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Model strateškega odločanja distribucije orodij z uporabo pravil mehke logike

Model of Strategic Determination of Tool Distribution Based on the Fuzzy Rules

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Cilj, ki ga želimo izpostaviti v prispevku, je izdelava modela mehke logike, s katerim simuliramo dinamični sistem distribucije orodij. Narejen je model gibanja orodij v proizvodnem procesu in skladišču srednje velikega podjetja. V podjetju je prilagodljivost proizvodnje v veliki meri odvisna od obsega zelo kakovostnih izdelkov, dobrega nadzora pretoka in strateške distribucije orodij, ki morajo biti na voljo vedno ob pravem času in v zadostnih količinah. Imamo dinamični pretok orodij, ki ga je mogoče nadzorovati z uporabo zakonov mehke logike in povratnih signalov. Z njimi primerjamo želene in dobljene vrednosti in krmilimo pretok. V prispevku je prikazan model, s katerim smo prikazali časovne odmike, ki nastanejo pri distribuciji orodij. Predstavljeni realni nadzorni sistem pretoka orodij v podjetu je sestavljen iz pretoka materiala, informacij in proizvodnih sredstev. V sistemu obstajajo zveze med posameznimi enotami podjetja, ki so povezana z informacijskimi tokovi, s katerimi smo povečali prilagodljivost sistema.

(Ključne besede: pretok orodij, načrtovanje, modeli, logika mehka)

This paper concerns the working out of a fuzzy algorithm model to simulate the dynamic system of tool distribution. A model of tool motion in the production process and in the store of a medium-size company is made. In a company, the production flexibility depends to a large extent on the high- quality manufacturing and the flow and strategic distribution of tools, which must always be available in time and in sufficient quantities. Tool flow is dynamical and can be monitored according to fuzzy algorithm principles by means of feedback signals with which the desired and obtained values are compared and the flow controlled. This paper shows the model with which we presented the time delays occurring during the tool distribution. The presented real tool distribution monitoring system of a company comprises the flow of materials, information and production means. The system features the interconnections between the individual units of the company, involved in the information flows with which the flexibility of the system was increased.

(Keywords: tool distribution, planning, models, fuzzy algorithms)

0 UVOD

Model prikazuje pretok orodja skozi skladišče v nekem proizvodnem podjetju. Večino orodja v proizvodnji porabimo, presežek orodja pa prodamo ali skladiščimo. Pretok orodja moramo optimizirati tako, da je količina orodja minimalna, zaradi česar zmanjšamo skladiščne stroške, obenem pa mora biti količina takšna, da ne pride do pomanjkanja, in bi nastali zastoji [4].

Model na sliki 1 je prikazan kot sistem s povratno zvezo, ki posreduje informacijski signal [6]. Ekonomske sisteme lahko opisujemo s pravili mehke logike, prav tako tudi tehnične sisteme ([7] in [10]). Naš primer je prikaz časovnega obnašanja zalog v skladišču, kjer nadzorujemo dotok orodja v skladišče

0 INTRODUCTION

The model represents the flow of tools through the store of a production company. Most of the tools are consumed in production, the surplus tools are sold or stored. The tool flow must be optimized so that the quantity of tools is minimal, which reduces the storage costs, but at the same time the quantity must be such that a tool shortage and resulting stoppages do not occur [4].

The model in Figure 1 shows a system with a feedback loop, which transfers an information signal [6]. The economic systems as well as the engineering systems can be described by fuzzy logic rules ([7] and [10]). Our example shows the time behavior of stocks in a store where the tool inflow into the store and in odtok iz njega, da bi zmanjšali stroške skladiščenja in proizvodnje. Z računalniškim programom smo izdelali sistem za simuliranje skladišča. Zahteve, ki jih moramo upoštevati pri nadzoru, so:

1. Pretok orodja v skladišču mora pokrivati lastno porabo, prodajo orodij in obvezno rezervo.
2. Uporabili bomo nadzorni sistem mehke logike, ki se uporablja pri odpravljanju motenj v sistemu.
3. V odvisnosti od pravil mehke logike, lahko izberemo obliko obnašanja sistema skladiščenja, lahko se pojavi recesija (pomanjkanje) ali konjunktura (presežek) orodij.

1 MODELIRANJE PROIZVODNIH SISTEMOV Z UPORABO ZAKONITOSTI MEHKE LOGIKE

Vsak sistem, naj bo mehanski, elektronski ali organizacijski, je zapleten zaradi velikega števila odnosov med elementi, ki ga sestavljajo ([12] in [13]). Sistemski prijem je eden od načinov za iskanje najboljših ali vsaj dobrih rešitev problemov, ob upoštevanju celovitosti in omejitve sistema. Upravljanje sistemov je omogočeno z načelom povratne zveze [11], ki velja za katerikoli sistem, tudi biološki. Zaradi velike zapletenosti sistemov je najlaže dobiti celoten pregled s simuliranjem in modeliranjem. Lahko rečemo, da brez zmogljivih računalnikov upravljanje velikih zapletenih sistemov ne bi bilo mogoče [1].

Vsak sistem, ki ga obravnavamo, je omejen od okolja. V našem primeru, ko imamo skladišče orodja, predstavljajo okolje dobavitelji in porabniki. Elementi iz okolja so povezani prek vhodov v sistem in izhodov iz njega. Cilj obravnave je poiskati odnose v sistemu, kar je podlaga za simuliranje. Metode, ki jih bomo uporabljali, bodo temeljile na matematičnih zakonih in računalniških programih. Rezultati bodo grafično prikazani.

Tehnični in tudi sistemi za nadzor pretoka orodij z uporabo pravil mehke logike temeljijo na načelu povratne zveze, pri katerem na sedanje stanje posameznega elementa vplivajo neposredno ali posredno prejšnja stanja. Sistem je sklenjen ali zančni sistem, pri katerem povratna zveza bistveno spreminja dinamiko sistema. Povratna zveza je lahko pozitivna ali negativna. Pozitivno zvezo poznamo v ekonomiji, biologiji, oziroma povsod, kjer se srečujemo z rastjo. Sistem brez povratne zveze ima takšno strukturo, da na delovanje ne vplivajo prejšnja stanja. Z modelom bomo analizirali gibanje zalog. V prispevku je predstavljeno nekaj zakonitosti mehke logike na primeru optimizacije zalog orodij v skladišču. Količina Q je tista kosovna količina orodij, ki jo želimo imeti v skladišču. Da to dosežemo, moramo imeti pretok orodja q', ki je odvod Q po času. Povečevanje količine orodja v skladišču, če nimamo odtoka, je prikazano na sliki 2 in enačbi (1), kjer je V_k varnostna količina.

outflow from it are monitored in order to reduce the storage and production costs. By means of a computer program we made a system for the simulation of such a store. The following requirements must be taken into consideration for monitoring:

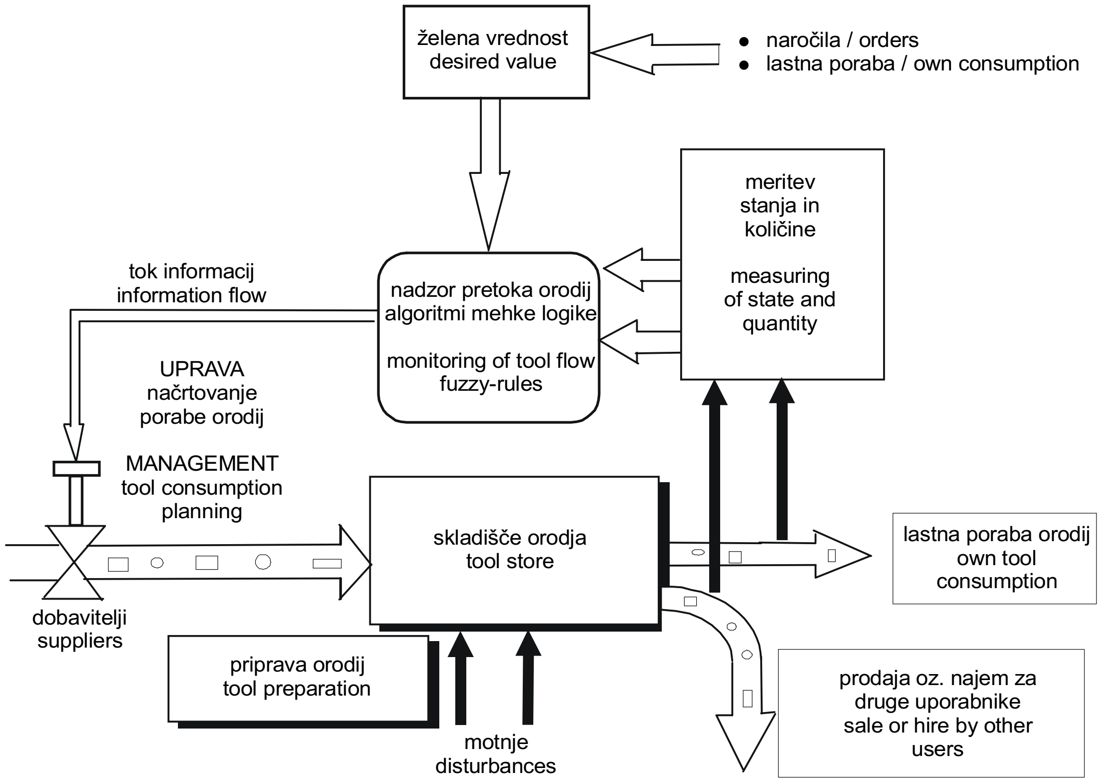
1. The tool flow in the store must cover the consumption, tool sales and an obligatory reserve.
2. A fuzzy algorithm monitoring system applicable for the removal of disturbances in the system will be used.
3. Depending on the parameters of the fuzzy algorithm it is possible to select the behavior of the storing system; recession (shortage) or upward trend (increase) of tools can occur.

1 MODELING OF PRODUCTION SYSTEMS BY MEANS OF FUZZY ALGORITHM RULES

Any system, either mechanical, electronic or organizational is complex due to the large number of relationships between the elements of which it consists ([12] and [13]). A systematic approach is one of the ways of searching for the best, or at least satisfactory, solution to the problem by taking into account the completeness and limitations of the system. The management of systems is ensured by the feedback loop [11] applicable for any system, even biological. Because of the high complexity of the systems, an overall survey can be most easily obtained by means of simulation and modeling. It can be claimed that the management of large complex systems would not be possible without highly capable computers [1].

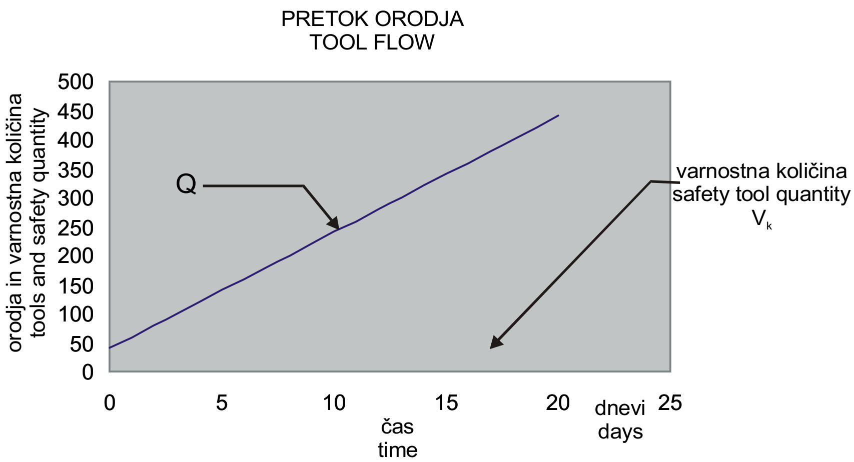
Any system to be dealt with is limited by the environment. In our case, when dealing with a tool store, the environment is represented by the suppliers and users. The elements from the environment are connected to the system through inputs and outputs. The aim of the treatment is to find the relationships in the system, which are the basis for the simulation. The methods, which will be used, are based on mathematical laws and software programs. The results will be graphically represented.

The engineering and tool flow monitoring fuzzy algorithms for the management are based on the principle of a feedback loop, where previous states directly or indirectly influence the present state of the individual element. The system is a closed loop, where the feedback loop significantly changes the dynamics of the system. The feedback loop can be positive or negative. The positive feedback loop occurs in economics and biology, or anywhere where growth is encountered. The system without a feedback can have a structure where the previous states do not influence the functioning. By means of the model the stock movements will be analyzed. This paper presents some fuzzy algorithm rules in an example of optimization of tool stocks in a store. The quantity Q is the number of tools desired in the store. In order to achieve this, the tool flow must be q', which is the derivative of Q by the time t. The increase of tools' quantity in the store, if there is no outflow, is shown in Figure 2 and in equation (1) where V_k is the safety quantity.



Sl. 1. *Model pretoka orodja skozi skladišče (prirejeno po [9])*
Fig. 1. *Model of tool flow through store(adapted from [9])*

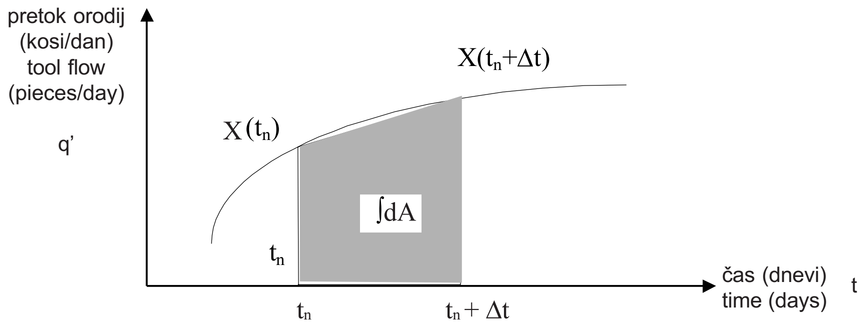
$$Q = q'\cdot t + V_k \text{ (kos - piece)}$$
$$q' = 20 \text{ (kos/dan - piece/day)} \quad (1).$$
$$V_k = 40 \text{ (kos - piece)}$$



Sl. 2. *Povečevanje količine orodij v skladišču pri konstantnem dotoku orodja, če ni porabe*
Fig. 2. *Increase of tool quantity in store with constant tool inflow if there is no application*

Pri programiranju smo uporabili trapezno integracijo, ki je sicer manj natančna, vendar z njo dosežemo dobre rezultate, če zgostimo delitev. Prikaz integracije z integracijskim elementom je na sliki 3.

For programming, the trapezoidal integration was used, which is less accurate, but by using it, good results are obtained if the division is high. The integration by means of an integration element is shown in Figure 3.



Sl. 3. *Integracija med dvema točkama, kjer površina pod krivuljo A pomeni količino orodja v skladišču*
Fig. 3. *Integration between two points where the surface below curve A represents the tool quantity in the store*

Integracijo med dvema točkama poenostavimo s površino v obliki trapeza. Enačba površine A je:

The integration between two points is simplified with the surface of a trapezoidal shape. Equation of surface A is:

$$\int dA = \frac{(X_n + X_{n+1})(t_{n+1} - t_n)}{2} \quad (2).$$

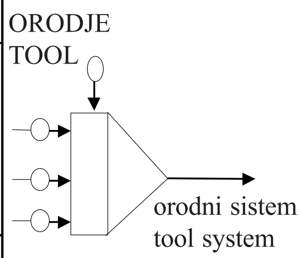
Na sliki 4 je prikazan simbol za integracijski element z več vhodi in enim izhodom. V sistem vstopajo orodja, pri čemer se njihove vrednosti seštevajo. V odvisnosti od tehnološkega procesa lahko z njim ponazorimo časovno odvisno gibanje orodij v različnih orodnih sistemih.

Pri modeliranju uporabimo program EXCEL, ki ima vgrajene matematične module. Nestabilnost popravimo s spremembo parametrov mehke logike. Načelo je uporabljeno tudi v skladiščih, kjer nadzorujemo pretok orodja.

Figure 4 shows the symbol for the integration element with several inputs and one output. Depending on the technological process, it is possible to represent the tool motion dependent on time in different tool systems.

For modeling, the EXCEL program, incorporating mathematical modules, is used. The instability is corrected by using the fuzzy algorithm. Such a principle is used also in a store where the tool flow is supervised.

STRUŽENJE TURNING	• rezalna ploščica /cutting insert • držalo /holder
VRTANJE DRILLING	• svedri / drills • vpenjalni del / clamping part • steblo / stem • glava / head
FREZANJE MILLING	• valjasto frezalo / cylindrical milling cutter • steblasto frezalo / stem milling cutter • kotno frezalo / angular milling cutter • vpenjalo / clamping device • frezalne glave / milling heads • rezalne ploščice / cutting insert
MODULNA orodja MODULAR tools (VARIOLOCK)	• osnovnovno držalo / basic holder • adapterji / adapters • rezalni modul / cutting module • rezalne ploščice / cutting inserts
sistemsko orodje s stožcem ISO system tool with ISO cone	• trni / mandrels • puše s stožcem morse / bushes with morse cone • frezalne glave / milling heads



Sl. 4. *Orodni sistemi za različne tehnologije, ki jih ponazorimo z integracijskimi elementi*
Fig. 4. *Tool system for different technologies, represented with integration elements*

Osnovna naloga vodenja in nadzora je hitra stabilizacija sistema in doseg želene vrednosti. V primeru, da se pojavijo v sistemu motnje (sprememba dotoka ali odtoka orodij), mora nadzor omogočiti takojšen popravek in ponovno stabilizacijo sistema.

Z računalniškim nadzorom laže načrtujemo pretok orodij za oskrbovanje večjega števila strojev [1]. V prispevku je prikazan model oskrbe strojev z orodij s pomočjo dobaviteljev in skladišča orodij. Zahteve po orodjih so odločilni parametri za načrtovanje porabe. Model je preverjen na praktičnem primeru [8], izdelan je v programskem jeziku EXCEL, s čimer smo nazorno dokazali pravilnost simuliranja. Dana je še varnostna količina orodij. Transportne in skladiščne stroške želimo zmanjšati, pri čemer nam pomaga program, ki izračuna stroške ob spremenjenih parametrih.

Namen modeliranja je poiskati povezave med posameznimi enotami podjetja, med poslovnimi enotami, med proizvodnjo, nabavo in prodajo. Vsak model mora omogočiti uporabniku, da izvaja odločitve in možnost preskusa celotnega poteka. V vseh dinamičnih sistemih, kjer nadziramo pretok z algoritmi mehke logike, je pomemben povratni tok informacij [2].

Referenčni model pomaga pri zgradbi organizacije sistema. S simuliranjem se korakoma približujemo realnemu stanju. Pri tem uporabljamo bazo podatkov, ki jo moramo nenehno dopolnjevati, obenem pa so osnovni podatki za naš organizacijski sistem.

Na sliki 5 je prikazan zahtevan pretok Yr orodja skozi skladišče v nekem časovnem roku. V skladišču imamo orodja preveč ali premalo (recesija, konjunktura).V skladišču je zaposleno več ljudi, ki skrbijo za nemoten pretok in za nastavljanje orodja. Prepustnost skladišča je odvisna od frekvence dotoka orodij in hitrosti nastavljanja, skladiščenja in transporta orodij. Izhod orodja iz skladišča Y je amplitudno enak vhodu v skladišče X, le da je med njima časovni razmik. Nastavitev, skladiščenje in transport povzročajo časovne premike med količino orodij, ki vstopa v skladišče in izstopa iz njega.

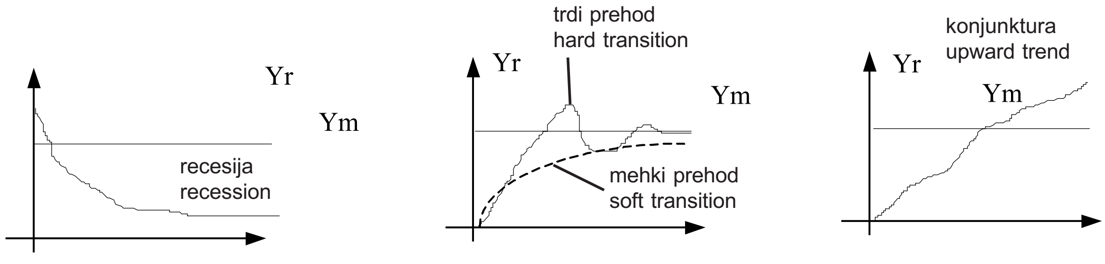
The basic task of the management and supervision is fast stabilization of the system and achieving the desired value. In the case of disturbances occuring in the system (change of tool inflow and outflow) the supervision must ensure immediate correction and re-stabilization of the system.

By means of computer monitoring the tool flow to a great number of machines is more easily planned [1]. This paper describes the model of tool supply to machines by tool suppliers. The requirements for tools are decisive parameters for the planning of consumption. The model is verified on a practical example [8]; it is made in the EXCEL program language so that the correctness of the simulation can be clearly demonstrated. A safety quantity of tool is also anticipated. Reduction of transport and storing costs is wished for; to this end a program is used that calculates the costs with changed parameters.

The purpose of modeling is to find interconnections between the individual units of a company, between the business units, production, purchasing and sales. Each model must enable the user to implement the decisions and the possibility of testing the entire process. In all the dynamic systems where the tool flow is controled by fuzzy algorithms, the return flow of information is important [2].

The reference model helps us to build the organization of the system. By means of simulation approach the real state we step by step. To this end we use a base of data, which must be constantly updated and at same time are the basic data for our organizational system.

Figure 5 shows the required tool flow, Yr, through the store within a certain time. Increasing and decreasing the number of tools in the store (recession, upward trend) are shown. Several employees, taking care of trouble-free flow and adjustment of tools, are employed in the store. The freedom of movement through the store depends on the frequency of the tool inflow and the speed of adjusting, storing and transporting the tools. The tool outflow from the store, Y, with respect to the amplitude, is equal to the inflow into the store, X, except that there is a time delay between them. Adjustments, storing and transport cause the time delays between the tool quantities that enter and leave the store.



Sl. 5. *Pretok orodij v skladišču v odvisnosti od parametrov logično mehkega krmilnika*
Fig. 5. *The trends of tools in store are obtained with dependence on the fuzzy controller*

2 LOGIČNO MEHKI KRMILNIK ZA KRMILJENJE PRETOKA ORODIJ

Na splošno je logično mehki krmilnik zelo primeren za sistem krmiljenja z več spremenljivkami. Znano je, da ima krmilnik z dvema vhodoma in enim izhodom dovolj dobre karakteristike za krmiljenje pretoka orodij ([3] in [5]). Dva vstopna signala v logično mehki krmilnik se imenujeta: napaka pretoka *E* in sprememba pretoka *CF*. Napaka pretoka *E* je razlika med referenčnim (priporočenim) pretokom Y_r in dobljenim pretokom Y_m. Sprememba pretoka *CF* pa je razlika med dobljenim pretokom *i*-tega koraka in (*i*-1)-tega koraka. Obe enačbi zapišemo:

2 FUZZY CONTROLLER FOR TOOL DISTRIBUTION CONTROL

Generally, the fuzzy controller is very suitable for the multi-variable control system. In experiments, it was found that a two inputs and one output fuzzy controller is suitable to obtain good performance in tool quantity control ([3] and [5]). The two inputs of the fuzzy controller are the output error, E, and the output change of tools, *CF*. The flow error, *E,* is the difference between the reference quantity of tools, Y_r, and the real quantity, Y_m . The tool quantity change, *CF,* is the difference between the real quantity of the *i*th period and the quantity of tools of the (*i* – 1)th period. That is:

$$E = Y_r - Y_m(i) \qquad (3),$$

$$CF = Y_m(i) - Y_m(i-1) \qquad (4).$$

Izhod nadzora mehke logike *X* je definiran kot sprememba ukaza o pretoku orodij. Zaradi tega je ukaz o spremembi pretoka i-te periode *X*(*i*) enak seštevku spremembe ukaza pretoka i-te periode d*X*(*i*) in ukaza o spremembi pretoka (*i*-1)-tega periode *X*(*i*-1). Enačba se glasi:

The output of the fuzzy controller, *X*, is defined as the change of the tool quantity command. Therefore, the tool quantity command of the *i*th output period, *X*(*i*), is equal to the summation of the change of the tool quantity command of the *i*th period, d*X*(*i*), and the tools quantity command of the (*i* – 1) *i*th period, *X*(*i*– 1). That is:

$$X(i) = X(i-1) + \mathrm{d}X(i) \qquad (5).$$

3 KRMILNI ALGORITEM MEHKE LOGIKE IN PRAVILA

Realno številčno stanje je treba realno stanje prikazati s pojmi mehke logike. Kot rezultat lahko navedemo naslednje jezikovne nize:

NV večja negativna vrednost
NS srednja negativna vrednost
NM manjša negativna vrednost
NČ nič
PV večja pozitivna vrednost
PS srednja pozitivna vrednost
PM manjša pozitivna vrednost

Niza za vhod in izhod logično mehkega krmilnika sta bila načrtovana v območju [-1,1]. Potrebno je določiti stopnje vstopnih in izstopnih vrednosti logično mehkega krmilnika. Slika 6 prikazuje pripadnostne funkcije na izstopu iz logično mehkega krmilnika, kar je ukaz za spremembo količine orodij d*X*, prikazane v enačbi (5).

Rezultat je: ukaz za določanje količine orodij se ne spremeni, če je majhna razlika med izstopno količino orodij in referenčno količino, ki se ustvari v odvisnosti od motnje.

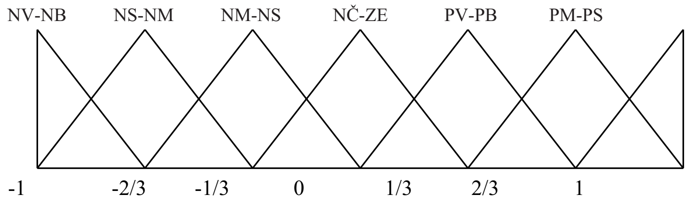
3 FUZZY CONTROL ALGORITHMS AND RULES

In order to let the quantity of the real world be fuzzified to the quality of the fuzzy world, it is necessary to qualify the quantitative statement. As a result, the following linguistic sets are assigned:

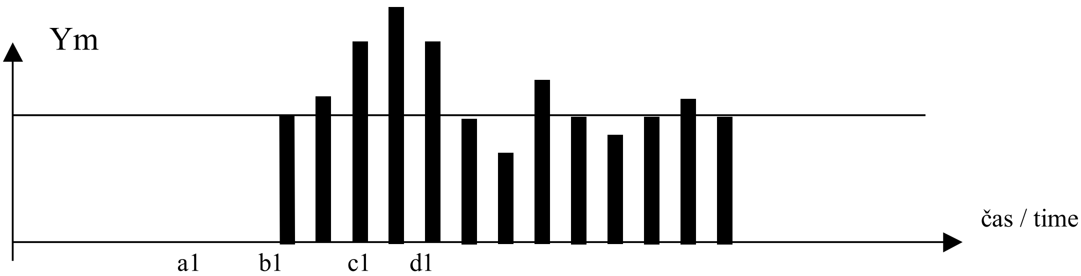
NB negative big,
NM negative medium,
NS negative small,
ZE zero,
PB positive big,
PM positive medium,
PS positive small.

The fuzzy sets for the input and output of the fuzzy controller have both been designed in the range of [-1, 1]. In other words, the scaling of the input and output values of the fuzzy controller is necessary. Figure 6 shows the shape of membership functions for the output of the fuzzy controller, i.e. the change of the tools quantity command, d*X*, see equation (5).

As a result, the tools quantity command is unchanged when a small variation between the output tool quantity and the reference quantity is generated owing to a disturbance.



Sl. 6. *Pripadnostne funkcije*
Fig. 6. *Shape of membership functions*



Sl. 7. *Časovni odziv količine orodij*
Fig. 7. *Tool quantity response in time interval*

Slika 7 prikazuje primer količine orodij na izstopu iz modela. Za točko a1 je napaka količine *E* enaka *PV* in sprememba količine *CF* je *NČ*. Zaradi tega je v točki a1 izhod krmilnega signala mehke logike d*X* enak *PB*. Glede na prejšnje opise, lahko zapišemo stanja v naslednjih oblikah:

- če je *E* enak *PB* in *CF* enak *ZE* sledi, da je d*X* enak *PB*.

Podobno zapišemo v točkah b1, c1, d1,…, naslednja stanja:

- če je *E* enak *NČ* in *CF* enak *PV* sledi da je d*X* enak *NS*
- če je *E* enak *NB* in *CF* enak *NČ* sledi da je d*X* enak *NV*
- če je *E* enak *NČ* in *CF* enak *NV* sledi da je d*X* enak *PS*

Končno lahko zapišemo določila mehke logike v odločitveni preglednici, kakor je prikazano v preglednici 1.

Figure 7 shows an example of the tool quantity response. For the point a1 the quantity error, *E,* is *PB* and the quantity change, *CF*, is *ZE.* Therefore, at the point a1, the output of the fuzzy controller, d*X*, should be *PB.* Therefore, based on the above discussion, a fuzzy conditional statement can be described in the following form:

- if *E* is *PB* and *CF* is *ZE* then d*X* is *PB.*

Similarly, at the points b1, cl, d1,..., a number of fuzzy conditional statements can also be described as:

- if *E* is *ZE* and *CF* is *PB* then d*X* is *NM*
- if *E* is *NB* and *CF* is *ZE* then d*X* is *NB*
- if *E* is *ZE* and *CF* is *NB* then d*X* is *PM*

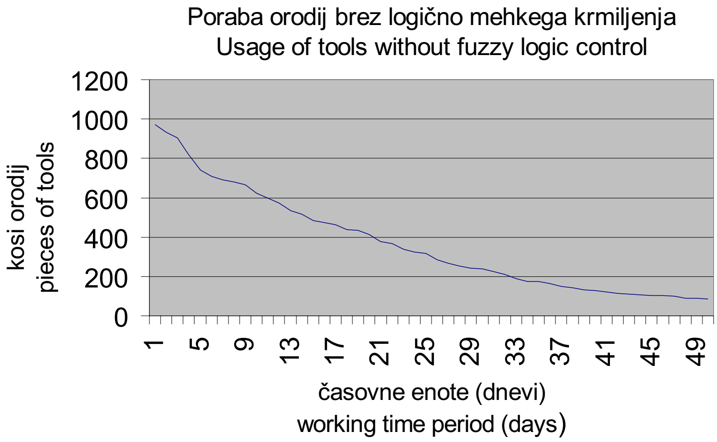
Finally, for convenience, these fuzzy conditional statements have been formulated and expressed as a decision table, see Table 1.

Preglednica1. *Logično mehki krmilni ukazi za spremembo količino orodij*
Table 1. *Fuzzy control rules for the tool quantity change*

CF *E*	*NV/NB*	*NS/NM*	*NM/NS*	*NČ/ZE*	*PM/PS*	*PS/PM*	*PV/PB*
NV/NB	*NV/NB*	*NV/NB*	*NV/NB*	*NV/NB*	*NV/NB*	*NV/NB*	*NV/NB*
NS/NM	*NS/NM*	*NS/NM*	*NV/NB*	*NV/NB*	*NV/NB*	*NV/NB*	*NV/NB*
NM/NS	*NM/NS*	*NM/NS*	*NM/NS*	*NS/NM*	*NS/NM*	*NV/NB*	*NV/NB*
NČ/ZE	*PS/PM*	*PM/PS*	*PM/PS*	*NČ/ZE*	*NM/NS*	*NM/NS*	*NS/NM*
PM/PS	*PV/PB*	*PS/PM*	*PM/PS*	*PM/PS*	*NČ/ZE*	*NM/NS*	*NM/NS*
PS/PM	*PV/PB*	*PV/PB*	*PS/PM*	*PS/PM*	*PM/PS*	*NČ/ZE*	*NM/NS*
PV/PB	*PV/PB*	*PV/PB*	*PV/PB*	*PV/PB*	*PS/PM*	*PM/PS*	*NČ/ZE*

4 SIMULIRANJE PRETOKA ORODIJ MED PROIZVODNIM PROCESOM

4 SIMULATION OF TOOLS DISTRIBUTION DURING THE MANUFACTURING



Sl. 8. *Količina orodij v skladišču med proizvodnim procesom*
Fig. 8. *The tool quantity in the storage during manufacturing*

Opis modela: V začetku proizvodnega procesa imamo 1000 kosov orodij. Količina mora zadostovati za oskrbo proizvodnega procesa. Slika 8 prikazuje, kako se količina orodij zmanjšuje. Določili smo varnostno količino, ki prepreči pomanjkanje orodij.

Varnostna količina je 300 kosov. Ko upade količina pod to vrednost, je treba naročiti od dobaviteljev novo orodje. Uporabo orodij določimo statistično in je predstavljena v enačbi kot naključno število RND. Za preprečitev pomanjkanja moramo pripraviti krmiljenje, temelječe na pravilih mehke logike. Enačbi (6) in (5) prikazujejo model porabe orodij, kjer smo z i označili časovne periode.

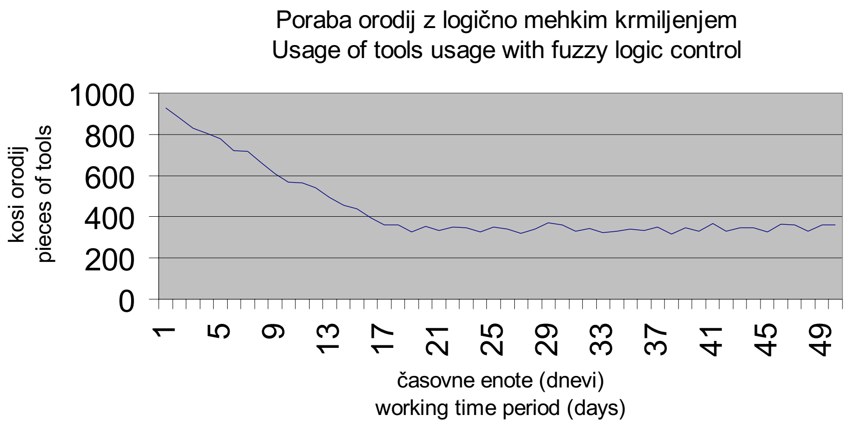
Description of model: In the beginning there are 1000 tool pieces. This quantity must cover all necessary consumption during the production process. In Figure 8 we find that the quantity of tools during the production process has been reduced. We have to determine the safety quantity, which prevents a tool shortage.

The safety quantity is 300 tool pieces. If the tool quantity is under this level then we must supply supplementary tools from suppliers to the magazine. The usage of tools is statistically determined and is represented as random function RND. For preventing a tool shortage we must prepare control based on fuzzy rules. The equations (6) and (5) represent the model of tool consumption where i is the time period.

$$Y_m(i) = Y_m(i-1) - Y_m(i-1) \cdot RND \cdot 0{,}1 + X(i) \qquad (6).$$

Na sliki 9 vidimo odvisnost števila kosov orodij pri krmiljenju, temelječem na pravilih mehke logike. Varnostna količina 300 kosov je tista optimalna količina, ki zmanjšuje stroške.

In Figure 9 we can see the tool quantity controled using fuzzy rules. The safety quantity of 300 pieces is the optimum quantity also reducing the tool costs.



Sl. 9. *Krmiljenje količine orodij, temelječe na pravilih mehke logike*
Fig.9. *Control of tools' quantity based on fuzzy rules*

5 SKLEP

Pretok orodij je dinamičen, saj je odvisen od časa in se prilagaja zakonitostim mehke logike. Pojavijo se amplitudni in fazni premiki, ki jih ponazorimo z zakonitostmi mehke logike. Minimalna finančna sredstva za material so eden od bistvenih dejavnikov prilagodljive proizvodnje. Za dosego prilagodljive proizvodnje je treba analizirati vse komponente, ki vplivajo na proizvodni proces. V skladu s strategijo podjetja morajo biti dobavitelji. Ti omogočajo hitro, kakovostno in poceni dobavo orodij in drugih materialnih sredstev, ki sodelujejo v procesu. Optimalno količino smo določili s statističnimi metodami, kjer moramo upoštevati obvezno rezervo. Koristna je praktična uporaba zakonitosti mehke logike pri modeliranju.

5 CONCLUSION

The tool flow is dynamical since it depends on time and adapts itself to fuzzy algorithm rules. Amplitude and phase delays occur that are represented by the use of fuzzy algorithm rules. Minimum funds for tools are one of key factors in flexible manufacturing. To achieve flexible manufacturing it is necessary to analyze all the components participating in the production process. Also, the suppliers must conform to the company’s strategy. They assure a fast, cheap and high-quality supply of tools and other material means participating in the process. The optimum quantity was determined by means of statistical methods where it is necessary to take into account the obligatory reserve. The use of fuzzy algorithm rules in modeling of the tool flow proves that they are a useful aid also for monitoring the tool distribution.

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