accuracy of the result. In order to get this done, the correlation matrix was constructed (Table 4).

According to the correlation matrix, it becomes possible to trace close connection ($|R| > 0.6$) between the variables. The correlation coefficient between the shares of content of birch and pine plantations equals 0.74. It is connected with the interspecific biological competition between these tree species that should be considered during building the model. Stand inventory variables such as average diameter, age, height and standing vol-

Table 2. Variables affecting results of cadastral valuation of forestlands (fragment).

Site #	Tree species composition, unit fraction					Age, years					Diameter, cm					Height, m	Standing volume, m³/ha
	Б	Ол	Е	С	Ос	Б	Ол	Е	С	Ос	Б	Ол	Е	С	Ос		
1	0,5	0,5	0	0	0	55	55	-	-	-	18	20	-	-	-	17	124
2	0,5	0,5	0	0	0	65	65	-	-	-	20	22	-	-	-	18	136
3	0	1	0	0	0	-	70	-	-	-		24	-	-	-	18	136
4	0,3	0,7	0	0	0	55	35	-	-	-	16	18	-	-	-	16	93
5	0,1	0	0	0,9	0	45	-	-	65	-	14	-	-	22	-	18	181
6	0	0	0	1	0	-	-	-	65	-	-	-	-	18	-	15	123
7	0,2	0	0	0,7	0,1	25	-	-	30	25	8	-	-	14	-	9	82
8	0,1	0	0,1	0,8	0	40	-	50	60	-	16	-	18	18	-	17	197
9	0,7	0,2	0,1	0	0	65	65	70	-	-	20	22	22	-	-	18	136
10	0,2	0	0,6	0,2	0	65	-	80	75	-	20	-	24	22	-	19	232
11	0,8	0	0,1	0,1	0	50	-	55	60	-	18	-	20	18	-	17	144
12	0,7	0	0,2	0	0,1	60	-	60	-	55	20	-	22	-	22	18	158
13	0,1	0	0,6	0,3	0	50	-	60	60	-	16	-	20	20	-	19	232
14	0,2	0	0,2	0,6	0	50	-	60	70	-	16	-	20	20	-	18	211
15	0,1	0	0	0,9	0	40	-	-	65	-	14	-	-	18	-	16	153

Note: Е – whitewood; С – redwood; Б – birch; Ол – alder; Ос – aspen.

Table 3. Variables affecting results of cadastral valuation of forestlands (fragment).

Site #	Tree species composition, unit fraction					Age, years	Diameter, cm	Height, m	Standing volume, m³/ha
	Б	Ол	Е	С	Ос				
1	0,5	0,5	0	0	0	55	19	17	124
2	0,5	0,5	0	0	0	65	21	18	136
3	0	1	0	0	0	70	24	18	136
4	0,3	0,7	0	0	0	41	17	16	93
5	0,1	0	0	0,9	0	63	21	18	181
6	0	0	0	1	0	65	18	15	123
7	0,2	0	0	0,7	0,1	28	11	9	82
8	0,1	0	0,1	0,8	0	57	18	17	197
9	0,7	0,2	0,1	0	0	66	21	18	136
10	0,2	0	0,6	0,2	0	76	23	19	232
11	0,8	0	0,1	0,1	0	52	18	17	144
12	0,7	0	0,2	0	0,1	60	22	18	158
13	0,1	0	0,6	0,3	0	59	20	19	232
14	0,2	0	0,2	0,6	0	64	19	18	211
15	0,1	0	0	0,9	0	62	18	16	153

Note: Е – whitewood; С – redwood; Б – birch; Ол – alder; Ос – aspen.

Table 4. Correlation matrix.

Variable	Tree Species					Age, years	Diameter, cm	Height, m	Standing volume, m³/ha
	Б	Ол	Е	С	Ос				
Б	1								
Ол	0,02	1							
Е	-0,19	-0,15	1						
С	-0,74	-0,38	-0,30	1					
Ос	0,40	-0,08	-0,12	-0,45	1				
Age	-0,39	0,06	0,27	0,22	-0,43	1			
Diameter	-0,31	0,10	0,42	0,03	-0,28	0,84	1		
Height	-0,16	0,02	0,37	-0,07	-0,09	0,76	0,90	1	
Standing volume	-0,47	-0,24	0,49	0,27	-0,33	0,69	0,73	0,77	1

Note: Е – whitewood; С – redwood; Б – birch; Ол – alder; Ос – aspen.

ume are interconnected; their correlation coefficients range from 0.69 to 0.90. Obviously, these four variables are interrelated: mature trees are higher and have a larger yield of wood than young ones. Thus, it is possible to exclude average diameter and height of the stand from the model, as these variables are closely related to the other two – age and growing stock, so average diameter and height can be expressed in terms of standing volume. We should note that economic attraction of a forest area is determined by standing volume, which essentially depends on these variables.

Considering the wood increment

It's should be noted that inventory data is received only once per ten years so it's important to consider the changes in inventory data during this period. In this study we have one main variable depending on forest stand age – it's standing volume. Using yield tables (Moshkalev, 1984) we can establish regression equation describing this dependence (1,2):

$$V_1' = V_1 \cdot (1 + \frac{14.783 \cdot \exp(-0.021 \cdot (t + \Delta t)) \cdot \Delta t}{100}) \quad (1)$$

$$V_2' = V_2 \cdot (1 + \frac{17.822 \cdot \exp(-0.03 \cdot (t + \Delta t)) \cdot \Delta t}{100}) \quad (2)$$

where:
V_1' – corrected standing volume of conifer species;
V_1 – simple standing volume of conifer species;
V_2' – corrected standing volume of broadleaved species;
V_2 – simple standing volume of broadleaved species;
t – average weighted forest stand age;
Δt – time from the last inventory to comparison year.

Preparatory stages

The next stage of the research is getting variable or the system of variables that would reflect the composition of forest stand, not overloading model with unnecessary information at the same time. Since the predominance of conifer species in the stand composition leads to the increasing of monetary value of the stand, and the predominance of broadleaved species leads to the reducing of it, it is possible to divide the entire stand into two corresponding groups; we measure them in unit fractions.

Use of the fractions of conifer and broadleaved species together is impractical because they are completely collinear (you always can express one through another). Therefore, we use fraction of the conifer species as the main variable, which reflects the composition of the forest stand (Table 5).

Table 5. Final presentation of the variables affecting the results of cadastral valuation of the forestlands (fragment).

Site #	Fraction of conifer species	Age, years	Standing volume, m³/ha
1	0	55	124
2	0	65	136
3	0	70	136
4	0	41	93
5	0.9	63	181
6	1	65	123
7	0.7	28	82
8	0.9	57	197
9	0.1	66	136
10	0.8	76	232
11	0.2	52	144
12	0.2	60	158
13	0.9	59	232
14	0.8	64	211
15	0.9	62	153

From the initial data, we can see that the vast majority of the forest stand has not reached the maturity stage, so the determining variable is not the age of stand, but the time remaining to the reaching of maturity age; this is the difference between the actual and the maturity age. In Russian forestry average normative maturity age equals 60 years for broadleaved species; for conifer species, it takes 80 years. Using the obtained data, we determine the weighted average time to the end of rotation period as the sum of productions of the time before harvesting for conifer and broadleaved species on their fraction in the composition of the forest stand.

To switch to the unified measurement system and correct account of distances between the variables, the obtained values were normed by dividing each of the values to the maximum value in the sample. Maximum standing volume which is taken as a unit, is on the site #34 and it equals to 268 m^3/ha.

As the dependence of the value on the time to the end of rotation period is inverse, it is profitable to turn it into direct for the convenience of working with it. For this purpose all normed values of the time to the end of rotation period were deducted from a unit and got forms of inverse values.

Fraction of conifer species contributes only to the cost per cubic meter, so it can be taken into account after all the basic calculations. According to the data of Rosstat (Russian Statistical Service) in the period from 2007 to 2013 one cubic meter of softwood cost from more than a cubic meter of hardwood in an interval between 0.95 and 1.40 times (mean for seven years equals 1.20 times). Then, the coefficient increasing the cost of timber for pure hardwood stand equals 1, and for pure conifer stand it equals 1.20. To the sites in the intermediate state formula has the form (3):

$$k = 1 + d \cdot 0.20 \qquad (3)$$

where:
k – coefficient increasing the cost of timber;
d – conifer species fraction in the forest stand.

Geometric interpretation

Thus, after excluding the fraction of conifer species, there are still two stand variables affecting the cadastral value – time to the end of rotation period and standing volume. Known variables for each site can be projected onto a plane, so that the ordinate is marked as standing volume and the ab-

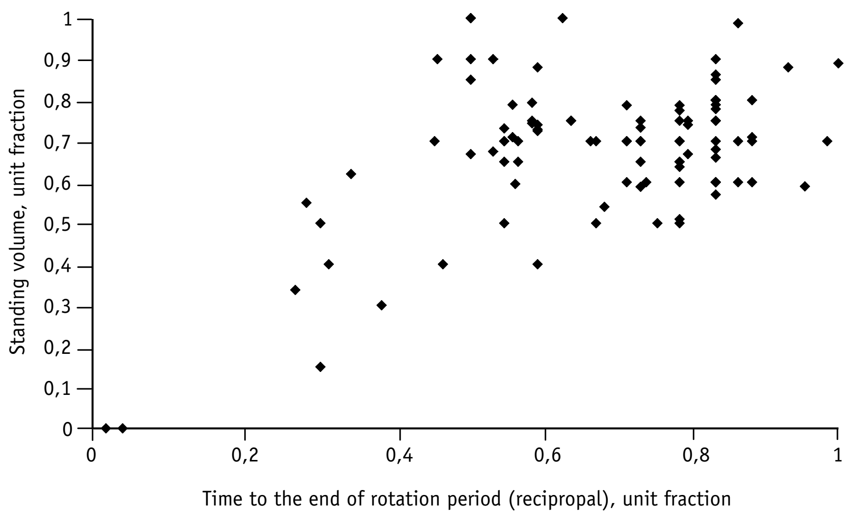

Figure 2. 2-dimensional visualisation of dependence between site value and main variables.

scissa is marked as time to the end of rotation period (Figure 2). In this case, Z-axis should be marked as cadastral value of the site.

At the next stage, we determined the direction of the regression line projection, which describes the dependence of the forestland value on the two stand parameters: time to the end of rotation period and standing volume. It is worth noting that the maximum value should be associated with sites with few years before harvesting and maximal standing volume, respectively all these sites are on the upper right side of the point cloud. Obviously, sites with standing volume tending to zero and having the maximal time to the end of rotation period have minimal cadastral value.

Thus, we can make a projection of the estimated regression line as connection of the corresponding points (Figure 3).

In this case, the length of an interval between the coordinate origin and the point of intersection of a perpendicular from the particular site variable point with the plane projection of the value line is the geometric expression (of the value) of the forestland value (f). Interval length calculates by the formula (4):

$$f = y \cdot \sin(\varphi) + x \cdot \cos(\varphi) \qquad (4)$$

where:
f – Length of the interval expressing the value;
x – Reading on the X-axis equals to normed time to the end of rotation period;
y – Reading on the Y-axis equals to normed standing volume;
[Phi] – The slope of the value line.

The obtained value of f is multiplied by the coefficient k for the each site. Then these values are normed by dividing them by the maximum value for all sites. Thus, as a result of work we obtain the relative cost values (Table 6) that are proportions of the cost of the best site, the cost of which is taken by the unit (site #34).

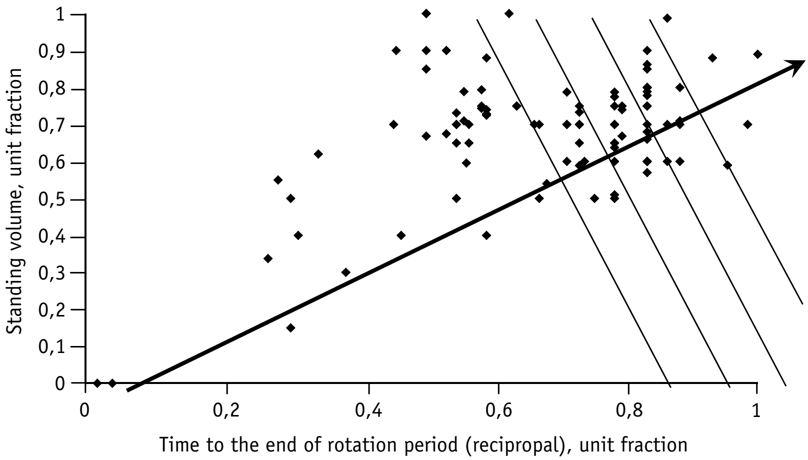

Figure 3. Projection of the value line on the plane.

Table 6. Norming of the relative cost coefficient.

Site #	Relative cost coefficient	Norm relative cost coefficient
1	0.820848	0.572178
2	0.906143	0.631634
3	0.906143	0.631634
4	0.590667	0.411729
5	1.085075	0.756360
6	0.872071	0.607883
7	0.388421	0.270752
8	1.088321	0.758628
9	0.877959	0.611988
10	1.414776	0.986181
11	0.816601	0.569218
12	0.921076	0.642043
13	1.285153	0.895826
14	1.221879	0.851720
15	0.948443	0.661120

Results validation

In order to validate these results the same forest areas are evaluated using the Roszemkadastr method. We changed the indicator related to the economic activity of business, which is extremely difficult to obtain, to the profitability of logging. Cost of one cubic meter of hardwood amounts to 1099 RUB (19.3 EUR). Cost of one cubic meter of softwood amounts to 1312 RUB (23.0 EUR). This is Rosstat data for the year 2008 – the last lossless year for Russian loggers. The discounting ratio is set at 0.014 (Federal State Statistics Service, 2015).

Obtained cadastral values are normed by dividing to the value of most expensive site (#34). Values obtained by the different methods correlate very close, $R^2 = 0.89$ (Figure 4).

Results and Discussion

To determine absolute values we propose to set absolute unit cost for site with average value (= 0.5) equal to the regional UPKS. It is average unit cost for forestlands in whole region, in Petersburg region it equals 7180 RUB/ha (126.0 EUR/ha). Then the cost of the most valuable site (relative value is 1) equals to 14360 RUB/ha (251.9 EUR/ha), and the cost of the less valuable trends to zero. The average value of the specific cadastral value is 9345 RUB/ha (163.9 EUR/ha), which is close to the average value determined using the

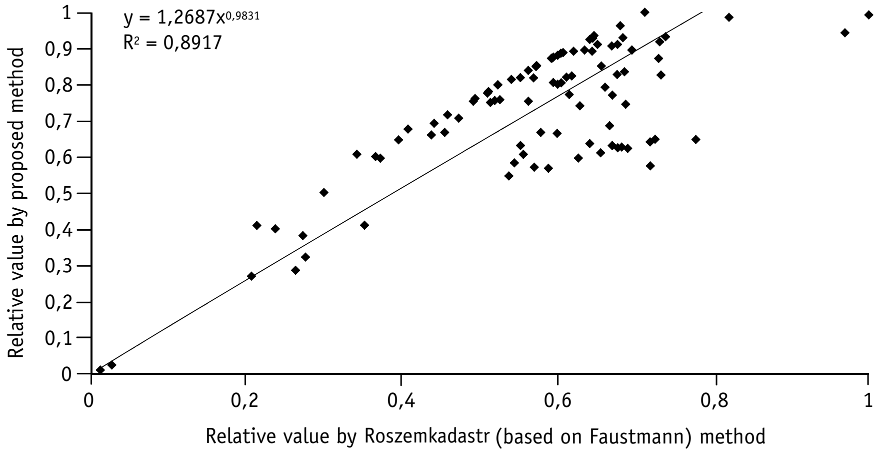

Figure 4. Correlation of the methods results.

old method (10850 RUB/ha ≈ 190.4 EUR/ha) and at the same time exceeds regional UPKS value. In general, the cadastral value for Pesochinskoye forestry of Kurortny forest park with an area of 3403 ha will increase of 7.4 million RUB (129 825 EUR) in total. It is worth noting again that during the determination of the cadastral value in Russia after the year 2009, we cannot speak about any comparison of methods, because the cadastral value of forestlands obtained by the Roszemcadastr method becomes negative.

The proposed method allows determining the cadastral value of the forestlands regardless of the economic condition of the logging business, but considering the forest stand quality. In contrast to the widespread use of common UPKS throughout the subject of Russia, our method gives the opportunity to differentiate sites by the cost depending on the stand parameters of the forest stand.

It is need to be mentioned that Roszemkadastr method largely copies basic Faustman method. As it said before results of proposed research correlate with Roszemkadastr/Faustman method, but they are more adapted for Russian forestry. There is no private forestlands in Russia so forest user can nott change type of its usage if harvesting is unprofitable. Lack of economical information about harvesters activities makes fair calculation of site value by discounting of land rent too difficult. Lack of forestland market makes comparative approach to evaluation impossible.

So, proposed method can be used in cases of private forestlands property deficiency and lack of statistical data about economical operations of harvesters.

Main problem of investigation is constant value of rotation period used in Russia. It is not correct because of rotation period length depend on economical causes such as timber costs or forest management charges. In future researches it's need to include this model into proposed method.

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