Óbuda University

PhD thesisbook

New adaptive methods for Robust Fixed Point Transformations-based control of nonlinear systems

by

Teréz A. Várkonyi

Supervisor:

Dr. József K. Tar
Doctoral School of Applied Informatics, Óbuda University

Budapest, 2013

I Antecedents

Nowadays, system control is essential in everyday life. It has a long history, e.g. it was applied already by the Romans to handle irrigation systems. In our days, the machines, like mechanical and electronic systems (from the excavators to the CD players) are unimaginable without control.

In the present, as a part of control, one of the most prevalent topics is the control of systems with uncertainties. The growing expectations of avoiding human assistance in situations that need increased attention because of the system's vagueness or dangerousness makes the role of the automated controllers (that can handle vagueness) increased. Just to mention some examples, the automated control of power plants [Pruessmann et al. 1997], trains [Yasunobu et al. 2002], or the now-tested "artificial drivers" for cars [Mahan 2013] are like this.

The uncertainties of systems can be divided into three main groups: 1. when the system contains unknown parameters 2. when the system has unknown dynamics 3. when the the system's state cannot be measured [Zhu 2001]. There are many possible ways how to control such systems, e.g. using as much a priori knowledge as possible, using the linear parametrization method, and/or applying learning mechanisms to gain more information about the uncertainty. After that many controllers can be designed for the system, for example sliding mode controllers [Slotine and Li 1991; Utkin 1992; Korondi 2006], fuzzy logic controllers [Tanaka and Wang 2001; Wang 1994], anytime controllers [Várkonyi-Kóczy et al. 2000; Várkonyi-Kóczy 2008], neural network controllers [Ge et al. 1998; Lin and Lee 1991; Miller et al. 1990], fault tolerant controllers [Piuri 1993; Piuri 1994], and robust controllers [Qu 1998; Tanaka et al. 1999]. When the system is not linear in its parameters different adaptive controllers can be designed, like [Lin and Qian 2002].

When the controlled system is just partly known robust controllers bring the most benefit. They have been designed and investigated since the 1950s [Barbot and Perruquetti 2002]. Since the first applications the area has started a fast progress because the first methods have been sometimes found to lack robustness. The other problem was that in some cases when Sliding Mode Controller, one of first robust controllers [Utkin 1992], was used the actuators have had to cope with high frequency chatter-like control actions that damaged the system. The third reason of the progress was that scientists have realized that robust controllers were very effective when model approximations and disturbances had to be handled in the control process. So the field began to develop. Because of today's higher expectations the topic is still growing.

One of the recent robust control strategies is the method called Robust Fixed Point Transformations (RFPT). It was first designed to overcome the complexity of Lyapunov function-based techniques for smooth systems [Tar et al. 2007] but after its robustness was improved [Tar et al. 2008; Tar et al. 2009] it became a powerful technique to reduce the disadvantages of the model approximations and disturbances. The method applies the concept of the so-called expected – realized system response and can be used in the environment of traditional feedback and Model Reference Adaptive control systems [Tar et al. 2010b]. In the first applications it was applied only for single input – single output systems but later it was extended to multiple input – multiple output systems, too [Tar et al. 2010a]. Its aim is to make controllers robust in that case when an approximate model is used to estimate the behavior of the system in the control process. Its great advantage is that it can significantly reduce the errors caused by the model approximation and that the disturbances barely affect its performance.

II Aims

This thesis focuses on improving RFPT, because though it gives the opportunity to avoid the complexity of Lyapunov's method, and it can reduce the disadvantages of the model approximation, there are several questions left open and also disadvantages to get rid of because they make uncertain or even limit the usage. The first drawback among them is that RFPT uses the local attraction of a fixed point. The local attraction means that it gains only local stability according to Lyapunov's stability theorem. This raises the issue if it was possible to achieve its stability.

The other property of RFPT is that theoretically it can improve any existing controller's results if the control task and the controller meet several conditions. Although, up to this point this statement was proved only for classical controllers. So the question if it could ameliorate other types of controllers is open-ended.

The third aspect which is not to be sneezed at is the applicational possibility in real life. On the one hand, there are fields of application that significantly contribute to the improvement of control science. The question is if RFPT could be utilized in these areas. On the other hand, assume that there exists a system or phenomenon which is too complex or some lacking resources (time, knowledge, etc.) do not let it to be modeled accurately. In this case, only a rough approximation of the system can be captured by a model. The main question here is if there is any connection between the analysis of the approximate model and that of the actual system. Is it possible to construct a controller which according to the approximate model's results can properly control the real system? Will the system reach the desired state accurately enough? And finally, since Robust Fixed Point Transformations is specialized in approximate models it is possible that it can improve the accuracy of the above mentioned controller so that the model generates truthful output?

The thesis deals with the above questions and gives positive answers to some of them.

III Scientific methods of the investigations

The basic method of the examinations carried out is the analysis of the results found in the literature, then the development and completion of the results using analytical methods, modeling, simulations, and verification of the results via comparison with real data. I examined the ordinary differential equations and their solutions with MATLAB and SCILAB. Then, I studied the nonlinear systems and their applications to describe real phenomenons, like the inverted pendulum systems, or chaotic phenomenons, like the different chaotic oscillators (FitzHugh-Nagumo, Matsumoto-Chua, Duffing, Van der Pol, etc.). After that, I investigated the classical and soft-computing-based controllers, their applications, and their stability analysis with Lyapunov's second method [Slotine and Li 1991]. Finally, I examined the basics of Robust Fixed Point Transformations.

The second part of the thesis introduces the basic terms of Lyapunov's stability theorem, some of the classical controllers, and some of the soft computing-based controllers.

The third part of the thesis examines several nonlinear systems widely used to try the effectiveness of controllers.

The fourth part of the thesis summarizes the mathematical background of Robust Fixed Point Transformations.

In the fifth part I propose a new application area for RFPT: the field of chaos synchronization. I examine several chaotic oscillators, I build approximate models for them, then I construct RFPT-based controllers to supervise them. In one case I introduce a model independent noise filter for thy systems, and finally, I analyze these systems by simulations in SCILAB environment.

In the sixth part I introduce a new structure for RFPT that can achieve more precise trajectory tracking of the controlled system. The results are analyzed via simulations in MATLAB-Simulink environment.

The seventh and eighth parts present two methods that make the RFPT-based controllers stable. To verify the results first, I design approximate models for the cart-pendulum system and the Φ^6-type Van der Pol oscillator, then I construct improved (RFPT-based) controllers in the SCILAB-Scicos environment. Finally, I analyze the simulation results.

In the ninth and tenth parts of the thesis I propose two soft-computing-based controllers, I extend them with RFPT, and finally, I implement them in MATLAB-Simulink environment.

The last two parts of the thesis contain a further aspect, the applicability of RFPT in complex real-life systems. First, I analyze a hydrodynamic model of freeway traffic (which has only partial information about its environment) from the viewpoint of stability: I determine its stationary solutions with polynomial fitting, and I analyze the stability of the solutions with perturbation calculus. Then I propose a simple control strategy with RFPT based on an introduced attribute to control the emission rate of exhaust fumes of the freeway traffic. Finally, I make simulations in Scilab-Scicos environment to examine the behavior of the model in case of different initial conditions. In the last part, I introduce a simple vehicle model (simpler than the effective models found in the literature) for an anti-lock braking system and propose a control strategy. I implement the problem is SCILAB-Scicos environment to verify the gained results.

IV The new scientific results of the thesis

I. Thesis Robust Fixed Point Transformations in chaos synchronization.

I proposed a new application area for Robust Fixed Point Transformations: the chaos synchronization. Based on the literature I studied the most important chaotic attractors (FitzHugh-Nagumo, Matsumoto-Chua, Duffing, and Van der Pol oscillators) and I designed approximate models and controllers for them. I showed that if the parameters of a chaotic system are not known exactly or external disturbances affect the system, then RFPT is an effective method to get more accurate trajectory tracking [J2, C1, C4, C5, C6, C7, C8, C19].

II. Thesis Mathematical development for Robust Fixed Point Transformation.

I analyzed the mathematical background of Robust Fixed Point Transformations. I proposed a new structure for RFPT in which two controllers are integrated into the system. I showed that the new structure gains an additional tracking error reduction compared to the original RFPT methods [J2].

III. Thesis group Stability of the Robust Fixed Point Transformations-based controllers.

3.1 I considered the stability of the Robust Fixed Point Transformations-based controllers and I introduced an innovative fuzzy-like parameter tuning method for RFPT. I showed that more stable results of RFPT can be gained if the fuzzy-like parameter tuning is applied in the control process [C12, C13, L1, C18].

3.2 I reconsidered the stability of the Robust Fixed Point Transformations-based controllers and I proposed a new VS-type stabilization algorithm for RFPT. I showed that when the RFPT-based controller falls out from the local interval of convergence it becomes unstable and generates the so-called chattering effect. I showed that the proposed algorithm can reduce the order of fluctuation and can stop chattering within very short time. As a consequence the stability of the RFPT-based controllers can be gained [C19].

IV. Thesis group Joint applicability of Robust Fixed Point Transformations.

4.1 I suggested the combination of fuzzy logic controllers (FLC) and RFPT and I designed an RFPT-based fuzzy logic controller. I compared the performance of the FLC and that of the RFPT-based FLC and I verified via simulations that the robustness of the original FLC can be increased with the application of RFPT and by this the error produced by the original fuzzy logic controller can be reduced significantly [C20].

4.2 I suggested the combination of neural network controllers (NNC) and RFPT and I designed an RFPT-based neural network controller. I compared the performance of the NNC and that of the RFPT-based NNC and I verified via simulations that the robustness of the original NNC can be increased with the application of RFPT and by this the error generated by the original neural network controller can be reduced significantly [J4].

V. Thesis group The applicability of Robust Fixed Point Transformations in complex, partially known systems.

5.1 I investigated the applicability of Robust Fixed Point Transformations in complex, partially known systems. For this, I studied a hydrodynamic model of freeway traffic. I determined the stationary solutions of the model, and analyzed their stability. I introduced a new attribute which is strongly related to the emission rate of exhaust fumes of the freeway traffic (and based on the new attribute the control strategy can be more simple). I designed an RFPT-based controller to control the emission rate of exhaust fumes for the quasi-stationary solutions based on the new attribute connected to the emission rate. I showed that the RFPT-based controller is able to limit the emission rate with proper control actions, while the original one (without RFPT) cannot [J1, C16, C17,U1].

5.2 I investigated a further new area where the Robust Fixed Point Transformations method is a promising candidate to improve the control performance. I suggested a simple vehicle model to be used in anti-lock braking systems. I showed that the introduced model is simpler (both from the point of view of complexity and that of the measurability of the considered effecting coefficients) than any effective model known from the literature. I designed a controller which uses only the suggested rough approximate model and showed that good braking strategy and good results can be gained with it [C2].

V Application

Recently, model-based approaches have proved to be very advantageous in control tasks. Although, many problems arise from the high complexity of the tasks and also from the inaccuracy and uncertainty of our knowledge about the systems to be controlled. In such situations, classical control methods may fail to work.

Robust controllers are one of the best solutions to handle uncertain systems, among which the Robust Fixed Point Transformations-based controllers are outstanding tools. They can advantageously be used to restructure and improve existing controllers that use approximate models for the control process. In this thesis, different application areas, e.g. chaos synchronization and traffic control, are suggested (and examples are shown) where RFPT can be a good candidate. Similar considerations can be made in other fields of engineering, like industry, manufacturing, and machines (etc.), where controllers are widely used and the uncertainties of the system approximations have to be handled.

VI References

[1] J. P. Barbot and W. Perruquetti. *Sliding Mode Control in Engineering.* New York: Marcel Dekker, 2002.

[2] S. Ge, T. Lee, and C. Harris. *Adaptive neural network control of robotic manipulators.* London: World Scientific Publishing Co Pte Ltd, 1998.

[3] P. Korondi. "Tensor Product Model Transformation-based Sliding Surface Design". In: *Acta Polytechnica Hungarica* 3.4 (2006), pp. 23–35.

[4] C. Lin and C. Lee. "Neural-network-based fuzzy logic control and decision system". In: *IEEE Transactions on Computers* 40.12 (1991), pp. 1320–1336.

[5] W. Lin and C. Qian. "Adaptive control of nonlinearly parameterized systems: a nonsmooth feedback framework". In: *IEEE Transactions on Automatic Control* 47.5 (2002), pp. 757–774.

[6] S. Mahan. *Self-Driving Car Test.* 2013. URL: `http://www.google.com/about/jobs/lifeatgoogle/self-driving-car-test-steve-mahan.html`.

[7] W. Miller III, R. Sutton, and P. Werbos. *Neural networks for control.* London: The MIT Press, 1990.

[8] V. Piuri. “Design of Fault-Tolerant Distributed Control Systems”. In: *IEEE Transactions on Instrumentation and Measurement* 43.2 (1994), pp. 257–264.

[9] V. Piuri. “Dynamic Reallocation of Processes and System Dimensioning in Fault-Tolerant Control Systems”. In: *Proc. of the IEEE Instrumentation and Measurement Technology Conference (IMTC)*. Irvine, CA, USA, 1993, pp. 752–757.

[10] D. Pruessmann, B. Krause, and C. von Altrock. “Fuzzy Logic Supervisory Control for Coal Power Plant”. In: *Proc. of the 6th IEEE International Conference on Fuzzy Systems*. Vol. 2. Barcelona, Spain, 1997, pp. 1320–1336.

[11] Z. Qu. *Robust Control of Nonlinear Uncertain Systems*. New-York: Wiley Inc., 1998.

[12] J. J. Slotine and W. Li. *Applied Nonlinear Control*. Upper Saddle River: Prentice-Hall, 1991.

[13] K. Tanaka and H. O. Wang. *Fuzzy Control Systems Design and Analysis*. New York: John Wiley & Sons, Inc., 2001.

[14] K. Tanaka, T. Taniguchi, and H. O. Wang. “Robust and Optimal Fuzzy Control: A Linear Matrix Inequality Approach”. In: *Proc. of the IFAC World Congress*. Beijing, China, 1999, pp. 213–218.

[15] J. K. Tar, I. J. Rudas, J. F. Bitó, K. R. Kozłowski, and C. Pozna. “A Novel Approach to the Model Reference Adaptive Control of MIMO Systems”. In: *Proc. of the 19th International Workshop on Robotics in Alpe-Adria-Danube Region (RAAD)*. Budapest, Hungary, 2010, pp. 31–36.

[16] J. K. Tar, I. J. Rudas, and K. R. Kozłowski. “Fixed Point Transformations-Based Approach in Adaptive Control of Smooth Systems”. In: *Robot Motion and Control*. Ed. by Krzysztof R. Kozłowski. Vol. 360. Lecture Notes in Control and Information Sciences. London: Springer-Verlag, 2007, pp. 157–166.

[17] J. K. Tar, J. F. Bitó, I. J. Rudas, K. R. Kozłowski, and J. A. Tenreiro Machado. “Possible Adaptive Control by Tangent Hyperbolic Fixed Point Transformations Used for Controlling the Φ^6-Type Van der Pol Oscillator”. In: *Proc. of the 6th IEEE International Conference on Computational Cybernetics (ICCC)*. Stará Lesná, Slovakia, 2008, pp. 15–20.

[18] J. K. Tar, J. F. Bitó, and I. J. Rudas. “Replacement of Lyapunov’s Direct Method in Model Reference Adaptive Control with Robust Fixed Point Transformations”. In: *Proc. of the 14th IEEE International Conference on Intelligent Engineering Systems (INES)*. Las Palmas of Gran Canaria, Spain, 2010, pp. 231–235.

[19] J. K. Tar, J. F. Bitó, L. Nádai, and J. A. Tenreiro Machado. "Robust Fixed Point Transformations in Adaptive Control Using Local Basin of Attraction". In: *Acta Polytechnica Hungarica* 6.1 (2009), pp. 21–37.

[20] V. I. Utkin. *Sliding Modes in Control and Optimization*. New York: Springer-Verlag, 1992.

[21] A. R. Várkonyi-Kóczy. "State Dependant Anytime Control Methodology for Non-Linear Systems". In: *International Journal of Advanced Computational Intelligence and Intelligent Informatics (JACIII)* 12.2 (2008), pp. 198–205.

[22] A. R. Várkonyi-Kóczy, T. Kovácsházy, O. Takács, and Cs. Benedecsik. "Anytime Algorithms in Intelligent Measurement and Control". In: *CD-ROM Proc. of the World Automation Congress (WAC)*. Maui, USA, 2000, ISIAC–156.

[23] L. X. Wang. *Adaptive Fuzzy Systems and Control: Design and Stability Analysis*. Upper Saddle River: Prentice-Hall, 1994.

[24] S. Yasunobu, S. Miyamoto, and H. Ihara. "A Fuzzy Control for Train Automatic Stop Control". In: *Transactions of the Society of Instrument and Control Engineers* E-2.1 (2002), pp. 1–9.

[25] Y. Zhu. "Adaptive Output Feedback Control of Nonlinear Systems". PhD thesis. Oklahoma State University, 2001.

VII Publications of the author strongly related to the scientific results

VII.1 Journal papers (international refereed periodicals)

J1. J. K. Tar, L. Nádai, I. J. Rudas, T. A. Várkonyi, "Adaptive Emission Control of Freeway Traffic Using Quasi-Stationary Solutions of an Approximate Hydrodynamic Model," *Journal of Applied Nonlinear Dynamics (JAND)*, 1(1), pp. 29–50, 2012, ISSN: 2164-6457.

J2. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Robust Fixed Point Transformations-based Control of Chaotic Systems," *Computing and Informatics (CAI)*, 32(6), 2013, ISSN: 1335-9150, Indexed by SCOPUS and SCI, IF=0.239, in print.

J3. T. A. Várkonyi, J. K. Tar, Imre J. Rudas, "Improved Stabilization for Robust Fixed Point Transformations-based Controllers," *Journal of Advanced Compu-*

tational Intelligence and Intelligent Informatics (JACIII), 17(3), pp. 418–424, 2013, ISSN: 1343-0130, Indexed by Scopus and EI.

J4. T. A. Várkonyi, J. K. Tar, Imre J. Rudas, "Improved Neural Network Control of Inverted Pendulums," *International Journal of Advanced Intelligence Paradigms (IJAIP)*, 2013, ISSN: 1755-0386, Indexed by SCOPUS and INSPEC, accepted.

VII.2 Journal papers (local refereed periodicals)

U1. J. K. Tar, I. J. Rudas, L. Nádai, T. A. Várkonyi, "A közúti közlekedés kvázistacionárius adaptív, iteratív szabályozása két ellentmondó kritérium szerint," (Quasi-stationary, Adaptive, and Iterative Control of Freeway Traffic by Two Inconsistent Criteria) *Közlekedéstudományi szemle*, 52(3), pp. 42–48, 2012, ISSN: 0023-4362 (In Hungarian).

VII.3 Conference papers (international refereed conferences)

C1. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Robust Fixed Point Transformations in Chaos Synchronization," In: *Proc. of the 11th IEEE International Symposium on Computational Intelligence and Informatics (CINTI)*, Budapest, Hungary, pp. 219–224, 2010, ISBN: 978-1-4244-9278-7.

C1 – C1 S. John, J. O. Pedro, L. T. Kóczy, "Adaptive Improvement of a Passive Antilock Brake Control," In: *Proc. of IEEE AFRICON*, Livingstone, Zambia, pp. 1–6, 2011.

C2. T. A. Várkonyi, J. F. Bitó, I. J. Rudas, J. K. Tar, "Preliminary Investigations on a Higher Order Modelfree Approach in Antilock Braking," In: *Proc. of the 9th IEEE International Symposium on Applied Machine Intelligence and Informatics (SAMI)*, Smolenice, Slovakia, pp. 259–263, 2011, ISBN: 978-1-4244-7428-8.

C2 – C1 S. John, J. O. Pedro, L. T. Kóczy, "Adaptive Improvement of a Passive Antilock Brake Control," In: *Proc. of IEEE AFRICON*, Livingstone, Zambia, pp. 1–6, 2011.

C3. J. K. Tar, I. J. Rudas, T. A. Várkonyi, K. R. Kozlowski, "Efficient and Simple Noise Filtering for Stabilization Tuning of a Novel Version of Model Reference

Adaptive Controller," In: *Proc. of the 5th International Workshop on Robot Motion and Control (RoMoCo)*, Bukowy Dworek, Poland, pp. 205–214, 2011.

C4. T. A. Várkonyi, J. K. Tar, J. F. Bitó, I. J. Rudas, "Simple Noise Reduction in the Adaptive Synchronization of Coupled Neurons by Robust Fixed Point Transformation," In: *Proc. of the 15th IEEE International Conference on Intelligent Engineering Systems (INES)*, Poprad, Slovakia, pp. 297–302, 2011, ISBN: 978-1-4244-8955-8.

C4 – B1 F. Adamčk, R. Andoga, L. Madarász, P. Krajňák, "Elimination of Dynamic Errors of Thermocouples in Aircraft Engines Using Neural Networks," In: *L. Madarász, Jozef Živčák (Eds.), Aspects of Computational Intelligence: Theory and Applications Topics in Intelligent Engineering and Informatics*, Springer Berlin Heidelberg, 2, pp. 185–194, 2013.

C4 – B2 R. Andoga, L. Madarász, T. Karol, L. Főző, V. Gašpar, "Intelligent Supervisory System for Small Turbojet Engines," In: *L. Madarász, Jozef Živčák (Eds.), Aspects of Computational Intelligence: Theory and Applications Topics in Intelligent Engineering and Informatics*, Springer Berlin Heidelberg, 2, pp. 85–104, 2013.

C4 – B3 T. Lazar, L. Madarász, V. Gašpar, "The Effectiveness of Experimental Identification of Cognitive Systems," In: *Proc. of the 11th IEEE International Symposium on Applied Machine Intelligence and Informatics (SAMI)*, Herl'any, Slovakia, pp. 211–214, 2013.

C5. J. K. Tar, I. J. Rudas, J. F. Bitó, T. A. Várkonyi, "Chaos Synchronization by Model Reference Adaptive Control Using Fixed Point Transformations," In: *Proc. of the 13th IASTED International Conference on Intelligent Systems and Control (ISC)*, Cambridge, United Kingdom, pp. 23–28, 2011, ISBN-13: 978-0-88986-889-2, ISBN-10: 0-88986-889-1.

C6. I. J. Rudas, J. K. Tar, T. A. Várkonyi, "Novel Adaptive Synchronization of Different Chaotic Chua Circuits," In: *Proc. of the Special International Conference on Complex Systems: Synergy of Control, Computing & Communications (COSY)*, Ohrid, Macedonia, pp. 109–114, 2011, ISBN: 978-9989-2175-8-6.

C7. T. A. Várkonyi, J. K. Tar, I. J. Rudas, S. Preitl, R.-E. Precup, "A Novel Approach to Robust Fixed Point Transformations," In: *Proc. of the 5th International Symposium on Computational Intelligence and Intelligent Informatics (ISCIII)*, Floriana, Malta, pp. 13–18, 2011, ISBN: 978-1-4577-1859-5.

C8. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Chaos Synchronization in Duffing Systems with Robust Fixed Point Transformations," In: *Proc. of the 7th International Symposium on Intelligent Signal Processing (WISP)*, Floriana, Malta, pp. 104–109, 2011, ISBN: 978-1-4577-1401-6.

C9. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Robust Fixed Point Transformations in Model Reference Adaptive Control for a 4 DOF Classical Mechanical System," In: *Proc. of inter-Academia*, 2011, Sucevita, Romania.

C10. J. K. Tar, J. F. Bitó, I. J. Rudas, T. A. Várkonyi, "Decentralized Adaptive Control with Fractional Order Elimination of Obsolete Information," In: *Proc. of the 4th International Conference on Emerging Trends in Engineering and Technology (ICETET)*, Port Louis, Mauritius, pp. 43–48, 2011, ISBN: 978-1-4577-1847-2.

C11. T. A. Várkonyi, J. K. Tar, J. F. Bitó, I. J. Rudas, "Situation-dependent Adaptive Control Polynomially Eliminating the Past Information of Fading Relevance," In: *Proc. of the 3rd IEEE International Symposium on Logistics and Industrial Informatics (LINDI)*, Budapest, Hungary, pp. 199–204, 2011, ISBN: 978-1-4577-1840-3.

C12. J. K. Tar, L. Nádai, I. J. Rudas, T. A. Várkonyi, "RFPT-based Adaptive Control Stabilized by Fuzzy Parameter Tuning," In:*Proc. of the 9th European Workshop on Advanced Control and Diagnosis (ACD)*, Budapest, Hungary, 2011.

C12 – T1 A. A. Dineva, "Nemlineáris dinamikai Rendszerek Adaptív Szabályozása Robusztus Fixpont Transzformációs Módszerrel," (Adaptive Control of Nonlinear Dynamical Systems with Robust Fixed Point Transformations Method) MSc Thesis, Óbuda University, 2013 (In Hungarian).

C13. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Fuzzy Parameter Tuning in the Stabilization of an RFPT-based Adaptive Control for an Underactuated System," In:

Proc. of the 12th International Symposium of Hungarian Researchers on Computational Intelligence and Informatics (CINTI), Budapest, Hungary, pp. 63–68, 2011, ISBN: 978-1-4577-0044-6.

C14. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Robust Fixed Point Transformations-based Model Reference Adaptive Control of Inverted Pendulums," In: *Proc. of the 12th International Symposium of Hungarian Researchers on Computational Intelligence and Informatics (CINTI)*, Budapest, Hungary, pp. 591–596, 2011, ISBN: 978-1-4577-0044-6.

C15. T. A. Várkonyi, J. K. Tar, J. F. Bitó, I. J. Rudas, "RFPT-based Decentralized Adaptive Control of Partially, Roughly Modeled, Coupled Dynamic Systems," In: *Proc. of the 9th IEEE International Symposium on Intelligent Systems and Informatics (SISY)*, Subotica, Slovakia, pp. 35–40, 2011, ISBN: 978-1-4577-1973-8.

C16. T. A. Várkonyi, J. K. Tar, I. J. Rudas, "Adaptive Emission Control of Freeway Traffic via Compensation of Modeling Inconsistences," In: *Proc. of the 10th IEEE International Symposium on Applied Machine Intelligence and Informatics (SAMI)*, Herlany, Slovakia, pp. 79–84, 2012, ISBN: 978-1-4577-0195-5.

C17. J. K. Tar, L. Horváth, I. J. Rudas, T. A. Várkonyi, "Adaptive Control of Approximately Modeled Freeway Traffic by Robust Fixed Point Transformations," In: *Proc. of the 12th WSEAS International Conference on Applied Computer Science (ACS)*, Singapore City, Singapore, pp. 81–86, 2012, ISBN: 978-1-61804-092-3.

C18. J. K. Tar, I. J. Rudas, Teréz A. Várkonyi, "Simple Practical Methodology of Designing Novel MRAC Controllers for Nonlinear Plants," In: *Proc. of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, Budapest, Hungary, pp. 928–933, 2012, ISBN: 978-1-4673-2575-2.

C19. T. A. Várkonyi, J. K. Tar, I. J. Rudas, I. Krómer, "VS-type Stabilization of MRAC Controllers Using Robust Fixed Point Transformations," In: *Proc. of the 7th IEEE International Symposium on Applied Computational Intelligence and*

Informatics (SACI), Timisoara, Romania, pp. 389–394, 2012, ISBN: 978-1-4673-1012-3.

C19 – T1 A. A. Dineva, "Nemlineáris dinamikai Rendszerek Adaptív Szabályozása Robusztus Fixpont Transzformációs Módszerrel," (Adaptive Control of Nonlinear Dynamical Systems with Robust Fixed Point Transformations Method) MSc Thesis, Óbuda University, 2013 (In Hungarian).

C20. T. A. Várkonyi, "Fuzzyfied Robust Fixed Point Transformations," In: *Proc. of the 16th IEEE International Conference on Intelligent Engineering Systems (INES)*, Budapest, Hungary, pp. 457–462, 2012, ISBN: 978-1-4673-2694-0.

VII.4 Conference papers (local refereed conferences)

L1. J. K. Tar, L. Nádai, I. J. Rudas, T. A. Várkonyi, "Robusztus Fixpont Transzformációkra alapozott adaptív szabályozók konvergenciájának stabilizálása súlyozott átlagokkal," (Stabilization of the Convergence of Robust Fixed Point Transformations-based Adaptive Controllers with Weighted Averages) In: *Proc. of Innováció és fenntartható felszíni közlekedés (IFFK-Konferencia)*, Budapest, Hungary, pp. 255–267, 2011, ISBN: 978-963-88875-2-8 (In Hungarian).

VIII Further publications of the author loosely related to the scientific results

VIII.1 Book chapters (international refereed books)

B1. T. A. Várkonyi, "Advantages of Fuzzy and Anytime Signal- and Image Processing Techniques - A Case Study," In: J. Fodor, R. Klempous, C. P. S. Araujo (Eds.) *Recent Advances in Intelligent Engineering Systems*, Berlin: Springer Berlin Heidelberg, pp. 283–301, 2012, ISBN: 978-3-642-23228-2.

VIII.2 Conference papers (international refereed conferences)

F1. A. R. Várkonyi-Kóczy, T. A. Várkonyi, "Anytime modeling: Compression and improvement of the approximation of SC based mappings," In: *Proc. of the 4th International Symposium on Computational Intelligence and Intelligent Informatics (ISCIII)*, Luxor, Egypt, pp. 107–112, 2009, ISBN: 978-1-4244-5380-1.

F2. T. A. Várkonyi, "Soft computing-based signal processing approaches for supporting modeling and control of engineering systems – a case study," In: *Proc. of the 14th International Conference on Intelligent Engineering Systems (INES)*, Las Palmas, Spain, pp. 117–122, 2010, ISBN: 978-1-4244-7650-3.

F3. T. A. Várkonyi, "Situation dependant evaluation of regression-type signal processing problems," In: *Proc. of the 4th International Workshop on Soft Computing Applications (SOFA)*, Arad, Romania, pp. 225–228, 2010, ISBN: 978-1-4244-7985-6.

F4. A. R. Várkonyi-Kóczy, T. A. Várkonyi, "Anytime Model Regression," In: *Proc. of the 10th IEEE International Symposium on Applied Machine Intelligence and Informatics (SAMI)*, Herl'any, Slovakia, pp. 253–258, 2012, ISBN: 978-1-4577-0196-2.