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TRENDOVI U INTELIGENTNOJ PROIZVODNJI
NEW TRENDS IN INTELLIGENT MANUFACTURING

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Sažetak: *U članku je dana analiza između nekolicine modernih inteligentnih proizvodnih sustava poput: biološkog, holonskog (HMS), fraktalnog (FrMS) te ubiquitous proizvodne koncepcije. Na brzorastućim tržištima ključna je fleksibilnost proizvodnih sustava kako bi se što učinkovitije moglo odgovoriti na promjene nastale u tržišnom okruženju. Dan je detaljan prikaz karakteristika navedenih sustava, te su navedene njihove komparativne prednosti i nedostaci. Prikazani su utjecajni čimbenici i dane su smjernice za daljnji nastavak istraživanja.*

Ključne riječi: – biološki, holonski, fraktalni, ubiquitous proizvodni sustav
– trendovi u proizvodnji
– inteligentni sustavi

Abstract: *This article gives an analysis of a few modern intelligent production systems: biological, holon (HMS), fractal (FrMS) and ubiquitous production concepts. The key to success in modern fast growing systems is a flexibility of the production system in order to respond quickly to changes within the market. A detail representation of the characteristics as well as the advantages and disadvantages for these systems is given. Influential factors have been listed as well as guidelines for further research.*

Keywords: – biological, holon, fractal, ubiquitous production system
– manufacturing trends
– intelligent systems

1. UVOD

Proizvodni je sustav prema definiciji, [1,2] složena socijalna i materijalna tvorevina kojom se obnaša proces stvaranja vrijednosti – materijalnih i drugih dobara. Pod pojmom procesa podrazumijeva se zbivanje označeno pretvorbom i/ili transportom tvari, energije, informacija kod kojega se prikladnim djelovanjem na utjecajne veličine postižu rezultati. Matematičko modeliranje i optimizacija su metode nadgradnje čiji je osnovni cilj inoviranje postojećih procesa i sustava, moderniziranje i podizanje na višu razinu inteligencije. U pozadini je svakog proizvodnog procesa balansiranje između trenutnih potreba tržišta za nekim proizvodom i realnih proizvodnih mogućnosti ukalkuliranih u proizvodni plan. Na početku modeliranja od iznimne je važnosti utvrđivanje zakonitosti međusobnih veza ulaznih i izlaznih parametara kako bi naš model mogao dobro funkcionirati i kako bi se pomoću njega postignuli kvalitetni odnosno optimalni rezultati.

2. NOVI TRENDOVI KONCEPCIJA IMS-A

Suvremene industrijske organizacije, [3] još uvijek nisu tehnološka idila, već su kontinuirano poprište različitih ljudskih interesa unutar organizacije i među

1. INTRODUCTION

A manufacturing system is by definition [1,2] a complex social and material product which carries the creation process of valuables material goods and other goods. The term process applies to actions referring to the transformation and/or transport of material, energy and information, which can be influenced by appropriate actions on the influential factors. Mathematical modeling and optimization are methods of upgrading whose primary purpose is the innovation of existing processes and systems as well as the modernization and achievement of a higher intelligence level. The basis of every production system is achieving a balance between the current market for a new product and realistic productional capabilities calculated within the production plan. It is of extreme importance to establish a valid connection of input and output parameters in order for our model to function well and to obtain quality and optimum results.

2. NEW IMS CONCEPT TRENDS

Modern manufacturing organizations, [3] are still far from a technological ideal, they are rather a continuous battlefield of different human interests within an organizacijama. Zapravo, radi se o kompleksnom odnosu industrije i tehnologije, ekonomije, tržišta, rada, osobe, grupe, socijalne strukture organizacije u kontinuiranoj dinamici promjena. Suvremeno dinamično proizvodno okruženje poligon je za konstanto unapređivanje i usvajanje novih znanja, ali i konstantno preispitivanje dosadašnjih proizvodnih koncepcija. Porast kompleksnosti proizvoda, proizvodne strukture i proizvodnih postupaka s jedne strane te turbulentno tržište s pripadajućim rastućim zahtjevima za kvalitetom i raznovrsnim proizvodima s druge strane, predstavljaju novi izazov u planiranju i realizaciji proizvodnog sustava. Osnovni je cilj poslovnih operacija u proizvodnom sektoru povećanje prodaje i profita. Kako bi se to postiglo, važno je slijediti želje kupaca u pogledu cijene koštanja i vremena isporuke kako bi se na taj način adekvatno odgovorilo na zahtjeve tržišta s konkurentnim proizvodom. Unatoč naporima istraživača fokusiranih na razvoj različitih strategija, još ne postoji univerzalni proizvodni koncept koji bi pod jednakim ili barem sličnim uvjetima dobro funkcionirao s različitim proizvodnim asortimanom. Jedna je od bitnih odlika modernih proizvodnih sustava (PS) heterarhija [4,5,7,11]. Heterarhija označava sustave u kojima nije izražena organizacijska struktura. U radu je dan kratki prikaz sljedećih proizvodnih sustava:

- biološki,
- fraktalni (FrMS)
- holonski (HMS),
- ubiquitous.

U nastavku slijede njihovi prikazi.

organization and among other organizations. Essentially, it is a complex relation of the industry, technology, economy, market, work, people, groups and social structures of the organization within a continuous dynamic of changes. A modern dynamic production surroundings represents a polygon for constant upgrades and adaptation to new cognitions, but also a constant questioning of existing production methods. With the growth of product complexity, production structure and production processes from one standpoint and a turbulent market with matching growing demands for quality and products of all types from the other, represent the new challenge in planning and realization of a production system. The basic goal of a business operation within a production center is an increase in sales and profit. In order to achieve this goal it's important to follow the demands of the customers regarding the cost and delivery terms so as to provide an adequate response to the market demands with a concurrent product. In spite of the research efforts focused on the development of different strategies, there is still no universal production concept that could, under equal or at least similar circumstances, function with a different production assortment. One of the more relevant attributes of modern manufacturing systems (MS) is heterarchy,[4,5,7,11]. Heterarchy is a name for systems with no pronounced organizational structure. This paper givess a short overview of the following production systems.

- Biological
- Fractal
- Holon
- Ubiquitous

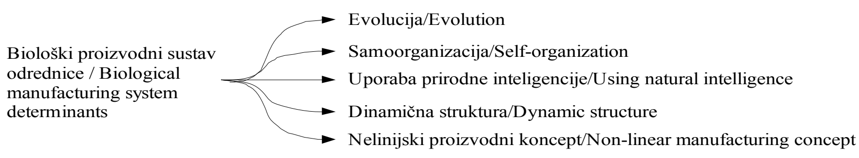
Their representations are show within the following text.

2.1. Biološki proizvodni sustav

Biološki proizvodni sustavi (BPS) imaju poveznicu s biološkim sustavima kakve nalazimo u prirodi. Prirodni biološki sustavi pokazuju mnoge značajke, [5,6,7,12] uključujući autonomnost i spontanost, socijalnu usklađenost prema organizaciji itd. Promatranjem strukturne organizacije može se zaključiti da biološka stanica čini osnovnu jedinicu koja sadrži sve ostale dijelove biološkoga sustava. Iako se čini da su stanice identične, one se razlikuju po funkcijama koje obavljaju kao i sposobnostima izvođenja više operacija istodobno. Odrednice BPS-a prikazane su na slici 1.

2.1. Biological manufacturing system

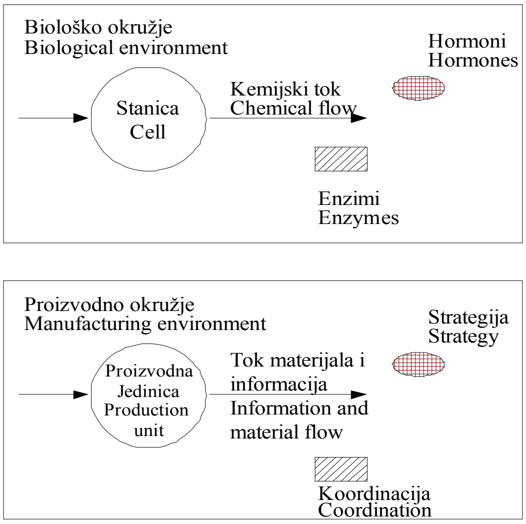
Biological manufacturing systems (BMS) are in correlation with biological systems as can be found in nature. Natural biological systems show many characteristics, [5,6,7,12] such as autonomy and spontaneity, social harmony in the organization, etc. By investigation of the structure of the organization, it can be concluded that the biological cell forms a basic unit, which includes all the others parts of the biological system. The cells look identical but they are different with respect to their functions and abilities for processing more operations at the same time. The main characteristics of BMS are shown in Figure 1.



Slika 1. Odrednice biološkog proizvodnog sustava
Figure 1. Determinants of biological manufacturing system

Stanice su posložene u blokovima čineći tako slojevitu hijerarhijsku strukturu u organizmu. Tako se primjerice mišićno tkivo sastoji od grupiranih stanica koje tvore organ s posebnom funkcijom (npr. tkivo srčanog mišića). Na sljedećoj razini postoje različiti organi koji zajedno čine tijelo odnosno sustav. Ovdje je posebno važno naglasiti da se stabilnost sustava zasniva na stabilnosti internih kemijskih reakcija koje se odvijaju u živom organizmu. One se održavaju putem različitih metaboličkih reakcija. Unutar stanice o tome se brinu enzimi koji djeluju kao katalizatori za ubrzavanje pojedinih procesa, ali i kao korektiv s druge strane za usporavanje reakcija. Koncept biološkoga proizvodnog sustava predložen je [6,7] kao proizvodni sustav sljedeće generacije. Funkcije živih organizama prikazuju se izražavanjem dvaju tipova biološke informacije DNA (genetskog tipa) koja evoluira kroz generacije i BN informacija (neuronskog tipa) koje se individualno uče i stječu tijekom životnoga vijeka svakoga pojedinog organizma. Jedan od izazova u istraživanju na koje će ova vrsta sustava morati odgovoriti jest ponašanje i odaziv sustava s porastom kompleksnosti i porastom količine informacija koje je potrebno obraditi. Na slici 2 dan je prikaz usporedbe organizacije rada biološke stanice s proizvodnim okružjem.

The cells are positioned in blocks making a multi-level hierarchy in the organism. For example, muscle tissue consists of groups of cells forming an organ with special function (heart tissue muscle). On the next level, different kind of organs exists that make up the body or system. It is very important to highlight the stability of a system constituted of chemical reaction stability, which happens in the live organism. They are maintained through numerous metabolic reactions. In the interior of the cell, there are enzymes working as catalysts, making a higher rate for some reactions. Furthermore, they can catalyze some reactions at a lower rate as a corrective function. The concept of the biological manufacturing system has been proposed [6,7] as the manufacturing model of the next generation. The functions of living organisms are mapped by two types of biological information. The first one is DNA (the genetic type) which evolves through generations and the second one is BN information (the neural type) which learns throughout the lifespan of every organism. One research challenge for this type of system is the need to address the behavior and response of the system when the complexity and quantity of information that must be processed increases. Figure 2 illustrates the working organization of the biological cell and the production environment.



Slika 2. Usporedba biološke stanice s proizvodnim okružjem
Figure 2. Comparison of biological cell with production environment

Biološki proizvodni sustav nastoji djelovati s nepredeterminističkim promjenama u proizvodnom okružju temeljeći se na idejama preuzetima iz prirodnog okružja, kao što su: samorast, samoorganizacija, prilagodba i evolucija. Vidljivo je da postoje mnoge sličnosti s hijerarhijskom i funkcijskom organizacijom. Jedinica dobiva traženi ulaz iz okoline i izvodi potrebne operacije. Izlazne vrijednosti vraćaju se u okolinu i proizvodne jedinice mogu slično djelovati na ćelije. U takvoj strukturi svaka velika sličnost u organizaciji

The biological manufacturing system operates with non-predeterministic changes in manufacturing environmentally. This production system is based on a concept, which has been taken from natural abilities such as: self-growing, self-organization, self-adaptation, and evolution. There are many similarities regarding hierarchical and functional organization. A unit receives the appropriate input and then the suitable operations are used. Output values are returned in the environment afterwards. Every level and every neighboring area is biološkog okruženja i proizvodnog okruženja. Kod genetskog algoritma funkcija dobrote (engl. *fitness function*) prema, [6] je:

supported in this type of structure. As shown in Figure 2, there is great organizational similarity between the biological and manufacturing environment. In Genetic algorithm (GA) optimization, the fitness function according to [6] is:

$$f_{ri} = C_{r1} vrijeme + C_{r2} zahtijev \qquad (1)$$

$$f_{wi} = C_{w1} vrijeme + C_{w1} rast + C_{w3} kolizija + C_{w4} odbijanje \qquad (2)$$

gdje su *C, vrijeme, zahtijev, rast i kolizija* konstante.

where *C, time, request, grow and collision* are constants.

Svi elementi BMS-a, kao što su primjerice radni materijal, strojevi, alati, transportna sredstva i roboti, usporedivi su s biološkim organizmom. Alati koji se upotrebljavaju prilikom modeliranja su genetski algoritam, genetsko programiranje, evolucijska strategija, L-sustav itd. U slučaju proizvodnih ćelija njihov je položaj utvrđen. Za razliku od položaja proizvodnih ćelija parametri pridruženi sirovom materijalu određuju njegovu putanju – od početne grube obrade, preko srednje obrade ka finoj obradi i finišu. Tijekom proizvodnje sustav se može razvijati i dodavati nove informacije koje kasnije mogu olakšati postupanje kod pojave nepredviđenih zastoja ili kvarova.

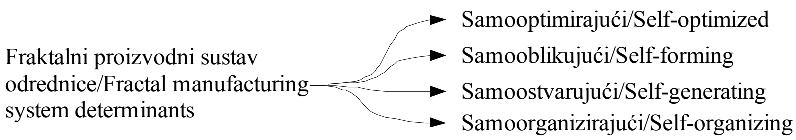
All BMS elements like working material, machines, tools, transport vehicles and robots can be compared to the biological organism. Tools used in the modeling phase are GA, genetic programming, evolutionary strategy, L-system etc. In the case of production cells, their role is established. As opposed to the location of the production cell, parameters joined to raw material determines their path from the initial crude processing, through medium processing to the final processing and finish. During production, the system can develop and add new information, which later can ease the procedure in the event of unexpected delay or errors.

2.2. Fraktalni proizvodni sustav

2.2. Fractal manufacturing system

Sam koncept fraktalnih tvornica sastoji se od puno manjih cjelina nazvanih *fraktali*. Svaki je fraktal komponenta koja je neovisna i može donositi samostalne odluke, ali u okviru širega konteksta, tj. cjeline. Autonomija i koordinacija, [8] ključni su kao i kod holona. Prema [4], matematička definicija fraktala glasi: fraktal je skup točaka čija je fraktalna dimenzija veća od topološke dimenzije. Još preciznije, fraktal je entitet koji ima necjelobrojnu – fraktalnu – dimenziju. Mogu se opisati pomoću specifičnih internih svojstava svake cjeline, odnosno fraktala. Na slici 3 dane su neke značajke fraktalnoga proizvodnog sustava

The concept of Fractal manufacturing plants consists of many numbers of units called fractals. Every fractal is an independent component that can make its own decisions, but limited in the framework of a broader context. Autonomy and coordination [8] are key components of holons, as well. According to [4], the mathematical definition of fractals is as follows: the fractal is a set of points with a fractal dimension higher than the topological dimension. More precise definition is: a fractal is an entity with a non-integer fractal dimension. They can be described by the specific internal properties of each unit (fractal). Figure 3 shows some characteristics of the fractal manufacturing system.

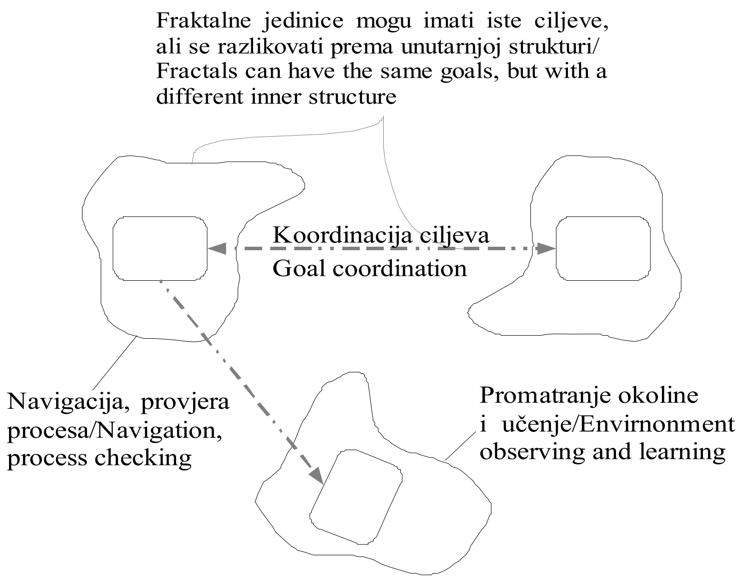


Slika 3: Odrednice fraktalnoga proizvodnog sustava
Figure 3: Determinants of fractal manufacturing system

Tako samoorganizacija predstavlja prvo svojstvo koje ujedno implicira određenu slobodu za fraktale u organizaciji prilikom izvršenja radnih zadataka. Oni mogu izabrati svoju metodu za rješavanje problema uključujući i samooptimizaciju u sklopu procesa poboljšanja. Sljedeće važno svojstvo leži u njihovoj dinamičnosti prilagodbe, naime fraktali mogu preuzeti dio ili biti potpuno pod utjecajem iz svojega okružja bez ikakvih formalnih ili strukturnih

Self-organization is the first property that implies some specific freedom to fractals in an organization to do some working tasks. They can choose their own problem solving method including self-optimization as a part of process improvement. The next very important property is in the dynamics of adaptation. Fractals can be partially ograničenja. Treće svojstvo predstavlja samosličnost (engl. self-similarity) koja podrazumijeva sličnost svake cjeline u postizanju zadanih ciljeva – svi čine cjelinu, a pritom su ipak svi autonomni. Na slici 4 dan je prikaz nekolicine fraktala.

or completely under the influence of the environment without formal or structural constraints. The third property is self-similarity, which means similarity of each unit in doing tasks, but on the other hand, fractals are autonomic. Some fractals are shown in Figure 4.



Slika 4: Prikaz fraktala
Figure 4: Fractal's overview

Pored navedenih značajki postoji potreba da fraktalni proizvodni sustav funkcionira kao koherentna cjelina. To je postignuto kroz proces sudjelovanja i koordinacije između samih fraktala i podržano je na svim razinama kako bi se osiguralo uspješno provođenje zadataka. Cjeline koje su na višoj razini odgovorne su za odvijanje procesa koji ne mogu biti izvršeni na nižim razinama. Taj princip jamči timski rad između fraktala i također u izvjesnom smislu osigurava ravnomjernu raspodjelu mogućnosti i odgovornosti. Fraktalni koncept ili njegovi dijelovi danas se također uspješno koriste za upravljanje proizvodnjom i kao pomoć u menadžmentu. Upravo je koncept prema [8] uspješno implementiran na zadacima razvoja novih proizvoda i razvijanja tehnologije.

In addition, before the mentioned characteristics there is the requirement that the Fractal manufacturing system must function as a coherent unit. This must be done through the process of participation and coordination between fractals. It must be done on all levels to ensure successful processing of tasks. Units on a higher level are responsible for a process that cannot be done at lower levels. This principle guarantees teamwork between fractals and also in some sense ensures the distribution of possibility and responsibility. The fractal concept or its parts are successfully used in the control of manufacturing and as an aid in management. The proposed concept [8] is successfully implemented in tasks of the development of new products and technologies.

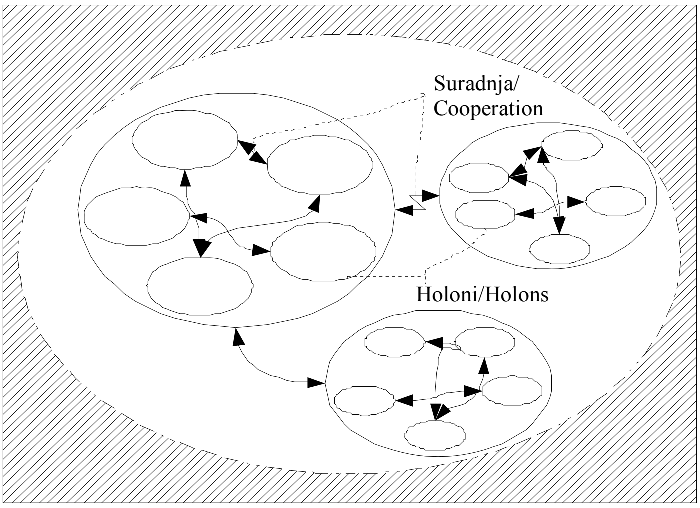
2.3. Holonski proizvodni sustav

Riječ *holon* potječe od grčke riječi – "holos", što znači *cjelina*, te nastavka "on" koji predstavlja dio, česticu (nalazi se i u riječima grčkog podrijetla kao što su proton, neutron). Holon (shematski prikaz dan je na slici 5) predstavlja hibridnu prirodu odnosa cjeline i dijelova u stvarnom svijetu, što istodobno objašnjava i samodostatnost holona [15,16] kao određene cjeline naspram njezinih dijelova, kao i ovisnost tih dijelova o cjelini. Do toga se zaključka došlo analiziranjem poretka i stabilnih srednjih oblika kod živih organizama i društvenih organizacija, te zapravo možemo tvrditi da

2.3. Holonic manufacturing system

The word "holon" is a compound–word from two Greek words – "holos", which means wholeness, and the suffix "-on" which represents a part, a particle (the same can be found in words of Greek origin as is the case in "proton" or "neutron"). Holon (the schematic depiction is shown in Figure 1) represents the hybrid nature of the relation between the wholeness and its parts in the real world, which simultaneously explains the self-sufficiency of a holon [15,16] as a particular wholeness towards its parts, and the dependence of these same parts on the aforementioned wholeness. Such conclusion has been reached through the analysis of the order and stable iako je lako identificirati podcjeline ili dijelove određene cjeline, cjeline i dijelovi u apsolutnom smislu ne postoje.

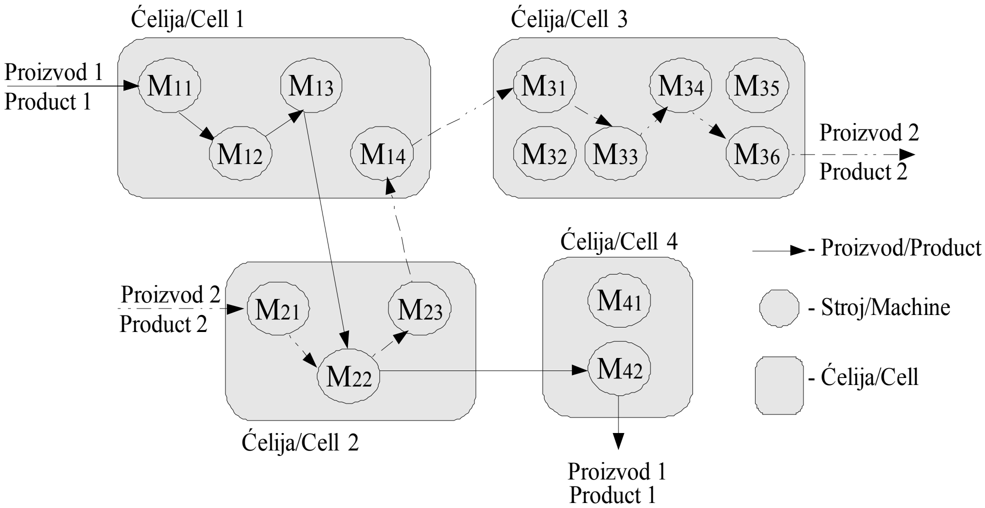
median forms of living organisms and social organizations, thus, in fact, we can claim that while it is easy to identify sub clusters or parts of an particular wholeness, wholenesses and parts in an absolute sense do not exist.



Slika 5: Prikaz holona
Figure 5: Holon's overview

Prema, [4] holonski proizvodni sustav takav je sustav u kojem ključni elementi poput strojeva, ćelija, dijelova proizvoda, operatora djeluju poput holona ponašajući se autonomno i kooperativno, [9]. Holon je u svojoj hijerarhiji (odnosno holarhiji) sastavljen od niza drugih holona zaduženih za provedbu točno određenoga dijela posla. Decentralizirana struktura, dinamično okružje, raspodijeljena funkcija odgovornosti uz prethodno nabrojene značajke HMS-a čine tu koncepciju iznimno prilagodljivom suvremenim izazovima koji se javljaju u proizvodnji. Na slici 6 dan je prikaz proizvodnoga plana za dva proizvoda

Therefore, according to, [4] a holonic manufacturing system is one in which the key elements like machines, cells, product parts and operators act like holons, behaving both autonomously and cooperatively, [9]. Holon is in its hierarchy (that is, holarchy) made from a series of other holons in charge with execution of specifically determined part of work. Decentralized structure, dynamical environment, divided function of responsibility with previously numbered HMS characteristics make this concept exceptionally flexible for solving challenges that occur in modern manufacture. Figure 6 shows a diagram of the plan for the manufacture of two products.



Slika 6: Proizvodni plan za Proizvod 1 i 2
Figure 6: Manufacturing plan for Products 1 and 2

U tablici 1. dan je prikaz rasporeda obrade za navedene proizvode.

Table 1 shows the work schedule for the named products.

Tablica 1: Putanje proizvoda
Table 1: Working paths

	Radni takt 1 Working sequence 1	Radni takt 2 Working sequence 2	Radni takt 3 Working sequence 3	Radni takt 4 Working sequence 4	Radni takt 5 Working sequence 5	Radni takt 6 Working sequence 6	Radni takt 7 Working sequence 7
Proizvod 1 Product 1	M11	M12	M13	M22	M42	–	–
Proizvod 2 Product 2	M21	M22	M23	M14	M31	M33	M36

Kako bi se što učinkovitije organizirala proizvodnja, definirano je pet vrsta holona, [4, 8] na toj razini. To su: proizvod, dio, ćelija, tvornički koordinator i tvornica. Holon *proizvod* odnosi se na proizvod koji se trenutačno obrađuje. On sadrži informacije poput vrsta i načina strojne obrade, popisa strojeva na kojima proizvod mora biti obrađen s pripadnim transportnim i obradnim rasporedima te putanju koju proizvod mora proći od ulaska u proizvodni proces do finalizacije. Holon *proizvod* ne sadrži informacije bitne za obradu na nekom stroju, poput primjerice parametara brzine i dubine bušenja, posmaka i broja okretaja kod glodanja itd. Te se informacije, [16] dodaju u trenutku kada određeni proizvod stigne na stroj i za njih se brine holon *dio*. On u ovoj fazi sadrži detaljni proizvodni plan obrade, brine se o trenutačnom statusu obrade i prema potrebi u koordinaciji s drugim holonima koordinira proizvodni proces. *Ćelijski* holon vrši nadzor proizvodne ćelije i sadrži podatke o vrsti strojeva, dijelovima i tvorničkom koordinatoru. Njegova je zadaća u kooperaciji s proizvodom i tvorničkim koordinatorom osigurati nesmetano odvijanje proizvodnje kako bi se ispunio proizvodni plan. Holon *tvornički koordinator* sadrži informacije o proizvodnji unutar svih ćelija. Njegov je glavni zadatak planiranje i koordinacija drugih holona kako bi im u najkraćem roku osigurao slobodan stroj ili ćeliju. Holon *tvornica* zadužen je za cijeli sustav. Njegov je zadatak brinuti se o sustavu kako bi funkcionirao bez prekida. Njegova holarhija sastoji se od sljedećih holona: ćelija, proizvod i tvornički koordinator.

In order to organize manufacture as efficiently as possible, five kinds of holons [4,8] have been defined at this level. These are: product, part, cell, factory coordinator and factory. Holon product is a name given to a product currently being machined. It contains information concerning the type and method of machining, a list of machines on which product has to be machined, along with accordant transport and machining schedules, and also information about the trajectory that a given product has to pass through, from entrance, through the process of manufacture and to finalization. A holon product does not contain information important for machining on a particular machine like, for instance, parameters of speed and drilling depth, shift and number of rounds per minute during grinding operations, etc. That information is added at the moment of a particular product‘s arrival at a machine and that information is taken care of by the holon part. This phase contains a detailed machining plan of production: it takes care of the current machining status and, if needed, in attunement with other holons, coordinates the manufacturing process. The cell holon keeps surveillance over the manufacturing cell and contains data on machine types, construction parts and the factory coordinator. Its task is to ensure the unobstructed unfolding of manufacture in order to fulfill the plan of manufacture, through cooperation with the product and factory coordinator. The factory coordinator holon contains data on manufacture within all cells. Its main task is the planning and coordination of other holons in order to ensure them with a free machine or cell as soon as possible. Factory holon is in charge of whole system. Its job is to take care of the system so that the system can function uninterrupted. Its holarchy is composed of the following holons: *cells, product,* and *factory coordinator*.

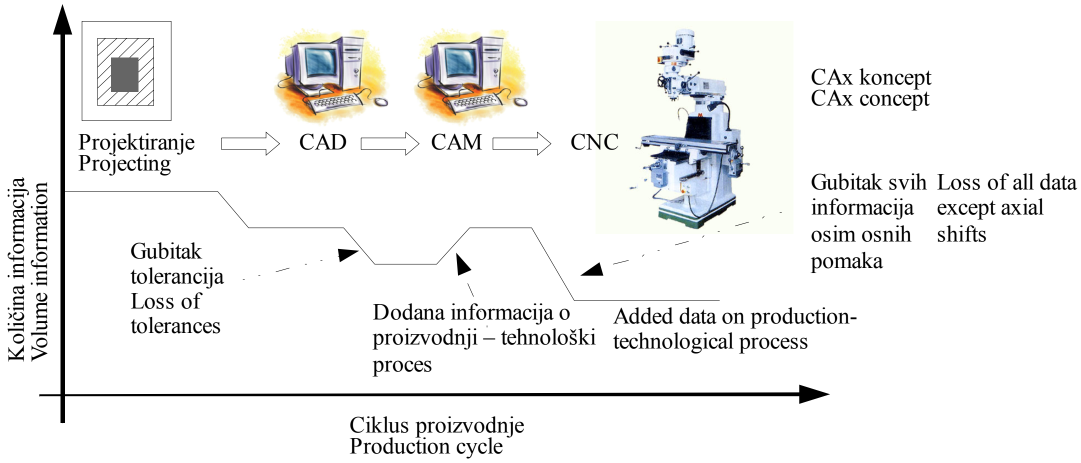
2.4. Ubiquitous proizvodni sustav

U novom razdoblju različitih proizvodnih koncepcija uočena je potreba za bržim rješavanjem kompleksnih proizvoda s njima pripadajućim specifičnim zahtjevima. Uočena je potreba za korištenjem dijela informacija koji se u dosadašnjem CAx konceptu rada i planiranja nepovratno gubio u određenim fazama. Kao primjer može se navesti gubitak dijela informacije o

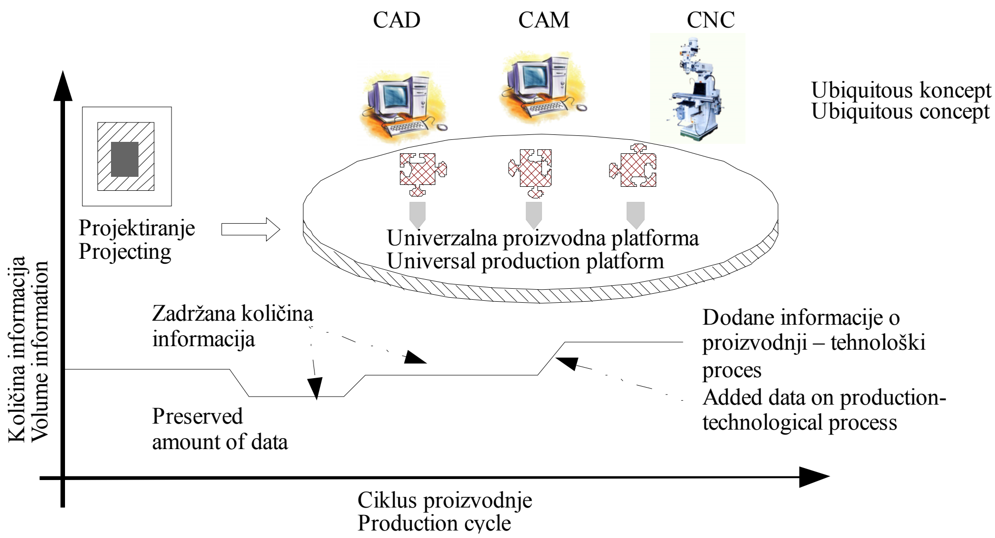
2.4. Ubiquitous manufacturing system

In a new period of different manufacturing concepts, the need has been observed for faster solutions for complex products along with their specific requirements. A necessity has been identified for the use of information parts that were once irretrievably lost during various phases of the heretofore CAx work and planning concepts. As an example, worthy of mention is the partial tolerancijama nakon završetka faze projektiranja, odnosno prijelaza iz faze CAD u fazu CAM kada se proizvod, uvjetno rečeno, prebacuje u proizvodnju. U tom trenutku, nakon što je pročitana informacija o polju, tolerancije i izvršeno kodiranje u G-kod, informacija o korištenom tolerancijskom polju nepovratno se izgubila. Usporedba dosadašnjega klasičnog CAx s *ubiquitous* konceptom rada prikazana je na slikama 7 i 8:

information loss on tolerances after projecting the loss of information's part about tolerances after projecting phase finish, that is, crossing from CAD to CAM phase Finishing phase, that is, in the crossover from the CAD to the CAM phase when the product is, conditionally speaking, transferred into production. At that moment, after information about the tolerance field has been read and coding into G-code has been conducted, information about the used field of tolerance was once irretrievably lost. Comparison of the heretofore classical CAx with the Ubiquitous work concept is shown in Figures 7 and 8:



Slika 7: Prikaz CAx koncepcije
Figure 7: CAx concept



Slika 8: Prikaz ubiquitous *koncepcije*
Figure 8: Ubiquitous concept

Na prikazanim usporedbama (slike 7 i 8) vide se nedostaci CAx koncepta rada. U prvom redu vidimo da se u trenutku kada proizvod izlazi iz koncepcijske faze, gube ostala idejna rješenja. Zatim se između CAD i CAM faze gube podaci o razradi tehnološkoga procesa. I, konačno, prilikom kodiranja, kako je već prije napomenuto, gube se svi dodatni podaci o tolerancijama (primjerice: polje tolerancije i sl.). U proizvodnoj praksi

In the comparisons shown in Figures 7 and 8, the shortcomings in the CAx work concepts can be seen. Firstly, we can see that at the moment of a product exiting the conceptual phase, other ideal solutions are lost. After that, between the CAD and CAM phase, data regarding the workup of a technological process is lost as well. Finally, during coding operations, as has already been mentioned, all additional data on tolerances (for example, to je posebno iskorišteno u automobilskoj industriji, u koju se *ubiquitous* proizvodna koncepcija dobro uklopila uz pomoć korištenja DBAgenata, [10, 17–19]. Tehnika softwarea tih agenata, [13, 14] sastoji se od senzora koji daju informacije iz njihove okoline. Te se informacije obrađuju i filtriraju. Pomoću raznih efektora agenti mogu djelovati unutar okoline. U samom središtu nalazi se softver odgovoran za donošenje odluka. Trenutačno se ispituju mogućnosti DBAgenata koji bi organizirali nabavu materijala za proizvodni proces.

4. ZAKLJUČAK

Proizvodni sustav složena je cjelina kojom se obnaša proces stvaranja novih vrijednosti. Kako zahtjevi tržišta svake godine rastu, tako se povećava kompleksnost proizvoda. Jedna je od odlika inteligentnih proizvodnih sustava brza promjena i prilagodba novim tržišnim zahtjevima. Stoga je velika fleksibilnost proizvodnih sustava bitna kako bi se na te zahtjeve pravovremeno moglo odgovoriti. U radu je dan pregled nekolicine novih inteligentnih proizvodnih koncepata poput biološkog, holonskog, fraktalnog i *ubiquitous* koncepta. Svi su predstavljeni proizvodni koncepti heterarhijski, tj. nemaju izraženu hijerarhiju. Unatoč naporima istraživača fokusiranih na razvoj različitih strategija, još ne postoji univerzalni proizvodni koncept koji bi pod jednakim ili barem sličnim uvjetima dobro funkcionirao s različitim proizvodnim asortimanom. Stoga je razvoj inteligentnih proizvodnih sustava bitan za daljnji razvoj sve kompleksnijih proizvoda.

tolerance field and the like) are finally lost. In automotive manufacturing, the environmental ubiquitous concept has using DBAgents, [10, 17–19]. These agents consist [13, 14] of a sensor which supplies him with the required applied very well by data from the environment. The data is then processed and analyzed. With different effectors, the agents can function from within the environment. In the kernel, there is a special code that is responsible for decision making. Currently, the possibilities of DBAgents for organizing material supply for the manufacturing process has been taken into consideration.

4. CONCLUSION

A manufacturing system is a complex social and material entirety that fulfills the process of creating new values. Parallel with market development, products are getting more and more complex. One of the significant characteristics of intelligent manufacturing systems is the ability to adapt quickly to new marketing demands. Hence, great flexibility of the manufacturing system is essential in order to respond quickly to demands. This article presents an overview of several new intelligent manufacturing systems such as biological, holonic, fractal and ubiquitous. They are all heterarhical. Heterarchy is the name for systems with no pronounced organizational structure. In spite of researcher efforts focused on the development of different strategies, there is still no universal production concept that could, under equal or at least similar circumstances, function with a different production assortment. Therefore, intelligent manufacturing system development is important for increasingly complex production development.

LITERATURA
REFERENCES

[1] Zhang X., Balasubramanian S., Brennan W. R., Norrie H. D., *Design and implementation of a real time holonic control system for manufacturing*, Information sciences 127 (2000), 23-44

[2] Bär T., Haasis S., *Step towards the Digital Factory*, 36th CIRP International Seminar on Manufacturing systems, (2003), 171-175

[3] Monostori L., Váncza J., Márkus A., Kádár B., Viharos J. Zs., *Towards the Realization od Digital Enterprises,* 36th CIRP International Seminar on Manufacturing systems, (2003), 99-106

[4] Gou L., Luh B. P., Kyoya Y., *Holonic manufacturing scheduling: architecture, cooperation mechanism and implementation,* Computers in Industry 37 (1998) 213-231

[5] El Maraghy H., Al Geddawy T., Azab A., *„Modelling evolution in manufacturing: A biological analogy“*, CIRP Annals - Manufacturing Technology, Volume 57, 2008, Pages 467-472

[6] Ueda K., Vaario J., Ohkura K., *Modelling of Biological Manufacturing Systems for Dynamic Reconfiguration*, Annals of the CIRP Vol. 46/1, 1997.

[7] Ueda K., Hatono I., Fujii N., Vaari J., *„Reinforcement Learning Approaches to Biological Manufacturing Systems“*, CIRP Annals - Manufacturing Technology, Volume 49, Issue 1, 2000, Pages 343-346

[8] Tharumarajah A., Wells A. J., Nemes L., *Comparison of Emerging Manufacturing*, CSIRO Manufacturing science& Technology, Preston, Victoria, Australia

[9] Sluga A., Butala P., *Self-organization in a distributed manufacturing system based on constraint logic programming,* CIRP Annals, Vol. 50/1 (2001), 323-326

[10] Turgay S., *Agent-based FMS control*. Robot Comput Integr Manuf (2008)

[11] Butala P., Sluga A., *Dynamic structuring of distributed manufacturing systems*, Advanced Engineering Informatics 16 (2002), 127-133

[12] Car Z., Hatono I., Ueda K., *Reconfiguration of Manufacturing Systems based on Virtual BMS,* Proceedings of The 35th CIRP, (2002), 19-24

[13] www.sapmag.com.hr/show_article.php?id=76

[14] Sluga A., Butala P., *Structuring of the information system for distributed manufacturing*, Manufacturing systems 27 (1998)

[15] Leitão P., Restivo F., *A holonic approach to dynamic manufacturingscheduling*, Robotics and Computer-Integrated Manufacturing 24 (2008), 625-634

[16] http://hms.ifw.uni-hannover.de/ public/ Concepts/ concepts.htm

[17] Cheng T.C.E., Ng C.T., Yuan J.J., *Multi-agent scheduling on a single machine with max-form criteria*, European Journal of Operational Research 188 (2008), 603-609

[18] Yuan J.J., Shang W.P., Feng Q., *A note on the scheduling with two families of Jobs*, Journal of Scheduling 8 (2005), 537-542

[19] Zunino A., Campo M., *Chronos: A multi-agent system for distributed automatic meeting scheduling*, Expert Systems with Applications (2008)

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