



## FRAMEWORK FOR RESEARCH OF INTERACTION BETWEEN OPERATOR-COMPUTER SYSTEM FOR MANAGEMENT OF TRANSPORTATION SYSTEM IN COAL MINES

### OKVIR ZA ISTRAŽIVANJE INTERAKCIJE OPERATOR-RAČUNARSKI SISTEM ZA UPRAVLJANJE TRANSPORTNIM SISTEMIMA U RUDNICIMA UGLJA

Dobrivoje MARJANOVIĆ<sup>1)</sup>, Miroljub GROZDANOVIĆ<sup>2)</sup>

1) *EI-IRIN, Niš, Serbia and Montenegro*

2) *Faculty of Occupational, Niš, Serbia and Montenegro*

**Abstract:** In this paper are briefly defined basical technical requests for computer system for transportation systems control in coal mines, bases of interaction (dialog) in system operator-computer system is presented and mathematical models for prosessing and calculation of main parameters of this system is given.

**Key words:** transportation system, man-machine interface, mathematical models

**Apstrakt:** U ovom radu kratko su obradeni osnovni tehnički zahtevi za računarski sistem za upravljanje transportnim sistemima u rudnicima uglja, prezentovani su osnovi interakcije (dijaloga) u sistemu operator-računarski sistem i izložen je matematički model za obradu i izračunavanje bitnih parametara ovog sistema.

**kliučne reči:** transportni sistemi, interfejs čovek mašina, matematički modeli

## 1 INTRODUCTION

Coal exploitation from underground or surface mines is different from manufacture of other products in one way by means of obtaining finished product, that doesn't include classically big number of operations for creation of wanted product from input raw matter or material, and in another way by difficult exploitation conditions and usage of big and complicated machine equipment which is autonomously complexly automatized and represents as a whole, machine system which needs to be rationalised by automatization. This especially relates to technological wholeness:exploitation (E) – transport (T) – hoisting (H), ETH system, in underground coal exploitation [1] and on open pits with continuous technology where important technological unit is machine system consisted of excavator(E),

## 1 UVOD

Eksplotacija uglja i iz podzemnih i iz površinskih rudnika razlikuje se od proizvodnje drugih proizvoda, s jedne strane po načinu dobijanja gotovog proizvoda, gde nema klasično velikog broja operacija potrebnih da se od ulazne sirovine ili materijala proizvede željeni proizvod, a sa druge strane po teškim prirodnim uslovima eksplotacije i korišćenju robustne i složene mašinske opreme koja se autonomno složeno automatizuje i predstavlja kao celina mašinski sistem koga treba automatizacijom racionalizovati. Ovo se posebno odnosi na tehnološku celinu otkopavanje (O)-transport (T)-izvoz (I), skraćeno OTI sistem, u podzemnoj eksplotaciji uglja [1] i na površinske kopove sa kontinualnom tehnologijom gde bitnu tehnološku celinu čini mašinski sistem koga čine

transporters with conveyor belt (T), and overburden or coal stack (S), ETS system. Optimal processing of these technological lines for production is in great deal depended on interaction and connection of particular process and equipment parts. Implementation of optimization is almost impossible without applying suitable process oriented computer systems (CS), [3].

Computer system efficiency is in great deal depended upon adequate choice of data that should be imported from ETH and ETS systems, defining of processing algorithm, generation of management actions and operator-computer system(O-CS) interaction. Choice of data depends upon machine equipment technical characteristic that is specified with technological mining project. This indicates that CSs must be modelled according to particular use and that different approaches are possible. Content, quantity and format of information display are here very important [4].

Analysis of current management and mine transport system solutions leads to conclusion that new approach, which demands significant changes in conception of system management, is necessary. This primarily relates to concepts of real-time management and off-line data processing in order that analysis and optimization of transport, ETH and ETS systems can be preformed on them individually. This kind of concept requires computer system that has bigger number of work stations and different data bases and that concept enables usage of its resources to bigger number of different users (dispatcher, production manager, maintenance manager, protection service etc.).

## 2 INTERACTION BETWEEN OPERATOR AND COMPUTER SYSTEM

Interaction (dialog) between operator and computer system is actually done via data display devices using mouse and keyboard. CS submits operator necessary facts with content of information presented on screen. Information that operator need to submit to CS is firstly composed on screen in picture or text format and then submitted. In this way constant dialog is present between operator and data display device, i.e. operator and CS. Modern CSs, besides capabilities to provide monitoring and management also have analysis, optimization, process projecting and management support functions, have several color monitors that are actually work stations periphery devices networked into unitary computer system.

bager (B), transport transporterima sa trakom (T) i odlagač jalovine ili uglja (O), skraćeno BTO sistem [2]. Optimalno odvijanje ovakvih proizvodnih tehnoloških linija umnogome zavisi od međusobne usklađenosti i povezanosti pojedinih delova procesa i opreme. Ostvarivanje optimizacije skoro je nemoguće bez primene adekvatnih procesno orjentisanih računarskih sistema (RS), [3].

Efikasnost RS-a umnogome zavisi od pravilnog izbora podataka koje treba uzeti iz sistema OTI i BTO, definisanja algoritma obrade i generisanja upravljačkih dejstava i međusobne usklađenosti odnosa operator-računarski sistem (O-RS). Izbor podataka, pak, zavisi od tehničkih karakteristika mašinske opreme predviđene tehnološkim rudarskim projektom. Ovo ukazuje da se RS-i moraju namenski modelirati i da su pritom mogući razni pristupi. Sadržaj, obim i format prikaza informacija su pri ovome veoma bitni [4].

Analizirajući postojeća rešenja upravljanja i vođenja rudničkih transportnih sistema dolazi se do zaključka da je potreban novi pristup koji zahteva značajne promene u koncipiranju sistema upravljanja. Ovde se prvenstveno misli na koncept upravljanja u realnom vremenu i off line obradu podataka u cilju analize i optimizacije transporta i sistema OTI i BTO kao celina. Ovakav koncept iziskuje da računarski sistem bude strukturiran sa većim brojem radnih stanica i različitim bazama podataka i da omogući korišćenje svojih resursa većem broju različitih korisnika (dispečer, rukovodilac proizvodnje, rukovodilac održavanja, služba zaštite idr.).

## 2 INTERAKCIJA OPERATORA I RAČUNARSKOG SISTEMA

Interakcja (dijalog) operatora i računarskog sistema odvija se preko sredstava za prikazivanje informacija uz korišćenje miša i tastature. Ono što RS treba da saopšti operatoru čini to sadržajem informacionih prikaza na ekranu. Ono što operator treba da saopšti RS-u čini to na taj način što svoju poruku najpre u vidu slike ili teksta pripremi na ekran pa zatim pošalje u RS. Na ovaj način vrši se stalni dijalog između operatora i sredstava za prikazivanje informacija, odnosno između operatora i RS-a. Savremeni RS-i koji pored monitoringa i upravljanja imaju i funkcije analize, optimizacije i projektovanja procesa i podrške rukovođenju, imaju više kolor monitora koji su, u stvari, periferije radnih stanica

Work stations are autonomous work places which are using CS resources via network. One of CS resources is data base that can contain different data classes for different users [5]. Relation between operator and CS represents targeted sum of actions and means for providing dialog-exchange of data between communications points in systems O-CS.

In basic case goal of interaction process can be:

- obtaining information, which consists in submitting of information, documents etc. in dialog process and
- management, which consists in giving advices, options, enc results and like-wise for decision making in dialog process.

In realization of interaction in O-CS system it is necessary to develop procedures for constructing interaction means. Basic procedures are:

- development of methodological bases for construction,
- construction of functional means ( for interaction planning, management and communication of interaction and for internal communication),
- projecting means of support (mathematical, informational, linguistic and means for organization of communication)
- creation of technical means,
- development of means for securing interaction security.

There are several ways of interaction. Most important are:

- with priority organization of interaction (with man priority, with computer priority and by planning, information and management channels),
- without priority organization of interaction,
- considering load distribution among communication subjects (equal or unequal distribution),
- without considering load distribution,
- active communication system,
- passive communication system,
- interaction with elastic model of communication,
- interaction with firm model of communication,
- with "question-answer" form of communication,
- with "menu choice" form of communication,

umreženih u jedinstveni računarski sistem. Radne stanice su nezavisna radna mesta koja preko mreže koriste resurse RS-a. To znači da postoji mogućnost istovremenog rada više radnih stanica. Jedan od resursa RS-a je baza podataka koja može sadržavati razne vrste odnosno klase podataka za razne korisnike [5]. Odnos operatora (O) i RS-a predstavlja, u stvari, ciljani skup radnji i sredstava za obezbeđivanje dijaloga-razmenu podataka između komunikantata u sistemu O-RS.

U opštem slučaju kao ciljna usmerenost procesa uzajamnog delovanja može biti:

- informisanje, koje se ispoljava u davanju informacija, dokumenata itd. u procesu dijaloga i
- upravljanje, koje se sastoji u davanju saveta, opcija, gotovih rezultata i sl. pri donošenju odluka u procesu vođenja dijaloga.

U realizaciji interakcije u sistemu O-RS potrebno je razraditi postupke izgradnje sredstava uzajamnog delovanja. Osnovni postupci su:

- razrada metodoloških osnova izgradnje,
- izgradnja funkcionalnih sredstava (za planiranje uzajamnog dejstva, za upravljanje uzajamnim dejstvom i za međusobno komuniciranje),
- projektovanje sredstava podrške (matematička, informaciona i lingvistička sredstva i sredstva organizacije komunikacije),
- stvaranje tehničkih sredstava i
- razrada sredstava za obezbeđenje bezbednosti interakcije.

Postoji više načina interakcije. Najvažniji su:

- sa prioritetnom organizacijom interakcije (sa prioritetom čoveka, sa prioritetom računara i po kanalima planiranja, informisanja i upravljanja),
- bez prioriteta organizacije interakcije,
- sa uzimanjem u obzir raspodele opterećenja među komunikantima (ravnomerna ili neravnomerna raspodela),
- bez uzimanja u obzir raspodele opterećenja,
- sistem aktivne komunikacije,
- sistem pasivne komunikacije,
- interakcija sa elastičnim modelom komunikacije,
- interakcija sa čvrstim modelom komunikacije,
- sa formom komunikacije "pitanje-odgovor",
- sa formom komunikacije "izbor menija",

- with usage of natural communication language,
- with usage of formalized language (with or without grammar).

In interaction process organization of procedure is by itself important, and is basically realised by creating measures for primary and secondary actions which are realised with CS. Basic group of measures consists of:

- primary measures (information organisation, interaction planning and support for interaction management),
- secondary measures or organization compatibility measures (language, semantic, pragmatic, psychological etc.).

### 3 CALCULATION OF INTERACTION IN OPERATOR-COMPUTER SYSTEM

Basic elements of this system are man and computer, whose work ratio is modified, in defined quantity of information exchange process between them. Specified quantities of information are characterized, up to some degree, with their complexity of perception by man( $C$ ), from which complexity ratio of information perception is also depended upon. Regulation of  $C$  and consideration of individual capabilities of perception can influence on man and system work efficiency in general:

$$C = \sum_{i=1}^{K_E} C(h_i) \quad (1)$$

where  $C(h_i)$  is complexity of perception quantity of information at  $i$ -th stage of communication,  $K_E$  - number of communication stages;

$$C(h_i) = \bar{L}(h_i)I(h_i), \quad (2)$$

where  $\bar{L}(h_i) = 1 - L(h_i)$ ;  $L(h_i), \bar{L}(h_i)$  specify accuracy (understanding) and inaccuracy of information included in  $h_i$ :

$$L(h_i) = 1 - \frac{h_i}{a}; \quad \bar{L}(h_i) = \frac{h_i}{a} \quad (3)$$

where  $h_i$  represents deviation from standard, that is formed by man, based on perception of previous information portions;  $a$  is deviation where full notion of standard is completely lost.

- sa korišćenjem prirodnog jezika komunikacije i
- sa korišćenjem formalizovanog jezika (sa ili bez gramatike).

U procesu interakcije važan je i sam postupak organizacije uzajamnog dejstva, koji se u osnovi ostvaruje stvaranjem mera osnovnih i pomoćnih radnji koje se realizuju pomoću računarskog sistema. Osnovni skup mera čine:

- osnovne mere (organizacija informacija, planiranje interakcije i podrška upravljanju interakcijom) i
- pomoćne mere ili mere organizacije kompatibilnosti (jezičke, semantičke, pragmatičke, psihološke i dr.).

### 3 PRORAČUN INTERAKCIJE U SISTEMU OPERATOR-RAČUNARSKI SISTEM

Osnovni elementi ovog sistema su čovek i računar, čiji se rad usklađuje u procesu razmene određene količine informacije između njih. Navedene količine informacija karakterišu se, u nekoj meri, složenošću njihovog percepiranja od strane čoveka ( $C$ ), od čega zavisi i stepen teškoće percepiranja informacije. Regulišući  $C$  i uzimajući u obzir individualne sposobnosti percepiranja, može se uticati na efikasnost rada čoveka i sistema u celini:

$$C = \sum_{i=1}^{K_E} C(h_i), \quad (1)$$

gde je  $C(h_i)$  složenost percepiranja količine informacija na  $i$ -toj etapi komuniciranja,  $K_E$  - broj etapa komuniciranja;

$$C(h_i) = \bar{L}(h_i)I(h_i), \quad (2)$$

gde je  $\bar{L}(h_i) = 1 - L(h_i)$ ;  $L(h_i), \bar{L}(h_i)$  označavaju preciznost (razumljivost) i nepreciznost informacije sadržane u  $h_i$ :

$$L(h_i) = 1 - \frac{h_i}{a}; \quad \bar{L}(h_i) = \frac{h_i}{a}, \quad (3)$$

gde je  $h_i$  odstupanje od standarda, koji je kod čoveka formiran na osnovu percepiranja prethodnih informativnih porcija;  $a$  je odstupanje pri kom se potpuno gubi puna predstava o standardu.

Accuracy  $L(h_i) = 0$  i.e. inaccuracy  $\bar{L}(h_i) = 1$  occurs when  $h_i = a$ . In that case it is impossible for picture of viewed object, which is perceived, to be connected with new quantity of information, that is significantly different from notion of that object, already created by man. With  $L(h_i) \rightarrow 1$ ,  $\bar{L}(h_i) \rightarrow 0$ , when  $h_i \rightarrow 0$ , small quantity of new notices about object is "written" in system of defining, created with man's realization, which characterizes object;  $I(h_i)$  - quantity of received information included in group of messages, which have deviation  $h_i$ :

$$I(h_i) = \ln \frac{h_i}{h_0} \quad (4)$$

where  $h_0$  is some value of  $h_i$ , which has physical sense like perception threshold of channel sensitivity. With  $h_i < h_0$  information is not perceived because  $I(h_i) = 0$ , [5]. Value  $h_i$  can be defined with overlapping degree of informational groups  $\Pi_i$  and  $\Pi_{i-1}$  in following way:

$$h_i = 1 - \bar{h}_i \quad (5)$$

where

$$\bar{h}_i = \Pi_i \cap \Pi_{i-1} / \Pi_i \cup \Pi_{i-1} \quad (6)$$

is non-existence of deviation from standard (characterises overlapping degree of  $\Pi_i$  and  $\Pi_{i-1}$ ). For instance, for textual messages

$$\bar{h}_i = m_{i,i-1} / M_{i,i-1} \quad (7)$$

where  $m_{i,i-1}$  and  $M_{i,i-1}$  are number of suitable elements which are overlapped and their total number in informational groups  $\Pi_i$  and  $\Pi_{i-1}$ . If a group  $\Pi_{i-1}$  is preceded with series of informational groups, then degree of overlapping  $h_i$  is determined in following way:

$$\bar{h}_i = \prod_i \bigcap_{l=1}^{i-1} \prod_l / \bigcup_{l=1}^{i-1} \prod_l \quad (8)$$

For instance, complexity of current informational group, that is received by human, can be expressed with:

$$C(h_i) = \frac{1 - \bar{h}_i}{a} \ln \frac{1 - \bar{h}_i}{h_0} \quad (9)$$

Preciznost  $L(h_i) = 0$  tj. nepreciznost  $\bar{L}(h_i) = 1$  nastaju ako je  $h_i = a$ . Tom prilikom javlja se nemogućnost da se slika posmatranog objekta, koji se percepira, poveže sa novom količinom obaveštenja, koja se u znatnom stepenu razlikuje od predstave o tom objektu, koja je već stvorena kod čoveka. Pri  $L(h_i) \rightarrow 1$ ,  $\bar{L}(h_i) \rightarrow 0$ , kad  $h_i \rightarrow 0$ , mala količina novih obaveštenja o objektu se "upisuje" u sistem definisanja, stvoren čovekovim saznanjem, koji karakteriše objekat;  $I(h_i)$  - količina primljenih informacija sadržanih u skupu poruka, koje imaju odstupanje  $h_i$ :

$$I(h_i) = \ln \frac{h_i}{h_0}, \quad (4)$$

gde je  $h_0$  neka vrednost  $h_i$ , koja ima fizički smisao praga osjetljivosti kanala percepiranja. Pri  $h_i < h_0$  informacija se ne percepira jer je  $I(h_i) = 0$ , [5]. Veličina  $h_i$  može biti određena merom poklapanja (podudaranja) informacionih skupova  $\Pi_i$  i  $\Pi_{i-1}$  na sledeći način:

$$h_i = 1 - \bar{h}_i, \quad (5)$$

gde je

$$\bar{h}_i = \Pi_i \cap \Pi_{i-1} / \Pi_i \cup \Pi_{i-1}, \quad (6)$$

nepostojanje odstupanja od standarda (karakteriše meru poklapanja  $\Pi_i$  i  $\Pi_{i-1}$ ). Na primer, za tekstualne poruke je

$$\bar{h}_i = m_{i,i-1} / M_{i,i-1}, \quad (7)$$

gde su  $m_{i,i-1}$  i  $M_{i,i-1}$  broj odgovarajućih elemenata koji se podudaraju i njihov ukupan broj u informacionim skupovima  $\Pi_i$  i  $\Pi_{i-1}$ . Ako je skupu  $\Pi_{i-1}$  prethodio niz informacionih skupova, onda se mera poklapanja  $h_i$  utvrđuje na sledeći način:

$$\bar{h}_i = \prod_i \bigcap_{l=1}^{i-1} \prod_l / \bigcup_{l=1}^{i-1} \prod_l, \quad (8)$$

Na taj način, složenost tekućeg informacionog skupa, koga prima čovek, može se izraziti sa:

$$C(h_i) = \frac{1 - \bar{h}_i}{a} \ln \frac{1 - \bar{h}_i}{h_0}, \quad (9)$$

While  $h_i = 0$ , notion of standard is completely lost, and from that follows  $a = 1$ , so complexity degree (for textual messages) can be calculated from formula:

$$C(h_i) = (1 - \bar{h}_i) \ln \frac{1 - \bar{h}_i}{h_0} \quad (10)$$

For determination of complexity degree for other(all but textual) messages following method of calculation can be applied. Complexity of information is directly related for time of its reception and understanding by man -  $t_V$ :

$$t_V = \frac{1}{V(1-q)} C(h_i) \quad (11)$$

where  $V$  represents permeable ability of human channels for precipitation;  $q$  - perception tension function; characterizes degree of exhaustion and human informational burden. It is obvious that tension decreases with informational groups degree of overlapping increase and vice versa, with degree of overlapping decrease, tension increases. Supposable,  $q$  function has exponential character:

$$q = 1 - e^{-Zh_i} \quad (12)$$

where  $Z$  is perception tension coefficient, characteristic for individual human skills in information precipitation. Consequently, expression  $t_{V_i} = F(h_i, V, Z)$  is formed:

$$t_{V_i} = (1 - \bar{h}_i) \ln \frac{1 - \bar{h}_i}{h_0} \left/ V e^{-Z(1 - \bar{h}_i)} \right. \quad (13)$$

that helps determine human's weary during information precipitation and defines necessary flow of information during issuing messages to human, considering his individual characteristics ( $V$  and  $Z$ ), that satisfy individual and basic requests, established in interaction process.

In minimizing human's weary during message precipitation, important role is granted to procedure organization with goal to secure compatibility between human and computer in O-CS system, pointed into human attaining previous knowledge system, about communication language, semantics and pragmatism and onto storing all of that in computers memory. In that case total quantity of information that circulates in system can be decreased, complexity can also be decreased, and with that human's weary during

Pri  $h_i = 0$  u potpunosti se gubi predstava o standardu, iz čega sledi da je  $a = 1$ , pa se mera složenosti (za tekstualne poruke) može dobiti iz izraza:

$$C(h_i) = (1 - \bar{h}_i) \ln \frac{1 - \bar{h}_i}{h_0}, \quad (10)$$

Za određivanje mere složenosti za netekstualne poruke može se primeniti sledeća metodika proračunavanja. Složenost informacije neposredno je vezana za vreme njenog primanja i shvatanja od strane čoveka -  $t_V$ :

$$t_V = \frac{1}{V(1-q)} C(h_i), \quad (11)$$

gde je  $V$  propusna sposobnost čovečijih kanala percepiranja;  $q$  - funkcija napona percepkcije; karakteriše stepen zamaranja i informacionog opterećenja čoveka. Očvidno je da se napon smanjuje sa uvećanjem stepena poklapanja informacionih skupova i obrnuto, sa smanjenjem stepena poklapanja, napon se povećava. Neka funkcija  $q$  ima eksponencijalni karakter:

$$q = 1 - e^{-Zh_i}, \quad (12)$$

gde je  $Z$  koeficijent napona percepkcije, karakterističan za individualne osobine čoveka u percepiranju informacija. Otuda se formira zavisnost  $t_{V_i} = F(h_i, V, Z)$  oblika:

$$t_{V_i} = (1 - \bar{h}_i) \ln \frac{1 - \bar{h}_i}{h_0} \left/ V e^{-Z(1 - \bar{h}_i)} \right. \quad (13)$$

pomoću koje se utvrđuje trošenje čoveka prilikom percepiranja informacije i određuju neophodni potoci informacija prilikom izdavanja poruka čoveku, uzimajući u obzir njegove individualne karakteristike ( $V$  i  $Z$ ), koje zadovoljavaju pojedinačne i opšte zahteve, postavljene u procesu uzajamnog delovanja.

U minimiziranju trošenja čoveka prilikom percepiranja poruka, važnu ulogu dobija organizovanje postupaka s ciljem obezbeđivanja usklađenosti čoveka i računara u sistemu O-RS, usmerenih na to da čovek ovlađa sistemom prethodnih znanja o jeziku, semantici i pragmatici komuniciranja i da se sve to ugradi u memoriju računara. U tom slučaju može se smanjiti ukupna količina informacija koja cirkuliše u sistemu, smanjiti složenost i, samim tim, trošenje čoveka prilikom percepiranja poruka. Međutim, da bi se

message precipitation. However, for previous knowledge to be attained, additional time and funds are needed for work preparation of interaction system. That increases expenses in system organisation and decreases work commodity, because time of human preparation increases do to need for adaptation.

In interaction process input information transmission represents previous stage of messages processing by CS user. Transmission time( $t_T$ ) is included in user's total messages (requests) processing time ( $t_O$ ):

$$t_O = t_T + t_S \quad (14)$$

where  $t_S$  is seeking for information time in computer

Time  $t_O$  depends upon load and operational speed of central processor (CP) and external devices (SU) during transmission procedure and message searching realization, on computer:

$$t_O = t_C + t_U \quad (15)$$

where  $t_C$  represents CP operating time:

$$t_C = \frac{\delta_C}{v_C} \quad (16)$$

where  $\delta_C$  and  $v_C$  are suitable number of executed commands and CP operating speed during transport and seeking of information realisation;  $t_U$  is external device (SU) operational time:

$$t_U = \frac{\delta_U}{v_U} \quad (17)$$

where  $\delta_U$  and  $v_U$  are suitable invoking number and operational speed of external device during transport and seeking of information realisation. Time  $t_O$  represents communication device reaction time component,  $t_P$ , during human's communication with computer. This means that  $t_O$  influences users work commodity in interaction system. When there are several users in system,  $t_P$  is determined as:

$$t_P = t_R + t_O \quad (18)$$

where  $t_R$  is waiting for request processing time. Waiting time is  $t_P$  component. It also influences

stekla prethodna znanja, potrebno je dodatno vreme i sredstva za pripremu sistema uzajamnog delovanja za rad. To uvećava troškove u organizaciji sistema i smanjuje udobnost pri radu, pošto se povećava vreme čovekove pripreme zbog potrebe za adaptacijom.

U procesu interakcije prenos ulazne informacije predstavlja prethodnu etapu obrade poruka korisnika RS-a. Vreme prenosa( $t_T$ ) ulazi u ukupno vreme obrade( $t_O$ ) poruka (zahteva) korisnika:

$$t_O = t_T + t_S, \quad (14)$$

gde je  $t_S$  vreme traženja informacije u računaru.

Vreme  $t_O$  zavisi od opterećenja i brzine rada centralnog procesora (CP) i spoljnih uređaja (SU) prilikom realizacije načina prenosa i traženja poruke na računaru:

$$t_O = t_C + t_U, \quad (15)$$

gde je  $t_C$  vreme rada CP:

$$t_C = \frac{\delta_C}{v_C}, \quad (16)$$

gde su  $\delta_C$  i  $v_C$  odgovarajući broj izvršenih komandi i brzina rada CP prilikom realizacije prenosa i traženja informacije;  $t_U$  je vreme rada SU:

$$t_U = \frac{\delta_U}{v_U}, \quad (17)$$

gde su  $\delta_U$  i  $v_U$  odgovarajući broj obraćanja i brzina rada spoljnog uređaja prilikom realizacije prenosa i traženja informacije. Vreme  $t_O$  predstavlja komponentu vremena reakcije sredstava komuniciranja,  $t_P$ , prilikom komuniciranja čoveka sa računarom. Proizilazi da  $t_O$  utiče na udobnost rada korisnika u sistemu uzajamnog delovanja. Kad postoji nekoliko korisnika u sistemu,  $t_P$  se određuje kao:

$$t_P = t_R + t_O, \quad (18)$$

gde je  $t_R$  vreme čekanja na obradu zahteva. Vreme čekanja je komponenta  $t_P$ . Ono takođe utiče na udobnost rada korisnika u sistemu. Veličina  $t_R$

users work commodity in system. Value  $t_R$  depends upon number of users, and organisation of their work:

- upon communications correction procedures (correction on each step of communication cycle or correction after last step of communication cycle),
- upon users servicing strategy in time domain (servicing with or without priority),
- upon approach tactics of users to communication system (approach with or without priority) etc.

Waiting time also depends upon interaction process characteristics: distribution function of users question processing in time domain; number of interaction stages (steps and cycles); correction time; question processing time (CP operating time, speed and number of addressing SU). Considering that each communication cycle of  $j$ -th user is composed from individual steps, total time of reaction  $T_{P_j}$  of communication devices in work period in  $j$ -th user system, can be presented depended upon correction procedures, on following way:

$$T_{P_j} = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{P_{ij}} = \sum_{l=1}^C \sum_{i=1}^{K_l} (t_{R_{ij}} + t_{O_{ij}}) = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{R_{ij}} + \sum_{l=1}^C \sum_{i=1}^{K_l} t_{O_{ij}} \quad (19)$$

with correction on each step in communication cycle (processing with pauses in communication cycle), where  $C$  is number of communication cycles, and  $K_l$  number of steps in  $l$ -th communication cycle.

$$T_{P_j} = \sum_{l=1}^C T_{R_{ij}} + \sum_{l=1}^C \sum_{i=1}^{K_l} t_{O_{ij}} \quad (20)$$

with correction on cycle termination (processing without pauses in communication cycle). Average waiting time in first correction procedures is determined according to formula:

$$\bar{t}_{R_{ij}} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{ij}(t) \quad (21)$$

in case of service strategy with priority;

$$\bar{t}_{R_{ij}} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{ij}(t) + \frac{1}{2} \sum_{j=1}^n t_{O_j} \quad (22)$$

zavisi od broja korisnika, a takođe i od organizacije njihovog rada:

- od načina korekcije komuniciranja (korekcija na svakom koraku ciklusa komuniciranja ili korekcija po završetku poslednjeg koraka ciklusa komuniciranja),
- od strategije opsluživanja korisnika u vremenu (prioritetno ili bezprioritetno opsluživanje),
- od taktike pristupa korisnika sistemu komuniciranja (pristup sa prvenstvom ili bez prvenstva itd.).

Vreme čekanja zavisi takođe i od karakteristika procesa uzajamnog delovanja: funkcije raspodele obrade pitanja korisnika u vremenu; broja etapa uzajamnog delovanja (koraka i ciklusa); vremena korekcije; vremena obrade pitanja (vremena rada CP, brzine i broja obraćanja SU). Smatrući da se svaki ciklus komuniciranja  $j$ -ga korisnika sastoji iz pojedinih koraka, ukupno vreme reakcije  $T_{P_j}$  sredstava komuniciranja u periodu rada u sistemu  $j$ -ga korisnika, može se predstaviti u zavisnosti od načina korekcije, na sledeći način:

$$T_{P_j} = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{P_{ij}} = \sum_{l=1}^C \sum_{i=1}^{K_l} (t_{R_{ij}} + t_{O_{ij}}) = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{R_{ij}} + \sum_{l=1}^C \sum_{i=1}^{K_l} t_{O_{ij}}, \quad (19)$$

uz korekciju na svakom koraku u ciklusu komuniciranja (obrada sa zadrškama u ciklusu komuniciranja), gde je  $C$  broj ciklusa komuniciranja, a  $K_l$  broj koraka u  $l$ -tom ciklusu komuniciranja.

$$T_{P_j} = \sum_{l=1}^C T_{R_{ij}} + \sum_{l=1}^C \sum_{i=1}^{K_l} t_{O_{ij}}, \quad (20)$$

uz korekciju po okončanju ciklusa komuniciranja (obrada bez zadrški u ciklusu komuniciranja). Prosečno vreme čekanja kod prvog načina korekcije određuje se prema formuli:

$$\bar{t}_{R_{ij}} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{ij}(t), \quad (21)$$

u slučaju prioritetne strategije opsluživanja;

$$\bar{t}_{R_{ij}} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{ij}(t) + \frac{1}{2} \sum_{j=1}^n t_{O_j}, \quad (22)$$

in case of service strategy without priority; where  $j \neq j$ , and  $n$  number of serviced users in system; while:

$$tilj = \int_{s_j}^{f_j} t d\psi_{ilj}(t) \quad (23)$$

waiting time of question processing ( $ilj$ ) in interval  $(f_j - s_j)$  of servicing  $j$ -th user; and  $\psi_{ilj}(t)$  is distribution function of question processing ( $ilj$ ) in time domain:

$$\psi_{ilj}(t) = \begin{cases} 1, & (i-1)T_{ilj} \leq t \leq (i-1)T_{ilj} + t_{O_{ilj}} \\ 0 & \end{cases} \quad (24)$$

where  $T_{ilj}$  is processing period ( $ilj$ ):

$$T_{ilj} = t_{O_{ilj}} + t_{K_{ilj}} \quad (25)$$

where  $t_{K_{ilj}}$  is correction time ( $ilj$ ). Therefore:

$$\psi_{ilj}(t) = \begin{cases} 1, & (i-1)(t_{O_{ilj}} + t_{K_{ilj}}) \leq t \leq i t_{O_{ilj}} + (i-1)t_{K_{ilj}} \\ 0 & \end{cases} \quad (26)$$

Added up waiting time is here determined as:

$$T_{R_j} = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{R_{ilj}} \quad (27)$$

in case of service with priority;

$$T_{R_j} = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{R_{ilj}} \quad (28)$$

in case of service without priority

Average time of waiting for second correction procedure (processing without pauses in communication cycle) is determined as:

$$T_{R_j} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{lj}(t) \quad (29)$$

in case of service with priority;

$$T_{R_j} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{lj}(t) + \frac{1}{2} \sum_{j=1}^n t_{O_{lj}} \quad (30)$$

in case of service without priority;

u slučaju besprioritetne strategije opsluživanja, gde je  $j \neq j$ , a  $n$  broj opsluživanih korisnika u sistemu; dok je:

$$tilj = \int_{s_j}^{f_j} t d\psi_{ilj}(t), \quad (23)$$

vreme čekanja obrade pitanja ( $ilj$ ) u intervalu  $(f_j - s_j)$  opsluživanja  $j$ -tog korisnika; a  $\psi_{ilj}(t)$  je funkcija raspodele obrade pitanja ( $ilj$ ) u vremenu:

$$\psi_{ilj}(t) = \begin{cases} 1, & (i-1)T_{ilj} \leq t \leq (i-1)T_{ilj} + t_{O_{ilj}} \\ 0 & \end{cases}, \quad (24)$$

gde je  $T_{ilj}$  period obrade ( $ilj$ ):

$$T_{ilj} = t_{O_{ilj}} + t_{K_{ilj}}, \quad (25)$$

gde je  $t_{K_{ilj}}$  vreme korekcije ( $ilj$ ). Otuda je:

$$\psi_{ilj}(t) = \begin{cases} 1, & (i-1)(t_{O_{ilj}} + t_{K_{ilj}}) \leq t \leq i t_{O_{ilj}} + (i-1)t_{K_{ilj}} \\ 0 & \end{cases}, \quad (26)$$

Zbirno vreme čekanja ovde se određuje kao:

$$T_{R_j} = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{R_{ilj}}, \quad (27)$$

u slučaju prioritetnog opsluživanja;

$$T_{R_j} = \sum_{l=1}^C \sum_{i=1}^{K_l} t_{R_{ilj}}, \quad (28)$$

u slučaju besprioritetnog opsluživanja.

Prosečno vreme čekanja za drugi način korekcije (obrada bez zadržavanja u ciklusu komuniciranja) utvrđuje se kao:

$$T_{R_j} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{lj}(t), \quad (29)$$

u slučaju prioritetnog opsluživanja;

$$T_{R_j} = \frac{1}{2n} \sum_{j=1}^n \int_{s_j}^{f_j} t d\psi_{lj}(t) + \frac{1}{2} \sum_{j=1}^n t_{O_{lj}}, \quad (30)$$

u slučaju besprioritetnog opsluživanja.

Distribution function of  $K_l$  questions processing of  $j$ -th user in time domain is:

$$\psi_{lj}(t) = \begin{cases} 1, & (l-1)T_{lj} \leq t \leq (l-1)T_{lj} + T_{O_{lj}} \\ 0 & \end{cases} \quad (31)$$

where

$$T_{lj} = T_{O_{lj}} + T_{K_{lj}} ; \quad T_{O_{lj}} = \sum_{i=1}^{K_l} t_{O_{ilj}} \quad (32)$$

and  $T_{K_{lj}}$  is correction time of  $l$ -th communication cycle. Therefore:

$$\psi_{lj}(t) = \begin{cases} 1, & (l-1)\left(\sum_{i=1}^{K_l} t_{O_{ilj}} + T_{K_{lj}}\right) \leq t \leq l \sum_{i=1}^{K_l} t_{O_{ilj}} + (l-1)T_{K_{lj}} \\ 0 & \end{cases} . \quad (33)$$

Added up waiting time here is determined as:

$$T_{R_j} = \sum_{l=1}^C T_{R_{lj}} \quad (34)$$

when there is service with priority;

$$T_{R_j} = \sum_{l=1}^C T_{R''_{lj}} \quad (35)$$

when service with priority doesn't exist;

User's degree of service priority in O-CS system can be changed during communication. Cause of that can be existence of access precedence and users interest in system objectionable knowledge base space, for instance, towards specified files (in some moment of communication situation can occur, when user, who is working with file ( $\Phi$ ) that has largest precedence in service time, has to give up its spot to some other user, that has access precedence towards file ( $\Phi$ )). System knowledge base access precedence (towards files) can be conditional (user precedence is determined during service time) or unconditional (precedence is determined during service time independent of users wish). With times functional dependence from different factors enables regulation of interaction parameter value in O-RS system and choosing ones, which in best way satisfy established requests.

Funkcija raspodele obrade  $K_l$  pitanja  $j$ -ga korisnika po vremenu je:

$$\psi_{lj}(t) = \begin{cases} 1, & (l-1)T_{lj} \leq t \leq (l-1)T_{lj} + T_{O_{lj}} \\ 0 & \end{cases} , \quad (31)$$

gde je

$$T_{lj} = T_{O_{lj}} + T_{K_{lj}} ; \quad T_{O_{lj}} = \sum_{i=1}^{K_l} t_{O_{ilj}} , \quad (32)$$

a  $T_{K_{lj}}$  je vreme korekcije  $l$ -ga ciklusa komuniciranja. Otuda je:

Zbirno vreme čekanja ovde se određuje kao:

$$T_{R_j} = \sum_{l=1}^C T_{R_{lj}} , \quad (34)$$

kad postoji prioritet opsluživanja;

$$T_{R_j} = \sum_{l=1}^C T_{R''_{lj}} , \quad (35)$$

kad ne postoji prioritet opsluživanja.

Stepen prioriteta opsluživanja korisnika sistema O-RS može se menjati u toku komuniciranja. Uzrok tome može biti postojanje prvenstva pristupa i interesovanja korisnika u prostoru predmetne baze znanja sistema, na primer, prema određenim fajlovima (u nekom trenutku komuniciranja može nastati situacija, kada korisnik, koji radi sa fajлом ( $\Phi$ ) koji ima najveći prioritet u vremenu opsluživanja, mora da ustupi mesto nekom drugom korisniku, koji čeka u redu, a koji ima prvenstvo pristupa ka fajlu ( $\Phi$ )). Prvenstvo pristupa bazi znanja sistema (ka fajlovima) može biti uslovno (prvenstvo korisnika se odredi u toku vremena opsluživanja) ili bezuslovno (određuje se u toku vremena opsluživanja nezavisno od želje korisnika). Funkcionalne zavisnosti vremena čekanja od različitih faktora omogućuju regulisanje vrednosti parametara interakcije u sistemu O-RS i izbor onih od njih, koji na najbolji način zadovoljavaju postavljene zahteve.

## 4 CONCLUSION

Analysing of established dependencies which directly or indirectly mutually connect different attributes of interaction system, leads to conclusion that changing of parameters that influence speed and human resource usage in O-CS, changes speed and machine processing means. Size of this changes is in indirect proportion. So, with increasing of interaction steps number, it becomes possible to increase information elements overlapping degree and increasing message perception speed on each step of communication, and decreasing perception load. But, on the other hand, this leads to increase of question machine processing time. In each specified case, using established dependencies, message elements overlapping degree and number of steps can be determined, that in best way secures distribution and computer and man resource usage, in interaction system. Besides that, with alteration of expenses for human preparation (his adaptation and experience gathering in work with language means of communication in system), [6] computer resource distribution is altered. In capacity increase of language means and communication possibilities broadening, time consumption of generating (producing) messages by man is increased, and system (as a whole) reaction waiting time is also increased. Best solution in this case is applying of natural language, which allows wide communication possibilities and secures, not only fast adaptation of human onto language communication means in O-CS system (language compatibility), but also other forms of compatibility: semantic, pragmatic and psychological.

## 4 ZAKLJUČAK

Analizirajući postavljene zavisnosti koje direktno ili indirektno međusobno povezuju različite osobine sistema uzajamnog delovanja, može se zaključiti da se promenom parametara koji utiču na brzinu i korišćenje resursa čoveka u sistemu O-RS, menjaju brzina i sredstva mašinske obrade. Veličina ovih izmena je u obrnutoj zavisnosti. Tako, sa povećanjem broja koraka uzajamnog delovanja, postaje moguće uvećati stepen poklapanja elemenata informacija i samim tim povećati brzinu percepiranja poruka na svakom koraku komuniciranja, kao i smanjiti opterećenost percepiranja. Ali, sa druge strane, ovo vodi ka uvećanju vremena mašinske obrade upita. U svakom konkretnom slučaju, koristeći postavljene zavisnosti, može se utvrditi stepen poklapanja elemenata poruka i broj koraka, koji na najbolji način obezbeđuje raspodelu i iskorišćenje resursa čoveka i računara u sistemu uzajamnog delovanja. Osim toga, sa izmenom troškova za pripremu čoveka (njegovu adaptaciju i sticanje iskustva u radu sa jezičkim sredstvima komuniciranja u sistemu), [6] menja se i raspodela resursa računara. Kod povećanja kapaciteta jezičkih sredstava i proširenja mogućnosti komuniciranja rastu utrošci vremena na generisanju (proizvodnji) poruka od strane čoveka i njihovu obradu u sistemu O-RS a uvećava se i vreme čekanja reakcije sistema u celini. Najbolje rešenje u ovakvoj situaciji je primena prirodnog jezika, koji pruža široke mogućnosti komuniciranja i obezbeđuje, ne samo brzu adaptaciju čoveka na jezička sredstva komuniciranja u sistemu O-RS (jezičku kompatibilnost), već i druge oblike kompatibilnosti: semantičku, pragmatsku i psihološku.

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