Complex Systems Modeling Laboratory

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Research activity

As previously, in FY 2013 the research conduced by the Modeling Complex Systems Laboratory as a whole can be categorized as "Complex System Science," which is a novel interdisciplinary branch of science studding emergent phenomena met in a wide variety of systems different in nature, spanning from traditional objects of the inanimate world and technical systems up to social, economic, and ecological systems, where human or living beings play a crucial role.

The main research interest of Prof. I. Lubashevsky concerns the basic principles and mathematical formalism required for describing social systems and human behavior, including human memory dynamics, decision-making processes, perception and recognition, prediction, and learning.

In FY2013 the research conducted by Prof. I. Lubashevsky was mainly focused on:

- analysis of the basic properties of human intermittent control over unstable systems based on mathematical modeling and hybrid human-computer experiments (in collaboration with Prof. S. Kanemoto);

- mathematical formalism required for modeling human decision-making near the perception threshold that is able to account for the bounded capacity of human cognition;

- effects of human intrinsic motivations on the decision-making and a mathematical formalism required for their modeling;
- mathematical formalism required for modeling effects of scale-free human memory.

Among the results obtained during the reported period the following are worthy of noting.

1. To analyze the characteristic features of the human intermittent control over unstable systems of the first order experiments on balancing a virtual inverted pendulum with over-damped dynamics were conducted and experimental data were collected. These data were proceeded to construct the distribution functions of the pendulum angle and the angular velocity, the cart velocity and the distribution function of action points. These distributions were used to analyze the basic properties of the transitions between the active and passive phases of the human control and the properties of the active phase on its own. In particular, it has been demonstrated that independently of the subject age, gender, and skill of balancing as well as the difficulty of the pendulum balancing process these distribution functions have a rather universal form that, in the first approximation, can be represented as the Laplace distribution with heavy tails (result obtained in collaboration with Prof. S. Kanemonto).

2. An original model for balancing an over-damped pendulum has be developed. It appeals to the concept of dynamical traps with respect to the human perception of the pendulum angular velocity converted into the velocity of the cart. Noise imitates uncertainty in human perception near its threshold and describes the stochastic transition from the passive to active phases. The results of numerical simulation have demonstrated very good fit with the experimental data (result obtained in collaboration with Prof. S. Kanemonto).

3. Based on the comparison of the experimental and theoretical data we made a conclusion that the cart velocity (or the pendulum angle velocity) is an additional independent phase variable required to model human control over mechanical systems of the first order. It means that the introduction of extended phase space is necessary to allow for the human active behavior.

4. We have developed an original model for the transition from passive to active phases treated in terms of random bimodal processes. Using this model and

the aforementioned experimental data it is demonstrated that the concept of rigorous or fuzzy threshold is not relevant to the observed human behavior. Contrary, the concept of dynamical traps with anomalous kinetic coefficients seems to be appropriate.

5. Experiments on driving a virtual car within the car-following setup and the free-driving setup were carried out to analyze the characteristic properties of human control over systems of the second order. For this particular case it has been demonstrated that for the description of human behavior one has to use the extended phase space comprising the car position, velocity, acceleration, and jerk. So the description of human control over both the systems of the first and second orders cannot meet the paradigm of Newtonian mechanics (result obtained in partial collaboration with Prof. M. Mozgovoy).

6. Experiments on the shape recognition demonstrated that, first, the standard model for detecting noisy signals is not applicable to describing the human decision-making near the perception threshold and, second, this process can exhibit remarkable hysteresis.

7. A novel approach to describing long-term human memory has been proposed based on the formalism of the fractional differential equations with Caputor type time derivatives. Based on it the properties of forgetting, learning, and the spacing effect were studied numerically and compared with the available experimental data.

8. An original approach to the description of nonlinear stochastic processes with nonlinear noise has been worked out. Its key point is the introduction of the notion of complex elementary steps, which is essential for the construction of the "microscopic" description of human behaviour appealing to the notion random processes mimicking the human individuality effects.

The research interests of Prof. I. Khmyrova in FY2013 was focused on developing analytical and numerical models and simulation strategy for the light extraction through planar semiconductor-air interface of the light-emitting diode (LED). A test simulation of the LED output characteristics was performed and items which need further investigation were determined.

The research interests of Prof. M. Ryzhii are in the following areas.

- Theory and computer modeling of graphene based optoelectronic devices.

- Computer modeling of cardiac electrical activity.

External research grants received or being continued during the reported period

- "Extended Phase Space and Emergent Phenomena in Social Systems"

  JSPS "Grants-in-Aid for Scientific Research ” Program", Grant 2454041-00001, Duration: FY2012-FY2014 (in cooperation with Prof. Y. Watanabe)

Conducted Conferences and Workshops

- A local workshop devoted to modeling human opinion was conducted. Prof. A. Ishii (Tottori University) and Dr. Y. Kawahata (Kyushu University) were invited for presentation their recent investigations.

Education activity

In FY2013:

1. Under the supervision of Prof. Lubashevsky four undergraduate students defended their theses. One of them joined the Modeling Complex Systems Laboratory as master student (in partial cooperation with Prof. M. Mozgovoy).
2. Under the supervision of Prof. Lubashevsky one doctoral student prepared his thesis to be defended in FY2014.
3. Under the cooperative supervision of Profs. S. Kanemoto and I. Lubashevsky one undergraduate student defended his thesis.
4. Under the supervision of Prof. I. Khmyrova two master students defended their theses.

Member of laboratory taught the following courses:

Undergraduate courses:

F3 Discrete Systems;

P4 C++ Programing;

NS7 Introduction to Optoelectronics;

S2 Electric Circuits

O3-015 Computer Simulators and Virtual Experiments on Human Cognition Near Its Threshold

Graduate courses:

CSA17 Computer Simulation of Stochastic Processes;

SYA04 Optoelectronics. Computer and Communication Devices;

SYA07 Modelling of Advanced Devices;

SYA06 Advanced Devices for Computer and Communication Systems.

Refereed Journal Papers

[i-lubash-01:2013] I. Lubashevsky A. Zgonnikov. Extended phase space description of human-controlled systems dynamics. *Prog. Theor. Exp. Phys.*, pages 033J02(1–12), 2014.

Understanding how humans control unstable systems is central to many research problems, with applications ranging from quiet standing to aircraft landing. Much evidence appears in favor of event-driven control hypothesis: human operators are passive by default and only start actively controlling the system when the discrepancy between the current and desired system states becomes in some sense large. The present paper argues that the control triggering mechanism in humans is intrinsically stochastic. We propose a model which captures the stochastic threshold mechanism and show that it matches the experimental data on human balancing of virtual overdamped stick. Our results suggest that the stochasticity of the threshold mechanism is a fundamental property and may play an important role in the dynamics of human-controlled systems.

Refereed Proceeding Papers

[i-lubash-02:2013] D. Parfenov I. Lubashevsky, A. Zgonnikov. New Emergence Mechanism Caused by Human Fuzzy Rationality. In *Proceedings of International Academic Workshop on Social Science, IAW-SC 2013*, volume 59 of *Advances in Intelligent Systems Research*, pages 157–161, Amsterdam, Sept. 2014. Atlantis Press.

A new emergence mechanism related to the bounded capacity of human cognition is considered. It assumes that individuals (operators) governing the dynamics of a certain system try to follow an optimal strategy in controlling its motion but fail to do this perfectly because similar strategies are indistinguishable for them. The main attention is focused on the systems where the optimal dynamics implies the stability of a certain equilibrium point in the corresponding phase space. In such systems the bounded capacity of human cognition gives rise to some neighborhood of the equilibrium point, the region of dynamical traps, wherein each point is regarded as an equilibrium one by the operators. So when a system enters this region and while it is located in it, maybe for a long time, the operator control is suspended. This model is extended to take into account the effect of imperfect implementation of the desired control strategy. The operator of a dynamical system treats the current value of the control effort as

acceptable if it deviates insignificantly from the desired, or optimal value. The operator starts correcting the actions only when he identifies that this deviation has become considerably large. A non-Newtonian model capturing the operator fuzzy perception of his own actions is developed based on the previously introduced dynamical trap concept. It deals with the physical phase space of a controlled system extended with an independent phase variable characterizing the operator motivated actions. The present work draws on the results obtained previously as well as new ones and is mainly aimed at elucidating the basic principles in constructing a mathematical formalism describing this human feature. In particular, it is demonstrated that complex emergent phenomena can be caused by the fuzzy rationality of human behavior.

[i-lubash-03:2013] A. Zgonnikov T. Miyazawa D. Taniguchi I. Lubashevsky, S. Kanemoto. Dynamical Traps and Balancing of Overdamped Pendulums: Virtual Experiments and Universal Properties of Human Control. In J. Saski H. Fujita, M. Tuba, editor, *Proceedings of the 2nd International Conference on Automatic Control, Soft Computing and Human-Machine Interaction (ASME'13)*, volume 12 of *Recent Advances in Automatic Control, Modelling and Simulation*, pages 185–190, Morioka, 2013 2013. WSEAS Press.

Experiments on the balancing of virtual pendulums of various forms were conducted to examine the basic features of human control over unstable systems. The experiments involved 10 human subjects of different age and skill. Three types of pendulums: an inverted stick, a triangular pendulum, and a vibrating spring were used. The collected experimental data are analyzed by constructing the phase portraits in the space “angleangular velocity” and the distribution functions of the corresponding phase variables. It is demonstrated that actually only the dimensions of the phase space region wherein a given pendulum trajectory is located depend on the subject age and skill as well as the pendulum parameters determining the difficulty of the balancing. In contrast, the forms of the distribution functions are the same for all the subjects. Possible explanation of the found universality is given. The data of the virtual experiments are also compared to the results of numerical simulation of the so-called oscillator with dynamical traps studied previously. The phase trajectories and the phase variable distributions are shown to be similar for the two systems. Actually the latter result has encouraged us to apply the concept of dynamical traps to describing the basic features of human control, in particular, its fuzziness and discontinuity.

[i-lubash-04:2013] T. Miyazawa T. Suzuki S. Kanemoto, I. Lubashevsky and A. Zgonnikov. Balancing of Overdamped Virtual Pendulums: Universal Properties of Human Control. In *Proceedings of the 45th ISCIE International Symposium on Stochastic Systems Theory and Its Applications*, pages 101–102, 2013.

The results of experiments on balancing a virtual inverted pendulum with overdamped dynamics are reported. Three types of pendulum, namely, an inverted stick, a triangle pendulum, and a vibrating spring were used in experiments and subjects of different age, gender, and skill of balancing participated in these experiments. It is demonstrated that the main characteristics of human balancing under the analyzed conditions, in particular, the phase portraits and the distribution functions of the pendulum angle and the angular velocity are universal in form. Only the characteristic scales depend on the subject features and the difficulty of balancing.

[i-lubash-05:2013] Dmitry Parfenov Ihor Lubashevsky, Arkady Zgonnikov. Concept of Dynamical Traps: Model Systems of Human Actions and Experimental Evidence. In Rössler Otto E. Sanayei Ali, Zelinka Ivan, editor, *Proceedings of Interdisciplinary Symposium on Complex Systems (ISCS 2013)*, volume 8 of *Emergence, Complexity and Computation*, pages 151–161, Berlin Heidelberg, 2014. Springer-Verlag.

Dynamical traps as a new emergence mechanism related to the bounded capacity of human cognition is considered. It assumes that individuals (operators) governing the dynamics of a certain system try to follow an optimal strategy in controlling its motion but fail to do this perfectly because similar strategies are indistinguishable for them. This is described in terms of some neighborhood of the equilibrium point, the region of dynamical traps, wherein each point is regarded as an equilibrium one by the operators. So when a system enters this region and while it is located in it, maybe for a long time, the operator control is suspended. A simple model of oscillator with dynamical traps and the characteristic features of its dynamics are discussed. Experiments on the balancing of a virtual pendulum were conducted to examine the basic features of human control over unstable systems that are expected to be affected by human fuzzy rationality. It is demonstrated that practically only the dimensions of the phase space region wherein a given pendulum trajectory is located depend on the subject age and skill as well as the pendulum parameters determining the difficulty of the balancing. In contrast, the forms of the distribution functions are the same for all the subjects. The data of the virtual experiments are compared to

the results of numerical simulation of the oscillator with dynamical traps. The phase trajectories and the phase variable distributions are shown to be similar for the two systems. In addition a chain of oscillators with dynamical traps which mimics cooperative interaction of human operators is considered also. It is, actually, demonstrated that the human fuzzy rationality can cause complex cooperative dynamics in many-element ensembles.

[i-lubash-06:2013] A. Zgonnikov and I. Lubashevsky. Probabilistic Dynamical Trap: Intrinsic Stochasticity of Human Control. In *Proceedings of the 45th ISCIE International Symposium on Stochastic Systems Theory and Its Applications*, pages 103–104, 2013.

A new approach to describing stochastic transitions from passive to active phases of human intermittent control is developed.

[i-lubash-07:2013] Ihor Lubashevsky. Towards Multi-Dimensional Nonlinear Langevin Equation. In *Proceedings of the 45th ISCIE International Symposium on Stochastic Systems Theory and Its Applications*, pages 131–132, 2013.

The work is devoted to possible generalizations of the Langevin equation based on the notion of the intermediate point determining the contribution of nonlinear random forces.

[i-lubash-08:2013] I. Lubashevsky A. Zgonnikov. Intrinsically motivated reinforcement learning in socio-economic systems: the dynamical analysis. In *Development and Learning and Epigenetic Robotics (ICDL), 2013 IEEE Third Joint International Conference on*, pages 1–2. IEEE INSPEC Accession Number: 13882489, 2013.

We conduct a theoretical analysis of the effects of intrinsic motivation on learning dynamics. We study a simple example of a single agent adapting to unknown environment; the agent is biased by the desire to take those actions she has little information about. We show that the intrinsic motivation may induce the instability (namely, periodic oscillations) of the learning process that is stable in case of rational agent. Most interestingly, we discover that the opposite effect may arise as well: the cyclic learning dynamics is stabilized by high levels of agent intrinsic motivation. Based on the presented results we argue that the effects of human intrinsic motivation in particular and bounded rationality in general may appear dominant in complex socio-economic systems and therefore deserve much attention in the formal models of such systems.

[i-lubash-09:2013] I. Lubashevsky A. Zgonnikov. Unstable dynamics of intrinsically motivated learning. In M. Pauen I. Wachsmuth M. Knauff, N. Sebanz, editor, *Proceeding of the 35th Annual Meeting of the Cognitive Science Society*, pages 3853–3857, Austin, 2013. TX: Cognitive Science Society.

Employing the dynamical systems framework, we study the effects of intrinsic motivation on the dynamics of the learning processes. The intrinsic motivation here is the one's desire to learn not because it may cause some benefits in future, but due to the inherent joy obtained by the very process of learning. We study a simple example of a single agent adapting to unknown environment; the agent is biased by the desire to select the actions she has little information about. We show that intrinsic motivation may cause the instability of the learning process that is stable in the case of rational agent. Therefore, we suggest that the effects of human intrinsic motivation in particular and the irrationality in general may be of exceptional importance in complex sociopsychological systems and deserve much attention in the formal models of such systems.

[khmyrova-01:2013] S.Tomioka N. Watanabe J. Kholopova A. Kovalchuk E. Polushkin V. Zemlyakov I. Khmyrova, T. Hasegawa. Patterning of top metal electrode for light extraction improvement in light-emitting diodes. In *2013 International Semiconductor Conference,*, pages 255–258, 2013.

Light-emitting diodes (LEDs) with patterned metal electrode to the top p-semiconductor layer resulting in enhanced light extraction are studied. Analytical model which includes an efficient procedure for numerical calculation of light extraction under nonuniform current injection caused by contact patterning is developed and used for modeling.

[khmyrova-02:2013] T.Hasegawa Ju. Kholopova E. Polushkin A.Kovalchuk V. Zemlyakov I. Khmyrova, S. Tomioka and S. Shapoval. AlGaN/InGaN/GaN Light-Emitting Diode with Patterned Contact: Model for Light Extraction. In *40-th Int. Symp. on Compound Semiconductors - ISCS2013*, pages MoPC–03–12, 2013.

A model for the light-emitting diodes (LED) with the top p-electrode patterned as a mesh is developed

[khmyrova-03:2013] T. Hasegawa A. Konishi N. Watanabe Ju. Kholopova E. Polushkin A. Kovalchuk V. Zemlyakov I. Khmyrova, S. Tomioka and S. Shapoval. Novel algorithm for simulation of light extraction from

light-emitting materials with planar surface. In *Book of abstracts of The 12th Asia Pacific Physics Conference - APPC12*, page 209, 2013.

In this paper we propose an efficient algorithm for numerical simulation of the power of light extracted from the light-emitting material with the planar surface.

[khmyrova-04:2013] N.Nakasato J. Kholopova D. Kozlov I.Khmyrova, Yu. Murakami, , and S.Shapoval. Light-Emitting Diodes with Patterned Contact : Modeling of Light Extraction. In *9th Int. Conf. on Optics-Photonics Design and Fabrication -ODF'14*, pages 27–28, 2013.

Analytical and numerical models for straightforward computation of output optical power for the LEDs with patterned electrode are developed. The proposed approach is efficient for computing of extraction of light with spatially nonuniform intensity.

[khmyrova-05:2013] T. Hasegawa A. Konishi Ju. Kholopova E.Polushkin A. Kovalchuk V. Zemlyakov I. Khmyrova, S. Tomioka and S. Shapoval. Study of the effect of contact patterning on the light extraction in LEDs. In *Conf. on LED and its Industrial Applications - LEDIA'13*, pages 24p–LEDp3–1, 2013.

In this paper we present a more realistic model of the LED with the p-contact patterned as a mesh of crossed wires having finite radius. A procedure for calculation of the power of the extracted light generated under spatially nonuniform current injection is developed.

Grants

[i-lubash-10:2013] Ihor Lubashevsky and Yodai Watanabe. Extended Phase Space and Emergent Phenomena in Social Systems, 2012-2014.

JSPS "Grants-in-Aid for Scientific Research" Program, Grant 24540410-0001. The research is aimed at elucidating the mathematical formalism required for modelling social systems.

Academic Activities

[khmyrova-06:2013] I. Khmyrova, 2013.

Senior member

[khmyrova-07:2013] I. Khmyrova, 2013.

Member

[khmyrova-08:2013] I. Khmyrova, 2013.

Member

Patents

[khmyrova-09:2013] I. Khmyrova and E. Shestakova. Cantilever Array Resonant Sensor with Electrical Readout, 2013.

Ph.D and Others Theses

[i-lubash-11:2013] Ishida Shinya. Undergraduate thesis, Computer Science and Engineering / Division of Computer Science, 2014.

The main goal of the present work was the creation of a certain computer simulator that enables one to study the dynamics of human perception near its threshold. The task of categorizing a visible curve as a "circle" or "asymmetric ellipse" was used to analyze the fuzzy properties of human perception. The created computer program visualizes an ellipse whose asymmetry continuously changes in time. A subject is instructed to press the corresponding button when the transitions "circle" $\Leftrightarrow$ "ellipse" is the case from subject's point of view. When the curve is rather symmetric and has to be categorized as "circle," the direction of ellipse transformation is changed randomly to prevent the possibility of the subject guessing the curve form based on the previous observations. The program implementation is constructed in such a way that enables the high stability of the system dynamics and its practical independence of the subject actions during experiments. The program enables to change the main parameters of the system, for example, the rate of the ellipse transformation during runtime. The main output of the experiments based on this program is the asymmetry of the transitions "circle" $\Rightarrow$ "ellipse," "ellipse" $\Rightarrow$ "circle" and their dependence on the ellipse transformation rate. Preliminary results demonstrate the existence of hysteresis effects which is essential for mathematical description of human perception near its threshold.

[i-lubash-12:2013] Hiromasa Ando. Undergraduate thesis, Computer Science and Engineering / Division of Computer Science, 2014.

A rather simple car driving simulator was created based on the available open source engine TORCS and used to analyze basic features of traffic flow in the 'free flow' phase. In this case the interaction between cars can be ignored and the main goal of a driver is to keep up a certain safe velocity. We have posed a hypothesis that humans are not able to single out a certain fixed speed of motion regarded as the optimal safe velocity and to keep up the car speed in its close proximity. Instead, any velocity inside a rather wide interval is treated as optimal and kept for a long time until some event prompts the driver to change it or its variations are caused by random factors. Several subjects participated in these virtual experiments. They were instructed to drive a virtual car on an empty road during 30–60 minutes in the style comfortable for them. Based on the collected data the velocity distribution as well as the acceleration distribution were constructed. It turned out that the velocity distribution as well as the velocity time patterns are significantly different for all the subjects. It poses a question as to how wide the variety of possible human strategies might be when there are no causes forcing them to behave similar. Besides, the found distribution of the car jerk contains a sharp peak at the origin. It enables us to hypothesize that the car jerk is an individual phase variable required for describing car dynamics.

[i-lubash-13:2013] Minoru Kobayashi. Undergraduate thesis, Computer Science and Engineering / Division of Computer Science, 2014.

A computer program visualizing a sequence of ellipses whose asymmetry changes randomly in this sequence has been created to analyze human perception near its threshold. In the conducted experiments, subjects were instructed to categorize a currently visible curve as "circle" or "asymmetric ellipse" by pressing the corresponding joystick button, which is fixed by the program. After pressing a button, a new curve whose asymmetry coefficient ϵ is chosen randomly and independently from a certain interval is generated. Based on the collected data the psychometric function for several subjects is constructed. This function specifies the probability $P(\epsilon)$ of the corresponding subject pressing, e.g., the "circle"-button depending on the asymmetry coefficient ϵ. The parameters of the ellipse's generation were chosen in such way that the majority of experimental points fall into the neighborhood of the perception threshold ϵ_{th} where the probability distribution $P(\epsilon)$ exhibits considerable variation from 0 to 1. The asymptonic behavior of the obtained psychometric function is studied and

possible mechanisms governing the human perception near its threshold are discussed.

[i-lubash-14:2013] Yoshiaki Saito. Undergraduate thesis, Computer Science and Engineering / Division of Computer Science, 2014.

A rather simple car driving simulator was created based on the available open source engine "TORCS" and used to analyze the basic features of car following. Namely, subjects were instructed to driver the virtual car in a way enabling them to follow a robot car moving ahead with a fixed velocity. Actually in these experiments the driver has to keep up, on the average, a certain head distance between the virtual car and the robot car. The main goal of these experiments is, first, to verify whether the basic feature of car following found in this artificial situation are similar to those describing the real traffic flow. If so, it will enable us to state that these regularities are due to the basic feature of human perception rather some mechanical characteristics of car motion. Second, it is the verification of the hypothesis that the bounded capacity of human cognition affects essential the car driving, at least, in the given setup. Several subjects participated in these virtual experiments. They were instructed to driver a virtual in the car following setup during 30–60 minutes in the style comfortable for them. Based on the collected data the distribution of the headway, velocity, acceleration, and jerk as well as the corresponding phase portraits were constructed and compared with available experimental data collected previously by the analysis of the real traffic flow. Some found anomalous properties are discussed.

[khmyrova-10:2013] Ryosuke Yamase. Study of fringing effects in multi-cantilever resonant MEMS, Graduate, Master course, 2013.

[khmyrova-11:2013] Norikazu Watanabe. S tudy of light-emitting diodes with patterned contact, Graduate, Master course, 2013.

Others

[i-lubash-15:2013] B. Datsko I. Lubashevsky. Fractional Dynamics and Multi-Slide Model of Human Memory. arXiv:1402.4058, Feb. 2014.

We propose a single chunk model of long-term memory that combines the basic features of the ACT-R theory and the multiple trace memory architecture. The pivot point of the developed theory is a mathematical description of the

creation of new memory traces caused by learning a certain fragment of information pattern and affected by the fragments of this pattern already retained by the current moment of time. Using the available psychological and physiological data these constructions are justified. The final equation governing the learning and forgetting processes is constructed in the form of the differential equation with the Caputo type fractional time derivative. Several characteristic situations of the learning (continuous and discontinuous) and forgetting processes are studied numerically. In particular, it is demonstrated that, first, the "learning" and "forgetting" exponents of the corresponding power laws of the memory fractional dynamics should be regarded as independent system parameters. Second, as far as the spacing effects are concerned, the longer the discontinuous learning process, the longer the time interval within which a subject remembers the information without its considerable lost. Besides, the latter relationship is a linear proportionality.

[i-lubash-16:2013] Ihor Lubashevsky Arkady Zgonnikov. Human Fuzzy Control: Action Dynamical Trap Model. arXiv:1212.2717 V2, April 2013.

We develop a mathematical description of human fuzzy rationality. Human operators controlling dynamical systems are often incapable of precisely identifying and implementing the desired control strategy. The operator of a dynamical system treats the current value of the control effort as acceptable if it deviates insignificantly from the desired, or optimal value. The operator starts correcting the actions only when she identifies that this deviation has become considerably large. We propose a non-Newtonian model capturing the operator fuzzy perception of her own actions based on the previously introduced dynamical trap concept. It deals with the physical phase space of a controlled system extended with an independent phase variable characterizing the operator motivated actions. The properties of the model are illustrated via the simple example of an oscillator with action dynamical trap.

[i-lubash-17:2013] S. Kanemoto T. Miyazawa T. Suzuki A. Zgonnikov, I. Lubashevsky. To react or not to react? Intrinsic stochasticity of human control in virtual stick balancing. arXiv:1402.3022, Feb. 2014.

Understanding how humans control unstable systems is central to many research problems, with applications ranging from quiet standing to aircraft landing. Much evidence appears in favor of event-driven control hypothesis: human operators are passive by default and only start actively controling the system when the discrepancy between the current and desired system states becomes in some sense large.

The present paper argues that the control triggering mechanism in humans is intrinsically stochastic. We propose a model which captures the stochastic threshold mechanism and show that it matches the experimental data on human balancing of virtual overdamped stick. Our results suggest that the stochasticity of the threshold mechanism is a fundamental property and may play an important role in the dynamics of human-controlled systems.

[i-lubash-18:2013] Ihor Lubashevsky Arkady Zgonnikov. Unstable Dynamics of Adaptation in Unknown Environment: a Dual-System Model. arXiv:1305.3657 V3, Sept. 2013.

We investigate the effects of intrinsic motivation on the dynamics of learning processes. We construct a simple model of a single agent adapting to unknown environment. Performing a repeated choice between a number of initially unexplored alternatives, the agent gains rewards for each selected alternative and in doing so gradually comprehends the environment. In our model the agent choice is governed by two stimuli. The traditional extrinsic motive inclines the agent to maximize the cumulative payoff throughout the process, while the second, intrinsic one, biases the agent towards the novel options that she inherently likes. We show that the intrinsic motivation can induce an instability and periodic dynamics of the learning process which is always stationary in the case of selfish, rational agent. Interestingly, the opposite effect can arise as well: when the impact of intrinsic motivation on the agent choice is strong, the equiprobable choice equilibrium strategy becomes stable. Based on the presented results we argue that the effects of human intrinsic motivation in particular and bounded rationality in general may appear to contribute greatly to the dynamics of complex socio-economic systems and therefore deserve much attention in the formal models of such systems.