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BILATERALNO UPRAVLJANJE GIBANJEM ZA APSTRAKCIJU I REPRODUKCIJU STVARNE SILE

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Održavanje sposobnosti iskusnih operatera i uvježbavanje novih operatera postaje sve važnijim zadatkom u medicinskim i proizvodnim primjenama. Nove operatere najbolje uvježbavaju iskusni operateri, ali njih sve više nedostaje. Inovativno rješenje toga problema može biti pohranjivanje vještina iskusnih operatera u tzv. haptičku bazu podataka. U ovome se članku za razvoj haptičke baze podataka predlažu metode apstrakcije i reprodukcije stvarne sile u bilateralnom upravljanju te metoda rekonstrukcije udaljenoga stvarnoga prostora u kojemu djeluje prateći sustav. U apstrakcijskom načinu rada uspostavlja se bilateralno upravljanje između vodećeg i pratećeg sustava uz održavanje zakona akcije i reakcije između njih. Nakon toga estimiraju se sila, brzina i pozicija vodećeg i pratećeg sustava na temelju informacije o ubrzanju. U rekonstrukcijskom načinu rada rekonstruira se model udaljenoga stvarnoga prostora na osnovi podataka iz stvarnoga udaljenoga prostora. Na koncu, primjenom reprodukcijskog načina rada na strani vodećeg sustava operater bi trebao osjećati silu iz modela udaljenog prostora izgrađenog u rekonstrukcijskom načinu rada. Predloženi sustav omogućuje spremanje bilateralno prenošene sile u bazu podataka, što je potkrijepljeno eksperimentalnim rezultatima.

(Sl. 12, Tab. 2, Lit. 19 – original na engleskom) *Autori*

bilateralno upravljanje gibanjem, haptičko sučelje
haptička baza podataka, osjećaj stvarne sile

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KLIZNI REŽIMI U SUSTAVIMA UPRAVLJANJA GIBANJEM

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U ovom se članku razmatra realizacija sustava upravljanja gibanjem zasnovana na kliznim režimima. Pri sintezi bilo kojeg sustava upravljanja gibanjem treba uzeti u obzir neometano gibanje, općenito tretirano kao slijeđenje trajektorije, i gibanje sustava u kontaktu s nepoznatom okolinom, tretirano kao upravljanje silom i/ili upravljanje prianjanjem. Kod upravljanja zasnovanog na kliznim režimima upravljački se signal odabire tako da održava unaprijed zadanu ovisnost među varijablama sustava, tj. sustav se giba po zadanoj hiperravnini u prostoru stanja. U ovom je članku pokazano da takva formulacija problema upravljanja omogućuje jedinstveno tretiranje i neometanog gibanja i gibanja u kontaktu s okolinom, a zbog sinteze zasnovane na teoriji Ljapunova jamči se stabilnost gibanja. K tome, sinteza sustava upravljanja zasnovana na predloženoj metodologiji može se proširiti i na međuovisne dinamičke sustave, kao što su mobilni roboti i bilateralni sustavi.

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sustavi upravljanja gibanjem
klizni režimi
hibridno upravljanje
nelinearno upravljanje, sustavi s dinamičkim vezama

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MODELIRANJE LJUDSKE VOŽNJE PRIMJENOM PO DIJELOVIMA LINEARNOG MODELA

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Ovaj članak prikazuje razvoj strategije modeliranja ljudskog ponašanja pri vožnji, koja je utemeljena na po dijelovima linearnom (PWL) modelu fokusiranom na vozačev manevar zaustavljanja. Podaci o vožnji prikupljeni su korištenjem trodimenzionalnog simulatora vožnje zasnovanog na *CAVE Automatic Virtual Environment* (CAVE) koji osigurava potpuno stereoskopsko virtualno okruženje. Pri modeliranju je upravljački scenarij za vozača, odnosno preslikavanje vozačevih senzorskih informacija u operacije poput ubrzanja, kočenja i upravljanja vozilom, opisan PWL modelom. Kako PWL model uključuje istodobno kontinuirano ponašanje izraženo preko polinoma kao i diskretne logičke uvjete, takav se model može promatrati kao klasa hibridnih dinamičkih sustava (HDS). Transformiranjem uvjeta prekapčanja u binarne varijable, problem identifikacije PWL modela formuliran je kao mješoviti cjelobrojni linearni program (MILP). Iz dobivenih je rezultata vidljivo da vozač prekapča »zakon upravljanja« u skladu sa senzorskim informacijama. Rezultati omogućuju razumijevanje ne samo fizikalnog značenja sposobnosti vožnje već i sam aspekt donošenja odluka (uvjeta prekapčanja) prilikom vozačevog manevra zaustavljanja.

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ljudska vožnja, po dijelovima linearni model
simulator vožnje, identifikacija

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PRAĆENJE VIŠE GIBAJUĆIH OBJEKATA U STVARNOME VREMENU PRIMJENOM ČESTIĆNIH FILTARA I VJEROJATNOSNOG PRIDRUŽIVANJA PODATAKA

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Mobilni roboti i mobilna vozila sve se više koriste u dinamičkim okruženjima popunjenim ljudima i drugim gibajućim objektima. U tom je smislu važno praćenje gibajućih objekata u neposrednom okruženju kako bi se izbjegavale prepreke i planiralo gibanje. U ovome je radu predložena metoda detekcije i praćenja više gibajućih objekata primjenom čestičnih filtara za estimaciju stanja objekata i filtara za združeno vjerojatnosno pridruživanje uzorkovanih podataka kojima se povezuju značajke detektirane u mjernim podacima s odgovarajućim filtrima. Izvedena je nadzorna ljuska filtara za odgovarajuću integraciju očitanih značajki. Ukratko je opisana arhitektura implementiranog sustava praćenja objekata u stvarnom vremenu. Prikazani eksperimentalni rezultati dobiveni primjenom laserskog senzora udaljenosti potvrđuju izvedivost i učinkovitost predloženog sustava.

(Sl. 15 Lit. 12 – original na engleskom) *Autori*

mobilni roboti
čestični filtri
praćenje u stvarnome vremenu
vjerojatnosno pridruživanje podataka

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SLIDING MODES IN MOTION CONTROL SYSTEMS

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In this paper we discuss the realization of motion control systems in the sliding mode control (SMC) framework. Any motion control system design should take into account the unconstrained motion (generally perceived as a trajectory tracking) and motion of the system in contact with unknown environment (perceived as force control and/or compliance control.) In the SMC framework control is selected to enforce certain preselected dependence among system coordinates, what is interpreted as forcing the system state to stay in selected manifold in state space. In this paper it has been shown that such a formulation allows a unified treatment of the both unconstrained and constrained motion control and, due to the Lyapunov based design, it guaranty the stability of the motion. Moreover control design in this framework allows extension of the solution to control design in interconnected dynamical systems (like mobile robots or bilateral systems).

(Fig. 16, Ref. 16 – original in english) *Authors*

motion control
sliding mode
hybrid control
nonlinear control, interconnected systems

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BILATERAL MOTION CONTROL FOR ABSTRACTION AND REPRODUCTION OF REAL WORLD FORCE SENSATION

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In recent years, skill preservation of an expert and skill education for young technical workers have been serious issues in medical and production fields. The best way which young technical workers learn the ripe skill is that an expert teaches them. However, unfortunately, experts have lessened in these years. So, if digital skill pre-servation like a haptic database is attained, it may become an innovative solution of the above problem. Thus, as the fundamental technology for development of the haptic database, this paper proposes abstraction and reproduction methods on bilateral control of real world force sensation, and reconstruction of real world environment as well. In the abstraction mode, a master-slave system is composed, and the action-reaction law is attained through bilateral control. Later, based on acceleration information, the force, position and velocity of both master and slave systems are estimated and obtained. In the reconstruction mode, an environmental model is reconstructed based on the obtained data from real-world. Next, by using reproduction mode on master side, the operator would feel the force sensation from the obtained environmental model. Here, the proposed system is able to store the bilateral real-world force sensation to a sensation database. Finally, the experimental results show the validity of the proposed method.

(Fig. 12, Tab. 2, Ref. 19 – original in english) *Authors*

bilateral motion control, haptic interface
haptic database, real world force sensation

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REAL-TIME TRACKING OF MULTIPLE MOVIN OBJECTS USING PARTICLE FILTERS AND PROBABILISTIC DATA ASSOCIATION

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Abstract-Mobile robots and vehicles are increasingly used in dynamic environments populated by humans and other moving objects and vehicles. In this context, tracking of surrounding moving objects is important for obstacle avoidance and motion planning. In this paper we present a method for detection and tracking of multiple moving objects using particle filters to estimate the object states, and sample based joint probabilistic data association filters to perform the assignment between the features detected in the input sensor data and filters. Filters management operations are required for appropriate integration of the currently perceived features. A real-time architecture, developed to implement the tracking system, is briefly described. Experimental results obtained with a laser range scanner will be presented demonstrating the feasibility and effectiveness of the presented methods.

(Fig. 15 Ref. 12 – original in english) *Authors*

mobile robots
particle filters
real-time tracking
probabilistic data association

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MODELING OF HUMAN DRIVING BEHAVIOR BASED ON PIECEWISE LINEAR MODEL

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This paper presents development of the modeling strategy of the human driving behavior based on the expression as Piecewise Linear (PWL) model focusing on the driver's stopping maneuver. The driving data are collected by using the three-dimensional driving simulator based on CAVE Automatic Virtual Environment (CAVE), which provides stereoscopic immersive virtual environment. In our modeling, the control scenario of the human driver, that is, the mapping from the driver's sensory information to the operation of the driver such as acceleration, braking and steering, is expressed by Piecewise Linear (PWL) model. Since the PWL model includes both continuous behaviors given by polynomials and discrete logical conditions, it can be regarded as a class of Hybrid Dynamical System (HDS). The identification problem for the PWL model is formulated as the Mixed Integer Linear Programming (MILP) by transforming the switching conditions into binary variables. From the obtained results, it is found that the driver appropriately switches the 'control law' according to the sensory information. These results enable us to capture not only the physical meaning of the driving skill, but also the decision-making aspect (switching conditions) in the driver's stopping maneuver.

(Fig. 5, Tab. 3, Ref. 21 – original in english) *Authors*

human driving, piecewise linear model
driving simulator, identification

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VOĐENJE HODAJUĆEG ROBOTA U STRUKTURIRANOM PROSTORU ZASNOVANO NA RAČUNALNOME VIDU

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Lokomocija dvonožnog robota u prostoru s preprekama zahtijeva visoki stupanj koordinacije između percepcije i hodanja. U članku se opisuju ključne postavke strategije vođenja hodajućih robota zasnovane na računalnome vidu. Tehnike računalnoga vida primijenjene za reaktivnu adaptaciju slijeda koraka omogućuju robotu zaobilaženje prepreka, ali i njihovo prekoračivanje te penjanje na njih. Visoka točnost povratne informacije postignuta je kombinacijom analize linijskih segmenata u sceni i praćenjem značajki scene u stvarnome vremenu. Predloženi je sustav vođenja hodajućih robota eksperimentalno provjeren na stvarnome čovjekolikome robotu.

(Sl. 9, Lit. 16 – original na engleskom) *Autori*

dvonožni hodajući roboti
čovjekoliki roboti
računalni vid
strukturirani prostor
praćenje značajki u stvarnome vremenu

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JEDAN NOVI POSTUPAK ESTIMACIJE BRZINE VRTNJE VEKTORSKI UPRAVLJANOG ASINKRONOG MOTORA ZASNOVAN NA ADAPTIVNOM SUSTAVU S REFERENTNIM MODELOM I NEURONSKIM MREŽAMA

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U članku se predlaže novi postupak estimacije brzine vrtnje elektromotornog pogona s vektorski upravljanim asinkronim motorom. Postupak se zasniva na hibridnom adaptivnom sustavu s referentnim modelom (MRAS) i neuronskim mrežama. Takav postupak poboljšava prethodno razvijeni estimacijski postupak također zasnovan na »neuronskom MRAS-u«. U radu je realizirana integracija u otvorenoj petlji u referentnom modelu pomoću adaptivnog neuronskog integratora unaprijeđenog s filtrom čija prijenosna funkcija ovisi o brzini motora. Adaptivni je model zasnovan na točnijem diskretnom strujnom modelu motora dobivenom modificiranom Eulerovom integracijom, što rezultira stabilnijim vladanju pogona u režimu slabljenja polja. Adaptivni je model nadalje on-line obučavan korištenjem poopćene metode najmanjih kvadrata (»MCA EXIN +neuron« postupak) pri čemu se koristi parametrirani algoritam učenja. Zbog boljeg ponašanja neurona u dinamičkim stanjima poboljšava se konvergencija estimacije brzine s većom točnošću i manjim vremenom smirivanja. Za eksperimentalnu provjeru predložene metode izgrađena je laboratorijska maketa. Dobiveni rezultati potvrđuju valjanost metode na veoma niskim brzinama (ispod 4 rad/s) i u režimu nulte brzine.

(Sl. 15, Tab. 2, Lit. 31 – original na engleskom) *Autori*

elektromotorni pogoni s asinkronim motorom
bezsenzorsko upravljanje
adaptivno upravljanje s referentnim modelom
neuronske mreže

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NOVA SHEMA ZA IZRAVNO UPRAVLJANJE MOMENTOM ASINKRONIH MOTORA NAPAJANIH IZ TROFAZNOG IZMJENJIVAČA

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U ovome se članku opisuje novi regulator zasnovan na strategiji izravnog upravljanja momentom i razvijen za primjenu u upravljanju asinkronim motorima napajanim iz trorazinskih izmjenjivača napona. Taj tip izmjenjivača ima nekoliko prednosti u odnosu na standardne dvorazinske izmjenjivače napona, kao što je veći broj razina u izlaznom valnom obliku napona, niži du/dt, manja distorzija harmonika u valnim oblicima napona i struje i niže frekvencije komutacije. U novom regulatoru moment i pogreške u statorskom toku koriste se zajedno s kutnom frekvencijom statora za tvorbu referentne vrijednosti vektora napona. Eksperimentalni su rezultati novog sustava prikazani i uspoređeni s rezultatima klasičnog sustava koji koristi dvorazinski pretvarač napona. Novi regulator pokazuje smanjeni šum u odzivima momenta i toka motora. U predloženom je sustavu također postignuta i manja distorzija struje i manja frekvencija komutacije poluvodičkih sklopova.

(Sl. 11, Tab. 4, Lit. 18 – original na engleskom) *Autori*

elektromotorni pogoni promjenljive brzine
izravno upravljanje momentom i tokom
asinkroni motori
višerazinski pretvarači

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EKSPERIMENTALNO PONAŠANJE PROTOTIPA MATRIČNOG PRETVARAČA IZVEDENOG S NOVIM ENERGETSKIM MODULIMA

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Članak opisuje projekt i rješenja usvojena za prototip 10 kW matričnog pretvarača, izvedenog s novim integriranim energetskim modulima. Svojstva pretvarača provjerena su eksperimentalnim ispitivanjima.

(Sl. 15, Lit. 23 – original na engleskom) *Autori*

matrični pretvarač
elektromotorni sustav s pretvaračem
modulacijska strategija
strategija za komutaciju struje
integrirani elektronički energetski modul

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AN MRAS SENSORLESS TECHNIQUE BASED ON THE MCA EXIN + NEURON FOR HIGH PERFORMANCE INDUCTION MOTOR DRIVES

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This paper proposes a new sensorless technique for induction motor drives based on a hybrid MRAS-neural technique, which improves a previously developed neural MRAS based sensorless method. In this paper the open-loop integration in the reference model is performed by an adaptive neural integrator, enhanced here by means of a speed-varying filter transfer function. The adaptive model is based on a more accurate discrete current model based on the modified Euler integration, with a resulting more stable behaviour in the field weakening region. The adaptive model is further trained on-line by a generalized least squares technique, the MCA EXIN + neuron, in which a parameterized learning algorithm is used. As a consequence, the speed estimation presents an improved convergence with higher accuracy and shorter settling time, because of the better transient behaviour of the neuron. A test bench has been set up to verify the methodology experimentally and the results prove its goodness at very low speeds (below 4 rad/s) and in zero-speed operation.

(Fig. 15, Tab. 2, Ref. 31 – original in english) *Authors*

induction motor drives
sensorless control
model reference adaptive systems
neural networks

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VISION-GUIDED WALKING IN A STRUCTURED INDOOR SCENARIO

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Locomotion of a biped robot in a scenario with obstacles requires a high degree of coordination between perception and walking. This article presents key ideas of a vision-based strategy for guidance of walking robots in structured scenarios. Computer vision techniques are employed for reactive adaptation of step sequences allowing a robot to step over or upon or walk around obstacles. Highly accurate feedback information is achieved by a combination of line-based scene analysis and real-time feature tracking. The proposed vision-based approach was evaluated by experiments with a real humanoid robot.

(Fig. 9, Ref. 16 – original in english) *Authors*

biped walking robots
humanoid robots
computer vision
structured environment
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EXPERIMENTAL BEHAVIOR OF A MATRIX CONVERTER PROTOTYPE BASED ON NEW POWER MODULES

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This paper describes the design and the solutions adopted for a matrix converter prototype of 10 kW, based on new integrated power modules. The performance of the converter is verified by means of experimental tests.

(Fig. 15, Ref. 23 – original in english) *Authors*

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NEW DTC CONTROL SCHEME FOR INDUCTION MOTORS FED WITH A THREE-LEVEL INVERTER

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This paper presents a novel controller based on Direct Torque Control (DTC) strategy. This controller is designed to be applied in the control of Induction Motors (IM) fed with a three-level Voltage Source Inverter (VSI). This type of inverter has several advantages over the standard two-level VSI, such as a greater number of levels in the output voltage waveforms, lower dV/dt, less harmonic distortion in voltage and current waveforms and lower switching frequencies. In the new controller, torque and stator flux errors are used together with the stator flux angular frequency to generate a reference voltage vector. Experimental results of the novel system are presented and compared with those obtained for Classical DTC system employing a two-level VSI. The new controller is shown to reduce the ripple in the torque and flux responses. Lower current distortion and switching frequency of the semiconductor devices are also obtained in the new system presented.

(Fig. 11, Tab. 4, Ref. 18 – original in english) *Authors*

adjustable speed drives
direct torque and flux control
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