# Developing the model of an automated rotary-cut veneer sorting system

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# Developing the model of an automated rotary-cut veneer sorting system

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**Abstract**. The paper suggests an approach to developing the veneer sorting model based on fuzzy logic. Wide implementation and development of automated rotary-cut veneer sorting system is inhibited by the difficulties when creating analytical models. The reasonability of using fuzzy logics for veneer sorting is due to the large number of factors having significant impact, and rich expertise of engineers. The model was built and tested for two main factors: the number of healthy and deformed knots. Further studies shall be aimed at increasing the number of factors considered, collecting statistic and expert information in order to build membership functions for linguistic variables, and forming the base of rules bringing relation between the input and output variables.

## 1. Goals and tasks

The goal of this paper is to create control algorithms for sorting veneer by quality having a set of poorly formalized factors using fuzzy logic.

Currently specialists in automation of technological processes are interested in control laws based on fuzzy logic. The concept of fuzzy set is an attempt to formalize linguistic data to use them in mathematical models. This notion is based on idea that the elements of a set have common characteristics but share them to different degree. As result these elements may belong to the set to different degree. This allows to formalize tasks with large number of influencing factors, like sorting veneer by quality.

Veneer is the main semi-finished product that has been used for years in furniture industry, in laminated wood manufacture. With that, it is greatly suitable for contemporary trends toward intense and careful consumption of natural resources.

Depending on production types, veneer can be sliced or rotary-cut. Veneer is always sorted after drying.

Generally, veneer can be sorted according to the following properties [1]:

- Timber species. Determined during hydro-thermal treating;
- Veneer thickness. Set in the rotary lathe. After cutting, each pile consists only of veneers of the same thickness;
- Purpose. Plywood, single use, repairs, edge-gluing;
- Quality (by sorts).

First three properties are known or controlled during technological process, but sorting by quality requires additional technological operation.

Sorting veneer by quality is one of the most important operations in technological process. It defines product yield of various veneer sorts. Most often veneer is sorted by operators depending on a set of veneer sheet's flaws (flaws caused by natural conditions of growth and manufacturing defects). The number of possible combinations of flaws is very large. In addition, some defects are difficult to define with required accuracy. An operator should give correct general estimation of veneer sheet's quality, avoiding large variations of quality within one sort of veneer. As result, time spent for sorting one veneer sheet may vary greatly depending on operator's qualification. It may influence badly on general productivity and product quality due to significant impact of human factor.

When visually evaluating the sort, an operator is guided by GOST or product specifications. The main difficulty of sorting is to define correctly quality properties of veneer.

According to GOST 99-2016 [2], rotary-cut veneer has 5 sorts: E (elite), I, II, III, IV for hardwoods, and Ex (elite), Ix, IIx, IIIx, IVx for softwoods.

For each veneer sort, tolerable flaws and defects are determined. The most significant flaws are knots of different size and type, end shakes, abnormal stains and rot (black heart, brow stains, flecks, and blue stains), barking pocket — the flaws caused by natural conditions of growth. Manufacturing defects are uneven gage, roughness and waviness, splits, etc.

As described in GOST 99-2016, there are poorly formalized factors making sorting less automated and more labor-consuming. Usually, an operator visually evaluates the sort of each sheet and presses the number of the corresponding pocket. Veneer sheets are then transported to their dedicated places. Manual sorting, in its turn, is very intensive. The Order No. 1143n of the Ministry of Labor of the Russian Federation dated December 25, 2014 introduced the professional standard "Quality supervisor in producing of veneer, plywood, and wood boards".

Grade lines involving photosensors and built-in computers for automated sorting are already known. The system detects stains on a veneer sheet and their quantity, dimensions, area, and then compares these parameters with the reference standards in memory. Based on this, it assigns the appropriate sort [3, 4]. However, wide implementation and development of automated grade lines is inhibited by the difficulties when creating analytical models.

## 2. Research method

The paper suggests to automate the process of veneer sorting applying fuzzy logic. As mentioned in [5, 6], the reasonability of using fuzzy logic methods is driven by the difficulty of building analytical models of systems and the rich expertise of operators, their knowledge and skills in managing certain technological processes.

This paper suggests applying the fuzzy inference algorithm for architecting the model of an automated rotary-cut veneer sorting system. We can consider sorting only hardwood veneer, while the model for softwood veneer will be analogical. The tools used are Matlab (Fuzzy Logic Toolbox included), where the base is FIS (Fuzzy Inference System) that contains data required for implementing the input-output interaction.

The key principles of fuzzy logic are fuzzy set and linguistic variable.

A fuzzy set is characterized by a continuous membership function that can possess any intermediate values between 0 and 1. A linguistic variable is a variable set on the linguistic scale and takes on values in the form of words and phrases of a natural language. A separate value of a linguistic variable (linguistic term) is set with the single membership function — each term corresponds to a fuzzy set.

According to [2, 7], we pick out the parameters most significant for sorting:

- Healthy intergrown light or dark knots (Knots1). To be evaluated by the sum of multiplications of the numbers of knots and their diameters per 1 sq. m (mm);

- Partially intergrown, black knots, loose knots and apertures, wormholes (Knots2). To be evaluated by the sum of multiplications of the numbers of knots and their diameters per 1 sq. m (mm).

## 3. Modelling results

Thus, we have 2 input (Knots1 and Knots2) and 5 output (SortE, Sort1, Sort2, Sort3, Sort4) linguistic variables (see figure 1).

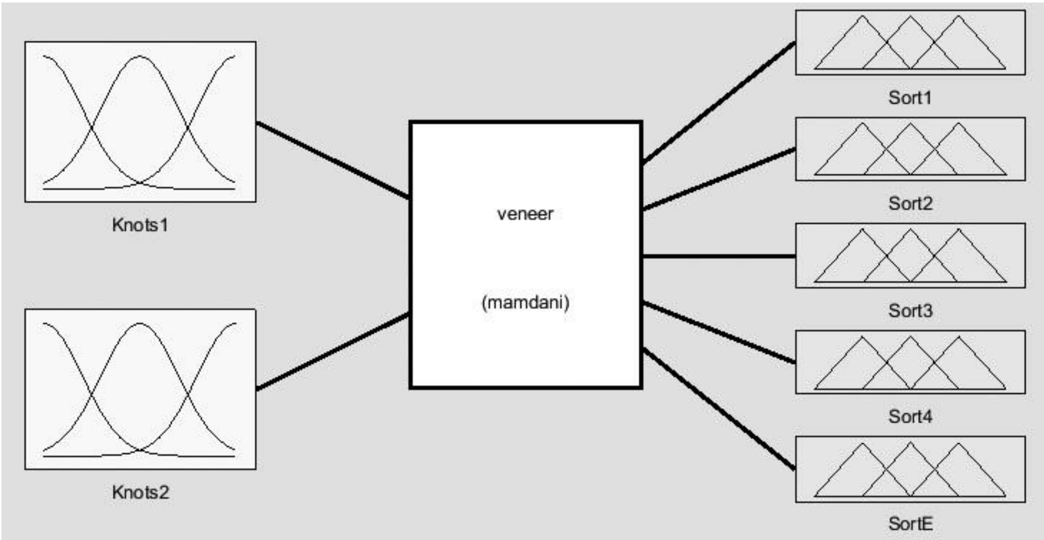


**Figure 1.** Sorting process based on fuzzy logic.

Membership functions, drawn in Matlab and regarding terms of input variables and the output variable Sort1 are given in Figures 2-4. For other output variables, membership functions have the similar form.

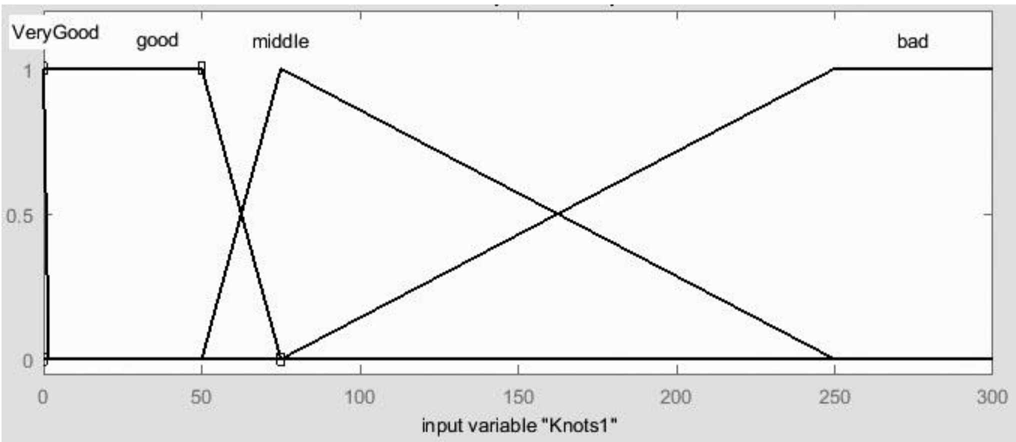


**Figure 2.** Membership functions for Knots1.

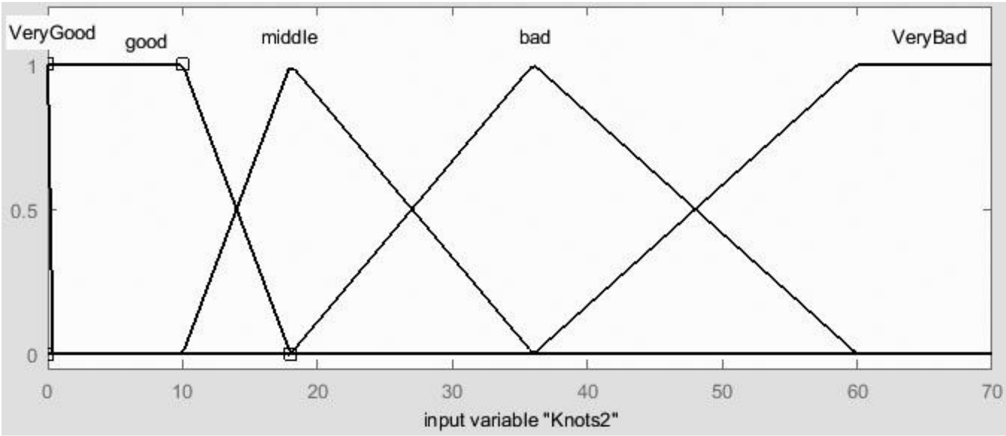


**Figure 3.** Membership functions for Knots2.

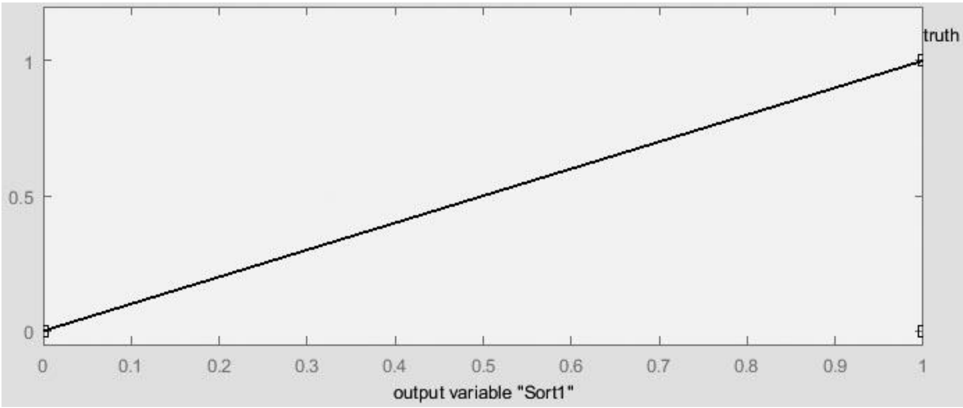


**Figure 4.** Membership functions for Sort1.

The base for the fuzzy inference is the rule base containing if-then fuzzy statements and membership functions for corresponding linguistic terms.

The rule base architected by means of the suggested algorithm and built membership functions is given in figure 5.

1. If (Knots1 is VeryGood) and (Knots2 is VeryGood) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is truth) (1)
2. If (Knots1 is VeryGood) and (Knots2 is good) then (Sort1 is truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
3. If (Knots1 is VeryGood) and (Knots2 is middle) then (Sort1 is not truth)(Sort2 is truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
4. If (Knots1 is VeryGood) and (Knots2 is bad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is not truth)(SortE is not truth) (1)
5. If (Knots1 is VeryGood) and (Knots2 is VeryBad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is truth)(SortE is not truth) (1)
6. If (Knots1 is good) and (Knots2 is VeryGood) then (Sort1 is truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
7. If (Knots1 is good) and (Knots2 is good) then (Sort1 is truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
8. If (Knots1 is good) and (Knots2 is middle) then (Sort1 is not truth)(Sort2 is truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
9. If (Knots1 is good) and (Knots2 is bad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is not truth)(SortE is not truth) (1)
10. If (Knots1 is good) and (Knots2 is VeryBad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is truth)(SortE is not truth) (1)
11. If (Knots1 is middle) and (Knots2 is VeryGood) then (Sort1 is not truth)(Sort2 is truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
12. If (Knots1 is middle) and (Knots2 is good) then (Sort1 is not truth)(Sort2 is truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
13. If (Knots1 is middle) and (Knots2 is middle) then (Sort1 is not truth)(Sort2 is truth)(Sort3 is not truth)(Sort4 is not truth)(SortE is not truth) (1)
14. If (Knots1 is middle) and (Knots2 is bad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is not truth)(SortE is not truth) (1)
15. If (Knots1 is middle) and (Knots2 is VeryBad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is truth)(SortE is not truth) (1)
16. If (Knots1 is bad) and (Knots2 is VeryGood) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is truth)(SortE is not truth) (1)
17. If (Knots1 is bad) and (Knots2 is good) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is truth)(SortE is not truth) (1)
18. If (Knots1 is bad) and (Knots2 is middle) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is truth)(SortE is not truth) (1)
19. If (Knots1 is bad) and (Knots2 is bad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is truth)(Sort4 is truth)(SortE is not truth) (1)
20. If (Knots1 is bad) and (Knots2 is VeryBad) then (Sort1 is not truth)(Sort2 is not truth)(Sort3 is not truth)(Sort4 is truth)(SortE is not truth) (1)

**Figure 5.** Rule base.

Using FIS Editor, we draw an example of an input-output surface corresponding to the created fuzzy system (see figure 6).

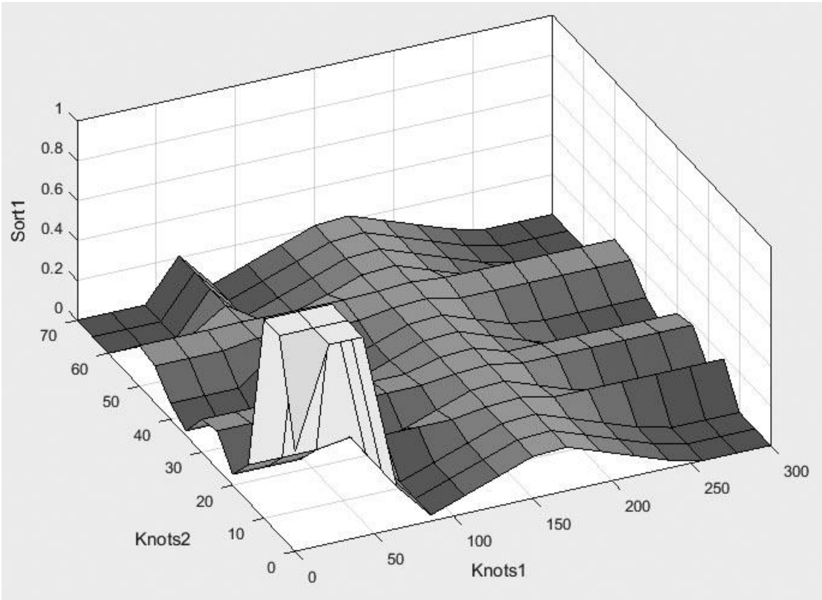


**Figure 6.** Dependence of Sort1 on Input Variables.

Testing the model created is based on setting values of input variables in Rule Viewer (see figure 7). With that, the program calculates the result through defuzzification. Figure 7 shows that at integral values of healthy knots (40 mm) and deformed knots (12 mm), a veneer sheet is likely to be assigned Sort 1. In arguable situations, a quality supervisor can be involved. The results acquired by means of the model, are adequate.

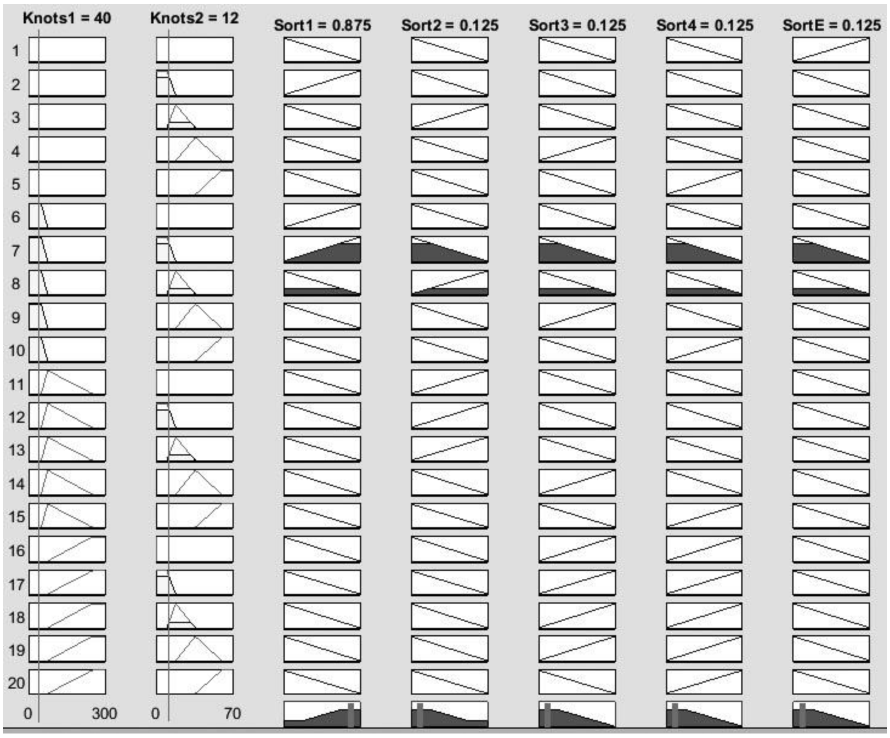


**Figure 7.** Testing the model.

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Thus, the paper suggests the approach to developing the model of rotary-cut veneer sorting system based on fuzzy logic. The model was built and tested for two main factors: the number of healthy and deformed knots. Further studies shall be aimed at increasing the number of factors considered, collecting statistic and expert information in order to build membership functions for linguistic variables, and forming the base of rules bringing relation between the input and output variables.

**References**

[1] Volynsky V N 2009 *Technology of laminated materials: tutorial* (Moscow)
[2] GOST 99-2016 *Rotary-cut veneer* (Moscow)
[3] Levin M G and Fokina L G 2004 Information support for recognition of rotary-cut veneer production defects *Proc. Methods and systems of information processing* **2** (Murom) pp 62-7
[4] Lustgarten Y L, Mezhenin D V and Fokina L G 2004 Automated evalution of the rotary-cut veneer grade *Proc. of Int. Scientific and Technical Conf. "LEN-2004"* (Kostroma: KGTU) p 174
[5] Shekhovtsov O I and Shifrin B M 2008 *Development of the model of boiling machine control system based on fuzzy logic* (Saint-Petersburg) pp 8-14
[6] Shifrin B M 2017 Development of the quality control model of chip plates, based on fuzzy logic *Automated design in machine engineering: proc. of the 5 th Int. Scientific Teleconference* (Novokuznetsk) **5** pp 39-43
[7] Hemmasi K 2016 Efficient production of veneer and plywood *Actual directions of scientific research of the XXI century: theory and practice* **(251)** pp 181-91