An Approach to Machine Tools Structure Selection for Wooden Product Machining Based on Evidence Networks

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During the product development phase, especially in the case of innovative products, designers used to face the unpleasant situation to be obliged to take decisions under conditions which are characterized by a relevant degree of uncertainty and even contradiction. This situation is quite frequent in the very early phases of the design process, where a large part of external conditions are not fully defined. It is also the case of a designer of machine tools. As methodological response able to fill this informative gap, the present paper presents a way for using "evidential systems" as supporting tool for designers. These tools represent a sort of expert systems in which knowledge is represented and processed by the function of the Belief Function Theory (also called Dempster-Shafer Theory). In particular, beyond a deep description of this methodology, the paper is focused on the conceptual design of a machine tool, i.e. determination of the best structure of machining center in the phase of conceptual design for a predefined group of wooden parts that are being machined on them.

Keywords: *Machine tools, Conceptual Design, Dempster-Shafer Theory, Evidence Networks, Wooden product*

1. INTRODUCTION

By the introduction of multi-axis CNC machine tools (machine centre), woodworking small and medium enterprises generate significant technical and technological advantages compared to production using conventional machines. Multiple-spindle heads, integrated warehouse with tools and automatic tool changer significantly increase the accuracy in the making, as the complete processing is performed only in one clamping. Automatic tool change, in fact, increases productivity and reduces the preparation time setting up and clamping of work pieces. Application of modern machining centres creates the possibility of efficient flexible highly productive manufacturing of a wide range of different work pieces, which generates the possibility for expansion of the production program for small and medium enterprises. Multi-axis numerical control machining centres enable high-quality processing of complex spatial objects on the surface of the wood, which creates the possibility of applying modern design in wood products and manufacturing stylish shaped furniture without limitation for designers of artistic ideas. Specifically, the introduction of automated machines in small and medium-sized enterprises contributes to increasing staff qualification structure engineers, who work on designing of products and technologies. These aspects can assume a not negligible role in the fast modernisation of developing economies [1,2,3,4,5].

Using CAD/CAM systems, significantly accelerates the process of producing, through simulation and visualization, reducing possible errors by designers. In this way, in fact, the direct effect of experience and knowledge workers on the production quality and technological management system, which ensures continuity in product quality, is reduced.

The introduction of multi-axis CNC machining centres in the industrial practice of wood processing requires the use of modern microprocessor, information and communication technologies. Improvement and modernization of technological systems in the wood-processing industry, give wide possibilities of automation manipulation process of work piece relative to the tool, work piece transport through automation production line automation and execution of complex technological operations [6].

During development of the machine tools for wooden product machining, the designer makes decisions in conditions of full uncertainty, contradiction, and not having enough knowledge about the matter. Whether and to which extent are those decisions right? How much do they affect customer's satisfaction? These are just some of the issues that designers face every day. Their openness is higher with development process being in early conceptual stages [7,8].

Several investigations demonstrated that during the conceptual design stage more than ten different versions have to be generated with the aim at obtaining the best solution of machine tool.

Usually the concept of "best solution" means that the lowest cost of product design for this equipment

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coupled with the lowest cost for manufacturing has to be obtained. This last aspect of optimisation of costs in production is complex since it has to be evaluated in accordance with numerous and inhomogeneous factors related to machining, precision, safety, specific materials under working and many other that can contemporary affect the productivity [7,8,9,10,11, 12].

An introduction of new methods and tools is requested to enable improvement in designers' knowledge and skills in the process of decision making [8].

Following these requests, this paper presents the way of using evidential systems, which are developed, based on belief function theory BFT) in conceptual designing [13,14]. This theory, also referred to as evidence theory or Dempster–Shafer theory (DST), is a general framework for reasoning with uncertainty, with understood connections to other frameworks such as probability, possibility and imprecise probability theories.

In this specific application, the main objectives are to improve designer's capability in decision-making process in the early stages of design. It is important to note that designer during the design process is moving inside uncertainty space and that uncertainty is greater in initial stages. Part of previously mentioned objectives can be illustrated as an effort made to reduce this uncertainty space. This applies to the development of methods that would allow designer to see the effects of decision immediately after making one, i.e. whether it is optimal or not.

As additional to above, the paper gives an approach to using new tools in the conceptual phase of the design process. We described it using this tool through determination of the best structure of machine tools (machining centres) for a predefined group of wooden parts that are being machined on them. Data, knowledge and experience of engineers from a middle scale wooden product company were used.

2. THEORY OF BELIEF FUNCTIONS

Making conclusions (reasoning) about a certain situation from the real world is often in difficult circumstances with insufficient knowledge, no clearly defined criteria and mutual antagonism. Information about evidence can come from different resources: based on a person's experience, from signals recorded by appropriate sensors, from the contents (the context) of published papers and so on. Such evidence is rarely clearly delimited; it is often incomplete, ambiguous in its meaning and full of flaws.

The Dempster-Shafer belief function theory provides powerful tools for mathematical presentation of the subjective (opposite of what probability theory is based on) uncertainty while it relies mainly on possibility of explicit definition of ignorance [14]. This theory is intuitively adapted formalism for reasoning below uncertainty limit. It, actually, represents the generalization of Bayesian theory of conditional probability. As such, it provides formally consistent method for interpretation and connection of evidence, which inside itself carries some degree of uncertainty, and in addition, provides getting meaningful answers to posed questions using only partial evidence. Complete records can be used only in necessary cases.

2.1 The basic concepts of Belief functions

A model of the belief function consists of variables, their values and the evidence, which supports the value of variables. Variables represent specific questions regar–ding the aspect of the problem under consideration. Given questions are answered using data originating from various sources, i.e., from context of published papers, measurement data, expert opinions, etc. Fully integrated support to the sought answer is called evidence.

Evidence can be represented by belief functions, which are defined as follows:

Definition.1. [13,14] Let Θ be a finite nonempty set called the frame of discernment, or simply the frame. Mapping *Bel*: $2^{\Theta}\rightarrow[0,1]$ is called the (un-normalized) belief function if and only if a basic belief assignment (bba) *m*: $2^{\Theta}\rightarrow[0,1]$ exists, such that:

$$\sum_{A\subset\Theta} m(A)=1 \quad (1)$$

$$Bel(A)=\sum_{B\subset A, B\neq\varnothing} m(B) \quad (2)$$

$$Bel(\varnothing)=0 \quad (3)$$

Expression *m*(A) can be viewed as the measure of belief which corresponds to subset A and takes values from this set.

Condition (1) means that one's entire belief, supported by evidence, can take the maximum value 1, and condition (3) refers to the fact that one's belief, corresponding to an empty set, must be equal to 0.

Value *Bel*(*A*) represents the overall belief corresponding to the set A and all of its subsets.

Each subset A such that *m*(A)>0 is called a focal element.

The empty belief function is the function which satisfies *m*(Θ)=1, and *m*(A)=0 for all subsets of $A\neq\Theta$. This function represents total ignorance about the problem under consideration.

2.2 Dempster rule of combining belief functions

Let several independent belief functions be given on the same recognition frame but with different bodies of evidence. The Dempster's combination rule (Fig. 1) (4, 5) produces a new belief function which represents the effect resulting from connecting of different bodies of evidence.

Let us assume that the belief functions Bel1 and Bel2 are created on Θ frame. Let A1,...,Ak, k<2|Θ| be the focal elements of function Bel1 with corresponding m – values m1(Ai) for i=1,...,k; and let B1,...,Bj, j<2|Θ| be focal elements of function Bel2 with corresponding m-values m2(Bi) for i=1,...,j.

Combination of these two functions is denoted as Bel1⊕Bel2 and its focal elements are C1,...,Cm with corresponding m-values m3(Ck) for k=1,...,m, created in the following way:

$$m_3(C_k) = K\left[\sum_{\substack{i,j \\ A_i \cap B_j = C_k}} m_1(A_i)m_2(B_j)\right] \qquad (4)$$

where K represents a normalization factor:

$$K = \left[1 - \sum_{\substack{i,j \\ A_i \cap B_j = \varnothing}} m_1(A_i)m_2(B_j)\right]^{-1} \qquad (5)$$

The normalization factor K is greater than 1 whenever Bel1 and Bel2 contain a part of mass of some belief that correspond to the subjective probability for the decoupled (contradictory) subsets of Θ. In fact, K represents the conflict measure of the two belief functions. Whenever two or more functions are combined, the combination rule is associative and commutative. In general, Bel⊕Bel=Bel. Combination of a certain number of belief functions Bel1⊕···⊕Beln is denoted as ⊕⊕{Bel1,···,Beln}.

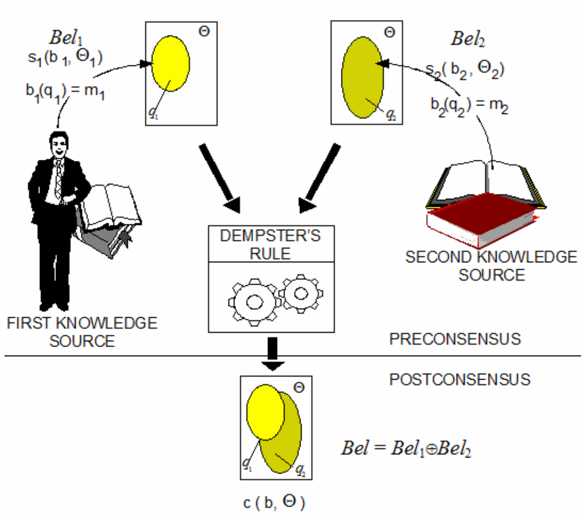

Figure 1. Graphics illustration using Dempsters rule of belief function combining

2.3 What are the Evidential systems?

Valuation Based Systems - VBS is an abstract framework proposed by Shenoy [15] for representing and reasoning on the basis of uncertainty. It allows representation of uncertain knowledge in various domains, including Bayes' probability theory, Dempster-Shafer's theory of evidence [13,14] which is based on belief functions and Zadeh-Dubais-Prad theory of possibility. Graphically presented VBS is called valuation network.

The VBS consists of a set of variables and set of valuations that are defined on the subsets of these variables. The set of all variables is denoted by U and represents a space covered with problem which is under consideration. Each variable represents a relevant aspect of a problem. For each variable X_i will be used ΘX_i to denote the set of possible values of variables called the frame of X_i. For a subset A (|A|>1) of U, set of valuations that are defined over ΘA represents the relationship between variables in A. Frame ΘA is a direct (Cartesian) product of all ΘX_i for X_i in A. The elements ΘA are called configurations of A.

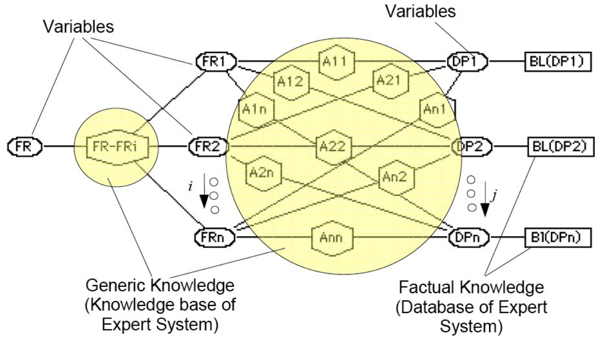

Figure 2. The concept of evidential networks

Knowledge presented in this type of valuations is called generic or general knowledge (Fig. 2), which can be represented as a knowledge base in expert systems.

The VBS also defines valuations on individual variables, which represents so-called factual knowledge, and it constitutes database in expert systems (Fig. 2). For a problem, general-generic knowledge defines an expert. During reasoning process that knowledge won't be modified. Factual knowledge will vary in accordance with condition of a problem currently being under consideration. The VBS treats on the same way these two kinds of knowledge.

The VBS systems suited for processing uncertain knowledge described by functions of belief function theory are called Evidential Reasoning Systems or Evidential Systems, and valuation networks are now called evidential networks (EN) (Fig. 2).

The objective of reasoning based on the evidence is an assessment of a hypothesis, in case when the actual evidence is given (the facts). This can be accomplished by evaluating valuation networks in two steps [16]:

Combining all belief functions in evidential network, resulting in a so-called global belief function;

Marginalization of global belief functions in the framework of each individual variable or subsets of variables produces marginalized values for each variable or subset of variables.

Easily way of understanding the reasoning process and its graphical interpretation is the condition on which depends whether and how fast these systems will be applied in solving everyday problems. As a software support to the VBS systems application, several software tools have been developed. For evidential systems the very known are: McEvidence, Pulcinella and DELIEF. McEvidence is an application that was developed for reasoning under conditions of uncertainty (Fig. 7). Using this system the user can create a graphical network of variables, their relationship and to bring in any records related to the variables. When all available input records that reflect current system status or process under analysis are being entered, evaluation of network can start.

During evaluation process first the global belief function is being generated by applying combining operation and then afterwards the marginalized values of all variables are being calculated.

3. DETERMINING MACHINE TOOLS OPTIMAL STRUCTURE

Evidence systems or the evidence networks can be a powerful tool in determining the optimal structure of the machine tools for the machining of various geometric shapes that can be found on the group of wood products. They can be used by designers of machine tools in the conceptual stage of defining the structure of the machine as well as employees in factories woodworking when to choose a machine where the optimum process group of parts with precisely defined geometric elements on it.

So this point has two explicit goals. The first one concerns the presentation of ability of evidential networks to absorb knowledge that was generated for years in the manufacturing engineering of the wooden product. The second one refers to extension of previously generated evidential networks and its usage as auxiliary tool in decision-making process.

The realization of these goals will be achieved through an example that relates to the choice of machine tool concept (machining centre) for processing a hypothetical group of wooden parts from wooden product factory Giugia, Kraljevo Serbia.

The company Giugia produces building joinery (windows and doors) wood. The production program includes a wide variety of construction solutions of different sizes and with different purposes and surface protection from different types of wood (spruce, oak, ash, ...). In our example we will analyze machining parts for wooden windows products sized up to 1000 [mm]. As an output of the analysis it was identified different surfaces classes on the all wooden window product (Fig. 3).

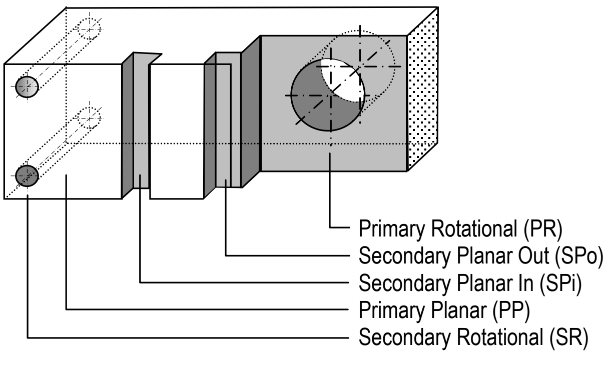

Figure 3. Different classes of surfaces

The machined surface type are Primary rotational (PR), Secondary Planar out (SPo), Secondary Planar In (SPi), Primary planar (PP), and Secondary Rotational (SR) as shown in Fig. 3. Primary surfaces give the parts its general outline shape. Secondary surfaces, such as planar in and out surfaces and auxiliary holes are machined out of primary surface.

The division of surfaces into primary and secondary hasn't been done according to the functional significance or according to the complexity of machining.

Based on the hypothetical part surface classification all parts are classified into eight categories as shown on the Fig. 4.

The classification of all parts into eight categories has been done according to combination of these surfaces and it's shown on Fig. 4. According to this and corresponding statistics in Table 1, we get the percentage of use of various machine tools, or types of mechanical operations for machining each category of parts. These percentage relations are kept also for total number of operations, and for final machining. In that way in the first category of parts 80,7% of the work represents Face Milling and 14,2% Cutting and 5,1 %.

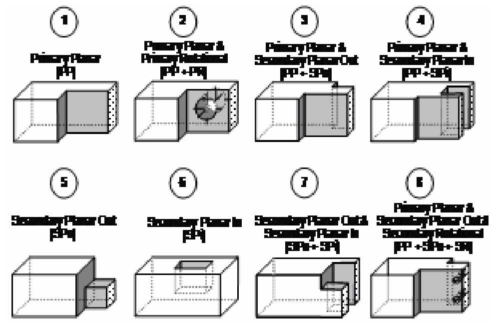

Figure 4. Categorization of wood parts in company Giugia Kraljevo, Serbia

It is important to note that the level of confidence in the accuracy of data in Table 1 cannot be 100%. By default we will assume that the level of confidence in the accuracy of data of these 95%. This mean that results of analysis which prepared engineers from *Giugia* company are reliably with confidence of 0.95.

Table 1. The percentage share from total assumed work for each operation of machining divided into categories of parts

Machining operations	Parts Category							
	PP	PP+ PR	PP+ SPo	PP+ SPi	SPo	SPi	SPo+ SPi	PP+SPo +SR
Face Milling	80.7	59.4				94.6		22.1
Peripheral Milling			83.8	77.3	81.7		74.2	49.5
Drilling		21.9						13.4
Cutting	14.2	13.5	12.9	16.1	5.5		14.7	10.7
Grinding	5.1	5.2	3.3	6.6	12.8	5.4	11.1	4.3

In the rest of this paper, it has been shown how to apply this generated knowledge into conceptual design of machine tools (machine centres). The belief function theory together with evidential systems, or evidential networks, made it possible to present this knowledge in an appropriate form, and later to use it as aid in decision making process.

The initial goal is to implement an expert system that will provide help in conceptual design stage to a designer who needs to choose a concept of machine tools structures. The application will be presented for a practical example in which a designer got an assignment to choose the right kinematical structure of CNC machine tools for multi-axis processing for a set of parts from Fig. 4. Giugia company has analyzed its production program and decided to acquire a new machine for machining parts from the first, second, third, fourth and eighth groups of parts from the Fig. 4. Percentage share parts of these groups with appropriate input belief functions are given Table 2.

Table 2. Percentage of group parts have to be machined on machine tools with appropriate input belief functions

Wooden parts Category	PP(1)	PP+PR(2)	PP+SPo(3)	PP+SPi(4)	PP+SPo+SPi(5)
Participation in the production program	16%	9%	28%	35%	12%
Input Belief functions	Bel(1) m(1)=0.16 ~m(1)=0.84	Bel(2) m(2)=0.09 ~m(2)=0.91	Bel(3) m(3)=0.28 ~m(3)=0.72	Bel(4) m(4)=0.35 ~m(4)=0.65	Bel(5) m(5)=0.12 ~m(5)=0.88

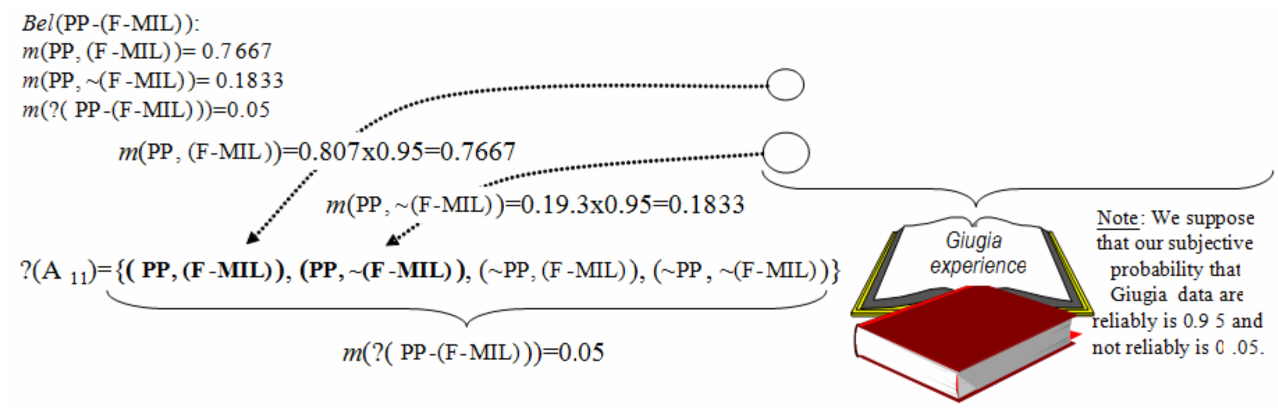

Figure 5. Approach to presenting knowledge from Table 1.[joint variable (PP-(F-MIL))] with the belief function]

Table 3. Knowledge for selected categories of parts from Table 1. presented as joint belief functions

Joint Variables	Input Belief Functions of Joint Variables	Joint Variables	Input Belief Functions of Joint Variables
(PP-(F-MIL))	***Bel*(PP-(F-MIL))**: *m*(PP, (F-MIL))= 0.7667 *m*(PP, ~(F-MIL))= 0.1833 *m*(Θ(PP-(F-MIL)))=0.05	(PP-CUT)	***Bel*(PP-CUT))**: *m*(PP, CUT)= 0.1349 *m*(PP, ~CUT)= 0.8151 *m*(Θ(PP-CUT))=0.05
(PP-GRIN)	***Bel*(PP-GRIN))**: *m*(PP, GRIN)= 0.1349 *m*(PP, ~GRIN)= 0.8151 *m*(Θ(PP-GRIN))=0.05	((PP+PR)-(F-MIL))	***Bel*((PP+PR)-(F-MIL))**: *m*((PP+PR), (F-MIL))= 0.5643 *m*((PP+PR), ~(F-MIL))= 0.3857 *m*(Θ((PP+PR)-(F-MIL)))=0.05
((PP+PR)-DRIL)	***Bel*((PP+PR)-DRIL)**: *m*((PP+PR), DRIL)= 0.2081 *m*((PP+PR), ~DRIL)= 0.7419 *m*(Θ((PP+PR)-DRIL))=0.05	((PP+PR)-CUT)	***Bel*((PP+PR)-CUT)**: *m*((PP+PR), CUT)= 0.1282 *m*((PP+PR), ~CUT)= 0.8218 *m*(Θ((PP+PR)-CUT))=0.05
((PP+PR)-GRIN)	***Bel*((PP+RP)-GRIN)**: *m*((PP+PR), GRIN)= 0.0494 *m*((PP+PR), ~GRIN)= 0.9006 *m*(Θ((PP+PR)-GRIN))=0.05	((PP+SPo)-(P-MIL))	***Bel*((PP+SPo)-(P-MIL))**: *m*((PP+SPo), (P-MIL))= 0.7961 *m*((PP+SPo), ~(P-MIL))= 0.1539 *m*(Θ((PP+SPo)-(P-MIL)))=0.05
((PP+SPo)-CUT)	***Bel*((PP+SPo)-CUT))**: *m*((PP+SPo), CUT)= 0.1225 *m*((PP+SPo), ~CUT)= 0.8275 *m*(Θ((PP+SPo)-CUT)=0.05	((PP+SPo)-GRIN)	***Bel*((PP+SPo)-GRIN))**: *m*((PP+SPo), GRIN)= 0.0313 *m*((PP+SPo), ~GRIN)= 0.9187 *m*(Θ((PP+SPo)-GRIN)=0.05
((PP+SPi)-(P-MIL))	***Bel*((PP+SPo)-(P-MIL))**: *m*((PP+SPi), (P-MIL))= 0.7343 *m*((PP+SPi), ~(P-MIL))= 0.2157 *m*(Θ((PP+SPi)-(P-MIL)))=0.05	((PP+SPi)-CUT)	***Bel*((PP+SPi)-CUT))**: *m*((PP+SPi), CUT)= 0.1529 *m*((PP+SPi), ~CUT)= 0.7971 *m*(Θ((PP+SPi)-CUT)=0.05
((PP+SPi)-GRIN)	***Bel*((PP+SPi)-GRIN))**: *m*((PP+SPi), GRIN)= 0.0627 *m*((PP+SPi), ~GRIN)= 0.8873 *m*(Θ((PP+SPi)-GRIN)=0.05	((PP+SPo+SPi)-(F-MIL))	***Bel*((PP+SPo+SPi)-(F-MIL)):** *m*(((PP+SPo+SPi), (F-MIL)))= 0.2099 *m*(((PP+SPo+SPi), ~(F-MIL)))= 0.7401 *m*(Θ(PP, (F-MIL)))=0.05
((PP+SPo+SPi)-(P-MIL))	***Bel*((PP+SPo+SPi)-(P-MIL)):** *m*(((PP+SPo+SPi), (P-MIL)))= 0.4703 *m*(((PP+SPo+SPi), ~(P-MIL)))= 0.4797 *m*(Θ(PP, (P-MIL)))=0.05	((PP+SPo+SPi)-DRIL)	***Bel*((PP+SPo+SPi)-DRIL):** *m*(((PP+SPo+SPi), DRIL))= 0.1273 *m*(((PP+SPo+SPi), ~DRIL))= 0.8227 *m*(Θ(PP, DRIL))=0.05
((PP+SPo+SPi)-CUT)	***Bel*((PP+SPo+SPi)-CUT):** *m*(((PP+SPo+SPi), CUT))= 0.1017 *m*(((PP+SPo+SPi), ~CUT))= 0.8483 *m*(Θ(PP, CUT))=0.05	((PP+SPo+SPi)-GRIN)	***Bel*((PP+SPo+SPi)-GRIN):** *m*(((PP+SPo+SPi), GRIN))= 0.0409 *m*(((PP+SPo+SPi), ~GRIN))= 0.9091 *m*(Θ(PP, GRIN))=0.05

The knowledge for previous selected group of parts from Table 1. has been presented using belief functions of joint variables on the Table 3 (Fig. 5) with our subjective probability that this data are reliably is 0.95. Also, on the Fig. 5 is presented way how this knowledge modeled by belief function for joint variables Bel(PP-(F-MIL)) or what percentage Face-Milling participates in the processing of parts Category 1.

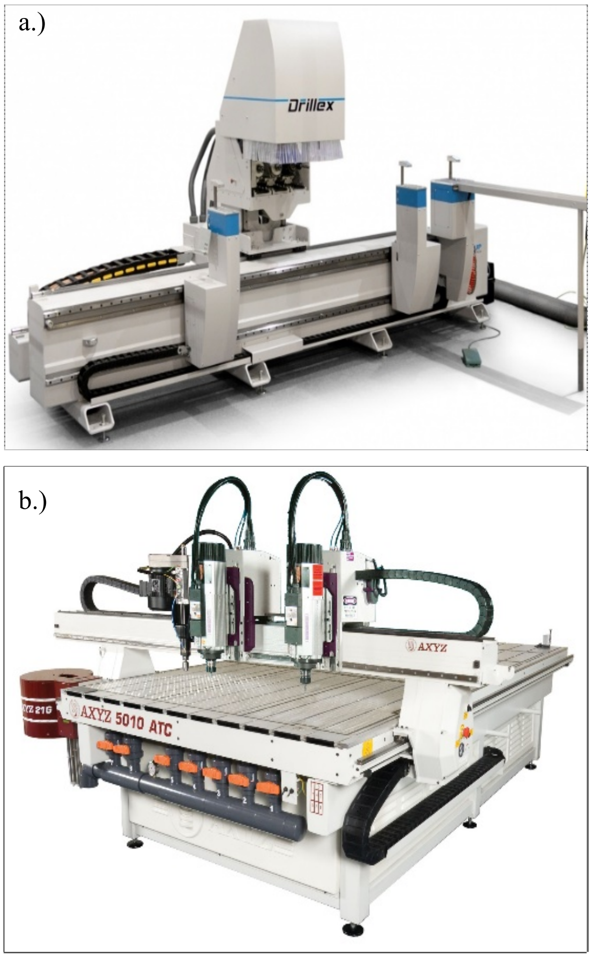

Figure 6: The horizontal (a) and vertical machining center (b)

Let's assume that in the mentioned example the designer has at his disposal modules of main rotating movements, modules of linear and rotating auxiliary movements of horizontal and vertical machining centers (Fig. 6). If we analyze how appropriate are particular structures of machining centers for certain type of machining over categories of parts from Tab. 1 (e.g. Face-Milling, Peripheral-Milling, Drilling, Cutting and Grinding) the following can be concluded [1,17,18].

The vertical structure of machining centers are most suitable for Face milling process, and in some cases Grinding and less suitable for Peripheral milling and the least suitable for Cutting. Horizontal structure is suitable for Cutting and Peripheral milling and in some case for Drilling and least suitable for Face milling process. This knowledge is presented in the Table 4 with appropriate belief functions of joint variables. If these expertise conclusions we describe with functions of belief function theory and can include into evidential network (Fig. 7.).

Now we finish modelling all necessary knowledge for creation appropriate evidence networks for selecting most suitable machine tools structure for machining certain group of wooden parts (Tab. 2).

In evidence networks knowledge can be grouped as Generic and Factual knowledge. Generic knowledge in the certain example is presented by belief function of joint variables in the Table 3 and Table 4. This type of knowledge can be represented as knowledge base in expert systems. This knowledge does not change during analysis.

The factual knowledge will vary in accordance with condition of a problem currently being under consideration and in our example is participation of a group of parts that are planned to be processed on machine center which is represented in the Tab. 2.

On the basis of previously explained modeling knowledge with belief function of Dempster-Shafer theory it is possible to create appropriate evidence network (Fig. 7). After creation of the evidence network it can be evaluated and used as a tool for selecting optimal machine tool structure. With evaluation of evidential network factual knowledge (information about machining certain group of parts represented by belief functions) changes states at all nodes including the output node MT which is in charge for choosing the concept of machining tools. This state is expressed by output belief functions MT (Output belief of MT on the Fig. 7). In this case, for selected structure of group of parts the concept of horizontal machine tool has basic belief assignment (bba) $m(\{\text{HOR-MT}\})=0.44407$, concept of vertical has $m(\{\text{VER-MT}\})=0.55494$ and ignorance about which concept is better $m(\{\text{HOR-MT,VER-MT}\})=0.00543$. From this it can be concluded that for assumed group of parts the more suitable is concept of vertical machine tools with CNC control.

4. CONCLUSION

In order to improve the ability of a designer in decision making process regarding optimal kinematics structure, it can be successfully applied the Dampster-Shafer belief function theory, or evidential systems that are developed on its basis in conceptual modular design of machine tools (machining centers). This is particularly important in the early stages of defining the support structure, kinematics and modules of the main and auxiliary movements of machine tools. In these stages the designer makes decisions on geometrical, energy, technological, statistical and kinematics characteristics under conditions when there is no reliable knowledge of what parts, from what materials and which technological processes will be used for processing the work pieces at machine tools during exploitation in its life time. The developed model allows the designer to have already defined main and optimal functional characteristics of machine tools in the phase of conceptual design, and with those characteristics he enters into calculations and dimensioning functional modules and components, which by integration into a single machining system enables cost-effective and productive processing of prismatic parts in optimal technological conditions.

Tab. 4 Knowledge about how appropriate particular structure of machine tools for certain type of machining wooden parts represented by belief functions

Mechanical operation	The suitability of machine structure for machining wooden products		Input Belief Function with confidence level of 95%	Remarks
	Horizontal Structure [%]	Vertical Structure [%]		
Face Milling (F-MIL)	25 (20-30)	75 (70-80)	*Bel*((F-MIL)-MT): *m*(((F-MIL), (MT-H))=0.7125 *m*(((F-MIL), (MT-H))=0.2375 *m*(Θ((F-MIL)-MT))=0.05	Horizontal mach. structure is suitable for Face milling in the (20-30%) cases. For simplicity we have avoided defining the belief function on the interval. Dempster-Shafer theory makes it possible. Instead of interval we used mean values. In the case of Face milling horizontal machine structure is suitable by 25%
Peripheral Milling (P-MIL)	67.5 (65-70)	32.5 (30-35)	*Bel*((P-MIL)-MT): *m*(((P-MIL), (MT-H))=0.30875 *m*(((P-MIL), (MT-H))=0.64125 *m*(Θ((P-MIL)-MT))=0.05	
Drilling (DRIL)	52.5 (50-55)	47.5 (45-50)	*Bel*((DRIL-MT): *m*(((DRIL), (MT-H))=0.45125 *m*(((DRIL), (MT-H))=0.49875 *m*(Θ((DRIL)-MT))=0.05	
Cutting (CUT)	87.5 (85-90)	55 (50-60)	*Bel*((CUT-MT): *m*(((CUT), (MT-H))=0.11875 *m*(((CUT), (MT-H))=0.83125 *m*(Θ((CUT)-MT))=0.05	
Grinding (GRIN)	45 (40-50)	55 (50-60)	*Bel*((GRIN-MT): *m*(((GRIN), (MT-H))=0.5225 *m*(((GRIN), (MT-H))=0.4275 *m*(Θ((GRIN)-MT))=0.05	

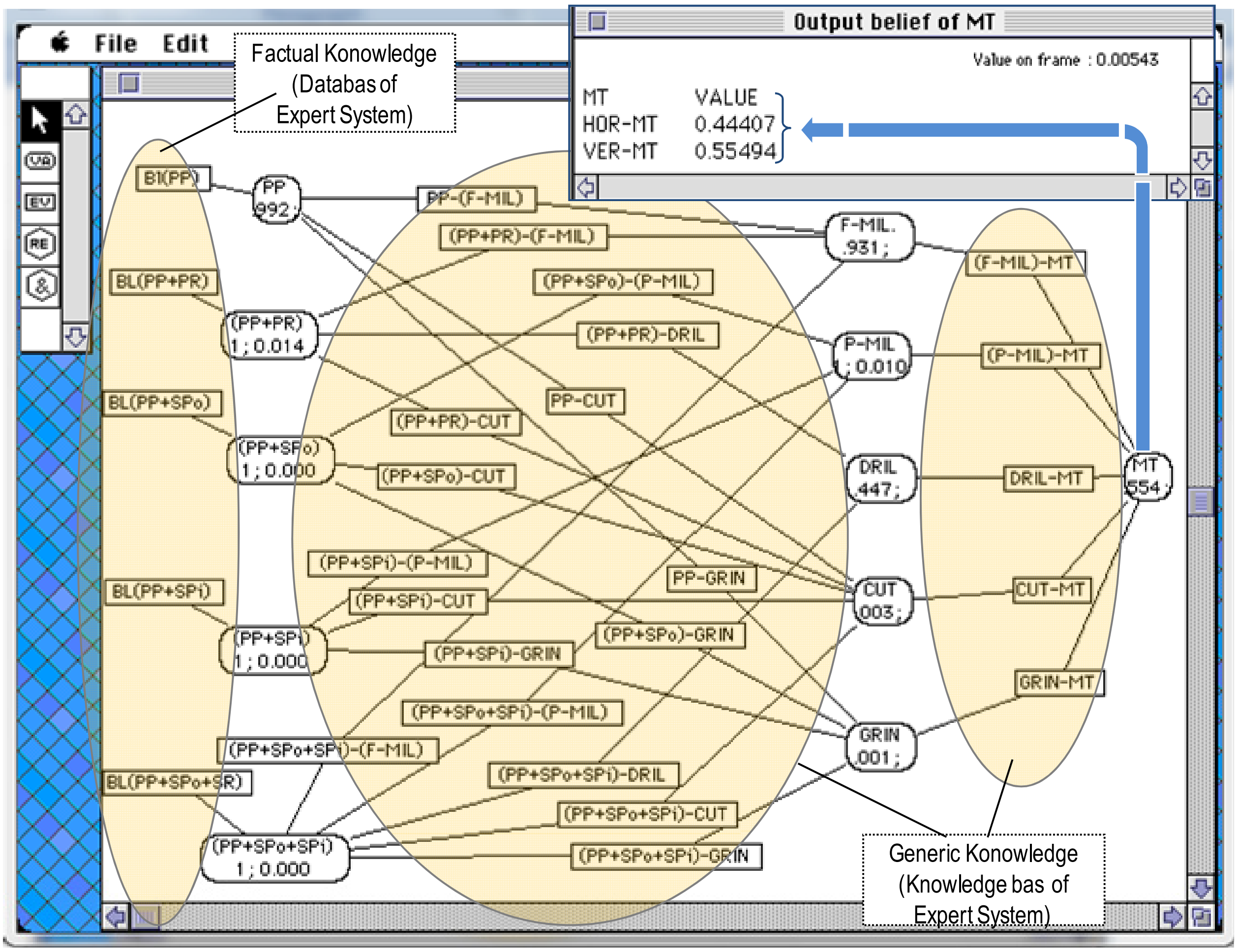

Figure 7. Evidence network with output belief (represent which of machine tools structure is most suitable for machining certain group of part

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ПРИСТУП ИЗБОРУ МАШИНСКИХ АЛАТА ЗА ИЗРАДУ ДРВЕНИХ ПРОИЗВОДА НА ОСНОВУ ОЧИГЛЕДНИХ МРЕЖА

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Током фазе развоја производа, нарочито у случају иновативних производа, дизајнери су се суочавали са непријатном ситуацијом да су у обавези да доносе одлуке под условима, које карактерише релевантан степен неизвесности и, па чак и супротно. Ова ситуација је веома честа у раним фазама процеса пројектовања, где није у потпуности дефинисан велики део спољашњих услова.
Исти је случај и са дизајнерима алатних машина. Као методолошки одговор, у стању је да попуни ову информативну празнину, у раду је приказан начин коришћења "доказног система" као алат подршке за дизајнере. Ови алати представљају неку врсту експертских система у којима је знање представљено и обрађено функцијом теорије Belief

(која се још назива Dempster-Chafer Теорија). После детаљног описа ове методологије, рад је фокусиран на концептуални дизајн алатих машина, односно одређивање најбољег структурног обрадног центра у фази идејног решења за претходно дефинисане групе дрвених делова који се на њима обрађују.