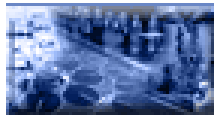
WP4a



WP4b

WP4c

WP4d

Benchmark (WP2 links)

Problems

Model

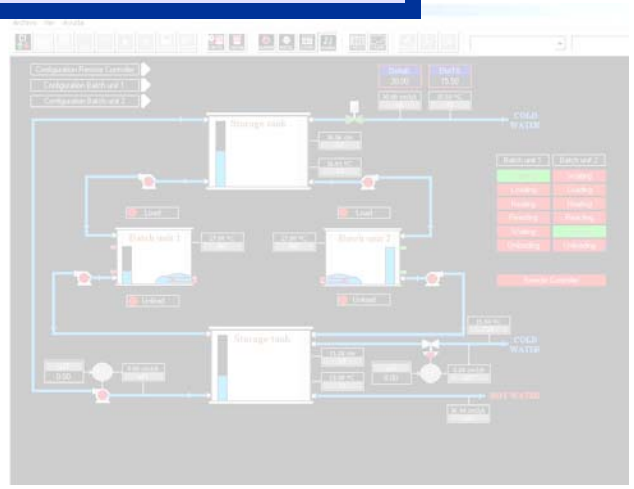
HYCON added value

Tools (WP3 links)

HYCON results

Methods

IAB involvement (WP6 links)



Content

WP4a	Voltage Control and Stabilization	Responsible: Bart De schutter <b.deschutter@dcsc.tudelft.nl>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
1	Stabilization of power generators	interaction with other HYCON research groups + relation to results of other teams (KTH (stability of switched systems) & University of Twente (modeling of interconnections))	standard third order nonlinear model including discrete interconnections	nonlinear robust adaptive control stabilization				LSS TUD ETH2	[a1.1]-[a1.2] [b]
2	Power transmission networks	interaction with other HYCON parters, in particluar ETH1, ETH2, and LSS HYCON provides platform for exchanging skills and knowledge related to hybrid systems from different backgrounds, in this case hybrid MPC, multi-agent control and power systems	Anderson-Farmer model power network model consisting of a 4 generator 9 bus network, taken from the book ”Series Compensation of Power Systems” by P. Anderson and D. Farmer; discrete dynamics are introduced due to discrete inputs, therewith obtaining a hybrid system	negotiation-based multi-agent MPC with one layer of control agents, each controlling a part of the network	Matlab + Tomlab's MINLP toolbox		interest from Siemens	LSS TUD ETH2	[a2.1]-[a2.2] [b] [c]
3	Emergency voltage control	interaction with other HYCON parters, in particular involvement of research groups coming from both control (TUD, ETH2) and power systems (ETH1) institutes is particularly beneficial	taken from the IEEE power systems library at http://psdyn.ece.wisc.edu/IEEEbenchmarks/ and containing 9 and 39 bus sample power grids and synchronous machines equipped with local controllers, model has been completely implemented in Matlab code Switched systems	MPC scheme based on a linearized model of the network at each sampling instant Lagrangian optimization MPC sliding modes Sensitivity analysis	Matlab + Multi Parametric Toolbox (MPT) Matlab/Simulink		interest from ABB	LSS TUD ETH2 CNRS-CRAN	[a3.1]-[a3.3] [b] [c]

[a] Publications

[a1.1] D. Flieller, P. Riedinger and J.P. Louis. “Computation and stability of limit cycles in hybrid systems”. In: *Nonlinear Analysis*, vol 64, pp. 352-367, 2006.

[a1.2] C. Iung, P. Riedinger, “Optimal control in hybrid systems”. To appear in *ADHS 2006*.

[a1.3] A. Giusto, R. Ortega and A. Stankovic: Power--shaping for transient stabilization of power systems, XII Latin-American Congress on Automatic Control, Salvador, Bahia, Brazil, Oct. 3-6, 2006.

[a1.4] A. Giusto, R. Ortega et A. Stankovic: On transient stabilization of power systems: a power--shaping solution for structure--preserving models, 45th IEEE Conference on Decision and Control, San Diego, CA, USA, decembre 13 - 15, 2006.

[a2.1] R.R. Negenborn, B. De Schutter, and H. Hellendoorn, “Multi-agent model predictive control of transportation networks”. In *Proceedings of the 2006 IEEE International Conference on Networking, Sensing and Control (ICNSC 2006)*, Ft. Lauderdale, Florida, pp. 296-301, Apr. 2006.

[a2.2] R.R. Negenborn, B. De Schutter, and J. Hellendoorn, “Multi-agent model predictive control for transportation networks with continuous and discrete elements”. in Proceedings of the *11th IFAC Symposium on Control in Transportation Systems (IFAC-CTS2006)*, Delft, The Netherlands, , pp. 609-614, Aug. 2006.

[a2.3] R.R. Negenborn, A.G. Beccuti, T. Demiray, S. Leirens, G. Damm, B. De Schutter, and M. Morari, "Supervisory hybrid model predictive control for voltage stability of power networks"accepted for the 2007 American Control Conference, New York, July 2007.

[a2.4] R.R. Negenborn, B. De Schutter, and H. Hellendoorn, "Multi-agent model predictive control for transportation networks: Serial versus parallel schemes," in Proceedings of the 12th IFAC Symposium on Information Control Problems in Manufacturing (INCOM'2006), Saint-Etienne, France, pp. 339-344, May 2006.

[a2.5] R.R. Negenborn, B. De Schutter, and J. Hellendoorn, "Efficient implementation of serial multi-agent model predictive control by parallelization," Accepted for the 2007 IEEE International Conference on Networking, Sensing and Control (ICNSC'07), London, April 2007.

[a2.6] E. Garcia-Canseco, R. Griñó, R. Ortega, M. Salich and A. Stankovic: Power factor compensation of electrical circuits: The nonlinear non--sinusoidal case, IEEE Control Systems Magazine, Vol. 27, No. 4, April 2007.

[a2.7] B. Jayawardhana, R. Ortega, E. Garcìa-Canseco and F. Castaños: Passivity of nonlinear incremental systems: application to pi stabilization of nonlinear RLC circuits, Systems and Control Letter, to appear.

[a2.8] B. Jayawardhana, R. Ortega, E. Garcìa-Canseco and F. Castaños: Passivity of nonlinear incremental systems, 45th IEEE Conference on Decision and Control, San Diego, CA, USA, Dec. 13 - 15, 2006.

[a3.1] A.G. Beccuti and M. Morari. “A distributed solution approach to centralized emergency voltage control”. In *Proceedings of the ACC 2006*. 14-16 June 2006, Minneapolis (MN), USA.

[a3.2] A.G. Beccuti, T. Geyer and M. Morari. “A hybrid approach in power systems voltage control”. In *Proceedings of the 44th IEEE Conference on Decision and Control and European Control Conference 2005*. 15-17 Dec. 2005, Seville, Spain

[a3.3] M. Zima, P. Korba and G. Andersson. “Power systems voltage emergency control approach using trajectory sensitivities”. Presented at the *IEEE Conference on Control Applications*, 23-25 June, Istanbul, Turkey, 2003.

[b] Software

Multi-paramtric toolbox (MPT), see http://control.ee.ethz.ch/~mpt/

[c] Experimental results

For the 2nd & 3rd case study mainly simulation results are foreseen

WP4a	Congestion Control	Responsible: Bart De schutter <b.deschutter@dcsc.tudelft.nl>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
4	Coordinated Control of FACTS devices	Interaction with other HYCON partners (TUD)	Total susceptance model for FACTS, static model of power system	Optimal Power Flow, Sensitivity analysis, current injection method	Matlab, Tomlab		ABB	ETH1, TUD	[a4.1], [a4.2]

[a] Publications:

[a4.1] G. Glanzmann and G. Andersson, "Incorporation of N-1 Security into Optimal Power Flow for FACTS Control", To be presented at the Power Systems Conference and Exposition (PSCE), 29th Oct. - 1st Nov. 2006, Atlanta, USA, 2006

[a4.2] G. Glanzmann and G. Andersson, "FACTS Control for Large Power Systems Incorporating Security Aspects", presented at the X SEPOPE, Florianopolis, Brasil, 2006

[a4.3] G. Hug-Glanzmann, R. Negenborn, G. Andersson, B. De Schutter, H. Hellendorn, „Multi-area control of overlapping areas in power systems for FACTS control“, to be presented at PowerTech, Lausanne, Switzerland, 2007

WP4a	Power Flow Control in Multi-Generation Systems	Responsible: Bart De schutter <b.deschutter@dcsc.tudelft.nl>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
5	Two generators system: Reliability and quality of power supply when renewable-energy generators are connected to the grid.	Analysis and new proposals for power management in power plants with non-conventional energy sources. Development of control methods for fuel cells. Interactions with other HYCON partners (ETH2, LSS)	Detailed dynamic simulation model developed using first principles and heuristics. Part of the model validated with real data. Control-oriented models based on MLD and PWA frameworks.	Model Predictive Control	Matlab	Relation to the Solar Cooling Plant benchmark in WP2.		US, ETH2	[a5.1]-[b5] [c5]
6	Power flow control between a local prime mover (a flywheel) and the electrical power network.	Development of novel switching strategies that provide a measure of stability for a highly nonlinear system with unstable zero dynamics and unpredictable switching events. Interactions with other HYCON partners (UT, US)	Detailed dynamic simulation model, including all nonlinear dynamics and switching actions, developed in the program 20-Sim (http://www.20sim.com/)	Total energy shaping methods, nonlinear PIs to stabilize equilibria; ad-hoc switching strategy has been proposed. New hybrid systems analysis techniques needed for validation - improvement				LSS, UT	[a6.1]-[a6.3] [b6] [c6]

[a] Publications

[a5.1] Carlos Bordons, Alicia Arce and Alejandro J. del Real. Constrained Predictive Control Strategies for PEM fuel cells. Proceedings of the 2006 American Control Conference, Minneapolis, Minnesota, USA, June 14-16, 2006

[a5.2] Alicia Arce, Alejandro J. del Real and Carlos Bordons. Application of Constrained Predictive Control Strategies to a PEM Fuel Cell Benchmark. European Control Conference ECC 07, Kos, Greece, July 2007.

[a5.3] Mirko Fiacchini, Teodoro Alamo and Eduardo F. Camacho. Piecewise Affine Model of a Fuel Cell for Safety Verification. American control Conference ACC 2007.

[a5.4] Mirko Fiacchini, Teodoro Alamo, Carolina Albea and Eduardo F. Camacho. Adaptive Model Predictive Control of the Hybrid Dynamics of a Fuel Cell System. MSC 2007.

[a6.1] C. Battle, A. Doria and R. Ortega: Power flow control of a doubly-fed induction machine coupled to a flywheel, European J of Control, Vol 11, No. 3, pp 1-13, 2005.

[a6.2] M. Becherif, E. Mendes and R. Ortega: Experimental results on pbc of a doubly-fed induction generator interconnected with an induction motor, IFAC World Congress 2005, Prague, CZ, July 4--8, 2005.

[a6.3] C. Battle, A. Doria and R. Ortega: A Robust Adaptive PI Controller For The Doubly-Fed Induction Machine, IEEE Trans Industrial Electronics, (submitted).

[a6.4] C. Batlle, A. Dòria-Cerezo and R. Ortega: A robustly stable pi controller for the doubly-fed induction machine IECON, Paris, 2006.

[a6.5] C. Batlle, A. Dòria-Cerezo, G. Espinosa-Pérez andt R. Ortega: Simultaneous interconnection and damping assignment passivity--based control: Two practical examples, IFAC Lagrangian and Hamiltonian Methods in Nonlinear Control, Nagoya, Japon, juillet 19 - 22, 2006, pp. 93--98.

[b] Software

[b5] Simulink model of the whole system

[b6] 20 Sim model of the whole system

[c] Experimental results

[c5] Validation results for the fuel cell model done on a 1.2 kW fuel cell at the Laboratory of the US

[c6] Completed at University of Catalonia for the machine operating as a motor. Current work deals with the switching operation.

WP4a	Hybrid Control of Switch-mode dc-dc Converters	Responsible: Sébastien Mariethoz <mariethoz@control.ee.ethz.ch>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
7	Control of the synchronous step-down dc-dc Converter	Common problem definition, intense interaction for the development of control schemes that achieve constraint satisfaction	Discrete-time sampled-data, periodically time-varying linear, switching linear, piecewise affine (PWA) models	H_{\inf}, relaxed dynamic programming, on-line optimal control techniques, explicit MPC, sliding mode control	HYSDEL, MPT		STM, Bombardier	KTH, LTH, CNRS-CRAN, ETH2	[a7.1]-[a7.7] [c]
8	Control of the step-up dc-dc Converter	Common problem definition, comparison of fixed and variable switching frequency techniques	Discrete-time sampled-data, periodically time-varying linear, switching linear, piecewise affine (PWA) models, bond graph formalism	H_{\inf}, relaxed dynamic programming, stabilizing, sliding mode, passivity based control, explicit MPC	HYSDEL, MPT, Bond Graph Formalism		STM	KTH, LTH, Supelec, ETH2	[a8.1]-[a8.3] [c]
9	Control of the three-level three-cell dc-dc Converter	Common problem definition, direct comparison of results obtained by different approaches	Switching linear model, bond graph formalism	Online optimal control techniques, stabilizing, sliding mode, passivity based control, MPC, sensitivity analysis	Bond Graph Formalism			CNRS-CRAN, Supelec	[a9.1]-[a9.3]

[a] Publications

[a7.1] D. Flieller, P. Riedinger, J.P. Louis: Computation and stability of limit cycles in hybrid systems. *Nonlinear Analysis*, Volume 64, Issue 2, 15 January 2006.

[a7.2] T. Geyer, G. Papafotiou, M. Morari: Model Predictive Control in Power Electronics: A Hybrid Systems Approach, *IEEE Conference on Decision and Control*, Seville, Spain, Invited paper in the tutorial session "Hybrid Control of Networked Embedded Systems", December 2005

[a7.3] Andreas Wernrud: Computation of approximate value functions for constrained control problems, to appear in Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems, Kyoto, Japan, July 2006.

[a7.4] H. Fujioka, C-Y Kao, S. Almèr and U. Jönsson. "LQ optimal control for a class of pulse width modulated systems", Automatica, 43(6):1009--1020, 2007.

[a7.5] S. Almèr, H. Fujioka, U. Jönsson, C.-Y. Kao, D. Patino, P. Riedinger, T. Geyer, A. Beccuti, G. Papafotiou, M. Morari, A. Wernrud, and A. Rantzer, "Hybrid control techniques for synchronous DC-DC converters part I: The step-down topology", In Proceedings of the American Control Conference, New York, NY, USA, 2007.

[a7.6] H. Fujioka, S. Almer, U. T. Jönsson, and C-Y Kao "Control synthesis for a class of PWM systems for robust tracking and H-infinity performance" In Proceedings of the 45th IEEE Conference on Decision and Control, pages 4861--4866, San Diego, CA, USA, 2006.

[a7.7] L. Iannelli, K. H. Johansson, U. Jönsson, and F. Vasca. "Subtleties in the averaging of hybrid systems with applications to power electronics.", In 2nd IFAC Conference on Analysis and Design of Hybrid Systems", Alghero, Sardinia, Italy, 2006.

[a8.1] A.G. Beccuti, G. Papafotiou, M.Morari: Optimal control of the boost converter. *Proc. of the joint CDC-ECC 2005*, Seville, Spain, December 2005.

[a8.2] Buisson, J., P. -Y. Richard and H. Cormerais: On the Stabilisation of Switching Electrical Power Converters. In Hybrid Systems: Computation and Control (HSCC2005) (M. Morari and L. Thiele (Eds.))

[a8.3] S. Almèr, U. Jönsson, C.-Y. Kao, and J. Mari. "Stability analysis of a class of PWM systems". To appear in IEEE Transactions on Automatic Control}, 2007.

[a8.4] A. G. Beccuti, G. Papafotiou, M. Morari, S. Almèr, H. Fujioka, U. Jönsson, C.-Y. Kao, A. Wernrud, A. Rantzer, M. Baja, H. Cormerais, and J. Buisson. "Hybrid control techniques for synchronous DC-DC converters part II : The step-up topology." In Proceedings of the American Control Conference, New York, NY, USA, 2007.

[a8.5] H. Fujioka, C-Y Kao, S. Almèr and U. Jönsson. "Sampled-Data H-infinity Control Design for a Class of PWM Systems", In Proceedings of the IEEE Conference on Decision and Control 2005, pages 4499--4504, Seville, Spain, 2005.

[a8.6] H.Fujioka, C-Y Kao, S. Almèr and U. Jönsson: Sampled-Data H-infinity Control Design for a Class of PWM Systems. In *Proc. the IEEE Conference on Decision and Control 2005*, pages 4499—4504, Seville, Spain, 2005.

[a9.1] Rchard, C. Morvan and J. Buisson: A Generic Passivity Based Control for Multicellular Serial Converters. In 16th IFAC World Congress, Praha 2005

[a9.2] Richard, P.-Y., H. Cormerais, C. Morvan and J. Buisson: Boolean Sliding Mode Control of Multilevel Power Converters. In 16th IFAC World Congress, Praha 2005

[c] Experimental results

Experimental results have been obtained for the Model Predictive Control of the synchronous step-down and the step-up converter, validating the proposed approach.

WP4a	Power Generation and Transmission control (new!!) Proposals to be finalized (details can be found in D4a.7.1.)	Coordinator: Bart De schutter <b.deschutter@dcsc.tudelft.nl>

No.	Proposal Title	Description	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
To be det.	Modeling and nonlinear hybrid control of PEM fuel cell systems with application to hybrid vehicle propulsion systems.	Energy/power flow control in applications where a switching policy has to be defined to commute between different sources feeding a common load. This is a topic of great interest that has many applications including the hybrid vehicle and isolated power generation units.	Dynamic model proposed by K.W. Suh (PhD Thesis, 2006). Model of the hybrid vehicle based on the book by Guzzella and Sciarreta*	Nonlinear hybrid control. Predictive control	Matlab			LSS US	[c]
To be det.	Multi Source Energy Systems	Traditionally, different energy infrastructures such as electricity and natural gas systems are considered to be independent, however integrated energy systems including multiple or hybrid energy carriers (electricity, natural gas and district heating) have also been suggested. The conversion of power between different energy carriers establishes a coupling of the corresponding power flows resulting in system interactions. Thereby, the focus is put on synergies among various forms of energy providing system improvements in terms of overall energy cost, system emissions and reliability of supply through redundancy.	Dymola			-	-	ETH1	None yet

To be det	Voltage Control and Stabilization in Power Networks	Voltage stability problems typically arise after an outage has occurred in the grid, following which the network can no longer feed the loads at a physically sustainable voltage level and thereby potentially leading to system collapse. In order to avoid this appropriate action must be taken on the available controls to adequately steer the system dynamics, involving a composite array of nonlinear and hybrid components, back to a safe region of steady state operation. This benchmark is actually an extension of one of the previously proposed WP4a benchmarks (see deliverable D4a.3.1).	taken from the IEEE power systems library at http://psdyn.ece.wisc.edu/IEEEbenchmarks/ and containing 9 and 39 bus sample power grids and synchronous machines equipped with local controllers, model has been completely implemented in Matlab code Switched systems	MPC scheme based on a linearized model of the network at each sampling instant Lagrangian optimization MPC sliding modes Sensitivity analysis	Matlab + Multi Parametric Toolbox (MPT) Matlab/Simulink	-	-	TUD ETH1 ETH2	None yet

[a] Publications

[b] Software

Matlab

[c] Experimental results

An experimental setup on a 1.2 kW fuel cell is available at US. Also, a benchmark setup of a 600 W fuel cell is in development at LSS in collaboration with LGEP.
A small hybrid vehicle is available at US.

References:
*L. Guzzella and A. Sciarreta. Vehicle propulsion systems: introduction to modeling and optimization. Springer-verlag, 2005.

WP4a	Hybrid Control of Switched-mode Power Converters (new!!!) Proposals to be finalized (details can be found in D4a.7.1.)	Coordinator: Sébastien Mariethoz <mariethoz@control.ee.ethz.ch>

No.	Proposal Title	Description	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
To be det.	Analysis and Hybrid Control of DC-DC Power Converters	This benchmark will focus on the analysis and control of DC-DC converters. It will be complementary with the previous benchmarks and focus on more complex problems such as discontinuous conduction mode or as the more complex issues with the boost (step-up) converter.	Discrete-time sampled-data, periodically time-varying linear, switching linear, piecewise affine (PWA) models	Frequency analysis, MPC, H_{\inf}, relaxed dynamic programming, on-line optimal control techniques,	HYSDEL, MPT	-	STM	KTH LTH ETH2	None yet
To be det.	Analysis and Hybrid Control of Active Front End Voltage Source converters	This benchmark will focus on active front end voltage source converter connected to the grid though a resonant filter. One part of this benchmark will be dedicated to the synthesis of sophisticated controller providing stability of the resonant filter as well as a good tracking of the reference current. The other part of the benchmark will be dedicated to the stability, robustness and harmonics analysis of the system	Discrete-time sampled-data, periodically time-varying linear, switching linear, piecewise affine (PWA) models	MPC sliding mode control	HYSDEL, MPT	-		ETH2 KTH LTH Supelec	None yet
To be det.	Hybrid Control of the SEPIC Converter	This benchmark will focus on the control of a more complex DC-DC converter, a non-inverting buck-boost structure, the SEPIC converter. Different control methods will be investigated.	Switching linear model, bond graph formalism	Stabilisation approach, Neuronal Predictive Control, passivity based control	Bond Graph Formalism	-		Supelec CRAN UT	None yet
To be det.	Hybrid Control of The Flying Capacitor Multilevel Converters	This benchmark will investigate the tracking problem on the flying capacitor multilevel converters for DC-AC applications. The control of this structure with a limited number of sensors, which is of practical interest, will also be considered in this research.	Switching linear model, bond graph formalism	Stabilisation approach, Neuronal Predictive Control, passivity based control	Bond Graph Formalism	-		CRAN Supelec LSS	None yet

WP4b	Parallel batch production line with continuous output	Responsible: Iliyana Simeonova <simeonova@auto.ucl.ac.be>

No.	Subproblem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
10a	On-line scheduling guaranteeing safety and non-blocking	Decomposition-based approach	Multirate timed automata	Standard verification procedures for timed automata			Problem derived from industrial problem at Solvay (PVC-plant)	TUB	[a10.1]
10b	Stabilization of the tank level	Investigation of mixed dynamics, limit cycles	MATLAB simulation	Simulation, stability analysis of periodic systems	MATLAB		As above	UCL	[a10.2] – [a10.3]
10c	Start-up and optimal operation in the presence of disturbances	Methodology for control of mixed continuous –batch processes	First principles model	Hybrid MPC with parameterized inputs	EcosimPro, NAG	Solar plant	As above	UCL UVA	[a10.4] – [a10.6]
10d	Optimal control of the outflow of a storage tank	Generic solution to a practical problem	First principles model (trivial)	MPC, other continuous and discrete controllers; controller verification in UppAal	MATLAB, UppAal		As above	UNIDO	

Publications:

[a10.1] D. Gromov, S. Geist and J. Raisch: Timed Discrete Event Control of a Parallel Production Line with Continuous Output. *ADHS* 2006, Preprints, pp. 205-210.

[a10.2] I. Simeonova, F. Warichet, G. Bastin, D. Dochain, and Y. Pochet: Feedback Stabilization of an Optimally Scheduled Operation of a Hybrid Chemical Plant. *CTS-HYCON Workshop on Nonlinear and Hybrid Control*, Paper id: 17, 2006.

[a10.3] I. Simeonova, F. Warichet, G. Bastin, D. Dochain, Y. Pochet: Feedback stabilization of the operation of an hybrid chemical plant. *ADHS* 2006, Preprints, pp. 191-198.

[a10.4] I. Simeonova, F. Warichet, G. Bastin, D. Dochain, and Y. Pochet: Online Scheduling of Hybrid Chemical Plants with Parallel Production Lines and Shared Resources: a Feedback Control Implementation. *Proc. 17th IMACS World Congress on Scientific Computation, Applied Mathematics, and Simulation*, 2005, Paper-ID: T5-I-76-0718.

[a10.5] M. Rodriguez, D. Sarabia, C. de Prada Hybrid Predictive Control of a Simulated Chemical Plant. *CTS-HYCON Workshop on Nonlinear and Hybrid Control*, Paper id: 31, 2006.

[a10.6] M. Rodriguez, D. Sarabia, and C. de Prada: Hybrid Predictive Control of a Simulated Chemical Plant. *Taming Heterogeneity and Complexity of Embedded Control, International Scientific & Technical Encyclopedia (ISTE)*, pp. 617-634, 2007.

Software:

A simulation model in EcosimPro is available

Experimental results

The hybrid MPC controller was validated in extensive simulations.

WP4b	Multiproduct batch plant	Responsible: Stephanie Geist <geist@control.TU-Berlin.de>

No.	Subproblem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
11a	Optimal hierarchical control	General approach to the hierarchical control of complex systems	First principles model, abstraction	Abstraction, dynamic programming,			Case study derived from an industrial problem	TUB	[a11.1], [a11.2]
11b	Logic controller design for the execution of a sequence of batches	Systematic logic controller design and verification for a complex plant	Abstract model of the original hybrid nonlinear ODE model in the form of timed automata (UPPAAL semantics)	Design of logic controllers (SFC) by systematic refinement of the specifications; conversion of the controller into a TA model, composition with a TA model of the process, and algorithmic verification using model checking	New tool for editing and simulating SFC, and for transformation into TA; UPPAAL		As above	UNIDO TUM	[a11.3]

Publications

[a11.1] J. Raisch and T. Moor: Hierarchical Control Synthesis and its Application to a Multiproduct Batch Plant. In: *Nonlinear Control and Observer Design*, LNCIS, Springer-Verlag, 2005.

[a11.2] T. Moor and J. Raisch: Hierarchical Control of a Multiproduct Batch Plant. In *Proc. 16th IFAC World Congress* , Prague, 2005.

[a11.3] S. Lohmann, L. A. Dinh Thi, O. Stursberg. Design of Verified Logic Control Programs. *Proc. IEEE Int. Conf. on Control Applications (CCA)*, 2006, pp. 1855-1860.

[b] Software:

Tools for logic controller design and for transformation of SFC to TA under development.

[c] Experimental results:

Testing of the design procedure for a realistic case study.

WP4b	Start-up of an evaporator system	Responsible: Christian Sonntag <c.sonntag@bci.uni-dortmund.de>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
12	Optimal start-up of a multi-stage evaporation system	Complex and challenging optimal control task, hybrid model with continuous dynamics described by switched DAE-systems	Nonlinear DAE model with switched dynamics, state resets, continuous and discrete controls (implemented in EcosimPro [UVA] and MATLAB [UNIDO])	UVA: Two-level approach, conventional control and optimization of parameterized input trajectories UNIDO: Direct input trajectory optimization by branch-and-bound with embedded nonlinear optimization of the continuous controls UMD/TUB: Investigation of the applicability of different approaches	UVA: EcosimPro, SQP algorithm (NAG library) UNIDO: simulation and optimization implemented in MATLAB	Possible inclusion into the benchmark repository)	Hybrid model developed in cooperation with Bayer Technology Services (BTS)	UVA UNIDO TUM TUB	[a12.1] - [a12.4]

Publications:

[a12.1] C. de Prada, J. J. Rosano: Optimal start-up of an evaporator station. Presented at the *HYCON Workshop*, Lund, 1.-2.6.2006, and at the ESCAPE16/PSE2006 Post-Conference Workshop Hybrid Control in the Processing Industry, Garmisch-Partenkirchen, 13.7.2006.

[a12.2] C. Sonntag, O. Stursberg, S. Engell: Dynamic optimization of an industrial evaporator using graph search with embedded nonlinear programming. *ADHS* 2006, Preprints 211-216.

[a12.3] C. de Prada, S. Cristea, and J. J. Rosano: Optimal Start-up of an Evaporation Station. Accepted for *8th International Symposium on Dynamics and Control of Process Systems (DYCOPS)*, Cancun, Mexico, 2007.

[a12.4] V. Miranda and C. de Prada: Controlador Predictivo Explicito de un Evaporador. XXVII Jornadas de Automática de CEA-IFAC, Almería (Spain), 2006.

[b] Software:

EcosimPro and Matlab simulation models are available

[c] Experimental results:

UVA: Determination of an optimized start-up strategy for the system with 3 evaporation vessels using continuous dynamic optimization in combination with the design of inventory control systems

UNIDO: Determination of an optimized start-up strategy for 1 evaporation vessel using branch-and-bound with embedded NLP and with embedded genetic algorithms.

WP4b	Plate reactor	Responsible: Staffan Haugwitz <staffan@control.lth.se>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
13	Start-up of the reactor and control of temperature and conversion	Development of control logic and continuous control for a highly nonlinear system modeled by PDE	Original model: partial differential equations Design model: discretized nonlinear ODE model	Lund: Heuristic design of the start-up logic, switched MPC controllers, full discretization UNIDO: Computation of optimal inputs by dynamic optimization	MATLAB, gPROMS, Modelica, IPOPT		Alfa Laval	LTH UNIDO	[a13.1] – [a13.4]

Publications:

[a13.1] S. Haugwitz, P. Hagander: Analysis and Design of Startup Control of a Chemical Plate Reactor with Uncertainties; a Hybrid Approach. Accepted for: *IEEE Multi-Conference on Systems and Control*, Singapore, 2007.

[a13.2] S. Haugwitz, J. Akesson, and P. Hagander: Dynamic Optimization of a Plate Reactor Start-up supported by Modelica-based Code Generation Software. Accepted for: *8th International Symposium on Dynamics and Control of Process Systems (DYCOPS)*, Cancun, Mexico, 2007.

[a13.3] S. Haugwitz, P. Hagander: Challenges in start-up control of a heat exchange reactor with exothermic reactions; a hybrid approach. *ADHS* 2006, Preprints 185-190

[a13.4] S. Haugwitz, P. Hagander, and T. Noren: Modeling and Control of a Novel Heat Exchange Reactor, the Open Plate Reactor. Accepted for: *Control Engineering Practice*, 2007.

[b] Software:

Simulation models in gPROMS and Modelica are available

[c] Experimental results:

LTH: Determination of robust start-up strategies using heuristic switched MPC controllers and NLP optimization on a fully discretized model.

UNIDO: Determination of optimal start-up strategies in gPROMS/gOPT.

WP4b	Refrigeration system for supermarket display cases	Responsible : Lars Larsen <lars.larsen@danfoss.com>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
14	Design of a switching controller	Methodologies for control of continuous processes with on/off control variables	UVA: Physical model provided by Danfoss UNIDO: Nonlinear ODE model with switched dynamics and switched inputs	UVA: Continuous time scheduling by MPC with parameterized inputs UNIDO: Hybrid MPC with embedded dynamic optimization Danfoss/Aalborg: simple control structures to achieve desynchro-nization of display cases	UVA: EcosimPro, NAG UNIDO: MATLAB-based simulation and hybrid MPC algorithms		Danfoss	Danfoss UVA UNIDO	[a14.1] - [a14.4]

Publications

[a14.1] L. F. S. Larsen, C. Thybo, R. Izadi-Zamanabadi, and R. Wisniewski: Synchronization and Desynchronizing Control Schemes for Supermarket Refrigeration Systems. Accepted for: *IEEE Multi-Conference on Systems and Control*, Singapore, 2007.

[a14.2] C. Sonntag, A. Devanathan, S. Engell, and O. Stursberg: Hybrid Nonlinear Model-Predictive Control of a Supermarket Refrigeration System. Accepted for: *IEEE Multi-Conference on Systems and Control, Singapore*, 2007.

[a14.3] D. Sarabia, F. Capraro, L. F. S. Larsen, and C. de Prada: Hybrid Control of a Supermarket Refrigeration Systems. Accepted for: *American Control Conference*, New York, USA, 2007.

[a14.4] C. Sonntag, A. Devanathan, S. Engell, and O. Stursberg: Nichtlineare modellprädiktive Regelung eines Supermarkt-Kühlsystems mit hybrider Dynamik. Accepted for: *VDI/VDE GMA-Kongress*, Baden Baden, Germany, 2007.

[b] Software:

Simulation models in EcosimPro, WinDali and Matlab are available

[c] Experimental results

The case study has been solved satisfactorily by both MPC approaches with parameterized inputs

WP4b	Plant-wide control of the crystallization section in a sugar factory	Responsible: Daniel Sarabia <dsarabia@autom.uva.es>

No.	Sub-Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
15a	On-line scheduling of batch units	A methodology for control of mixed continuous-batch processes	Reduced order physical model	Continuous time scheduling using MPC with parameterized inputs	EcosimPro, HITO, NAG	Solar Plant	AEA, Empresarios Agrupados	UVA	[a15.1]
15b	Continuous-discrete batch control	As above	Reduced order physical model	As above	EcosimPro, HITO, NAG	Solar plant	AEA, Empresarios Agrupados	UVA	[a15.2]
15c	On-line economic optimization	On-line integration of control and economic optimization	Reduced order physical model	As above	EcosimPro, HITO, NAG		AEA, Empresarios Agrupados	UVA	[a15.3]

Publications

[a15.1] D. Sarabia, C. de Prada, S. Cristea, R. Mazaeda, W. Colmenares Hybrid NMPC Control of a Sugar House. In: *Assessment and Future Directions of Nonlinear Model Predictive Control,* Springer Lecture Notes, LNCIS, to appear 2006. Also presented at the *International Workshop on Assessment and Future Directions of Nonlinear Model Predictive Control (NMPC'05)*, Freudenstadt, Aug. 2005.

[a15.2] C. de Prada, D. Sarabia, S. Cristea and R. Mazaeda Plant-Wide Control of a Hybrid Process. *International Journal of Adaptive Control and Signal Processing*, under review, Feb. 2006

[a15.3] D. Sarabia, C. de Prada, S. Cristea, R. Mazaeda, W. Colmenares Hybrid Model Predictive Control of a Sugar End Section. *European Symposium on Computer Aided Process Engineering, ESCAPE 16 / PSE2006*, Garmisch-Partenkirchen, Proc. 1269-1274.

[b] Software:

A detailed rigorous simulation in EcosimPro with is available.

Experimental results:

The case study has been solved satisfactorily in simulations, both as MPC control and as an economic optimization layer

WP4b	Mixed continuous-batch pilot plant	Responsible: Daniel Sarabia <dsarabia@autom.uva.es>

No.	Subproblem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
16.1	Scheduling of batch units and continuous control	A methodology for control of mixed continuous-batch processes	Reduced order physical model	Continuous time scheduling by MPC	EcosimPro, HITO, NAG	Solar plant	Empresarios Agrupados	UVA	[a16.1] - [a16.4]
16.2	As above, but modified problem	As above	Hybrid model with (approximated) linear dynamics described by switched ODEs with uncertain additive parameters and discrete inputs (implemented in MATLAB)	Synthesis of safe supervisory controllers based on abstraction and counterexample-guided refinement / controller reconfiguration as reaction to faults and recipe changes	Simulation and optimization software implemented in MATLAB			UNIDO/ TUM	[a16.5], [a16.6]

Publications

[a16.1] C. de Prada, S. Cristea, D. Sarabia, W. Colmenares: Hybrid Control of a Mixed Continuous-Batch process. *Computer Aided Process Engineering* series, vol. 18, ISBN: 1570-7946 / 0-444-51694-8, Elsevier, 2004, pp.739-744

[a16.2] C. de Prada, S. Cristea, D. Sarabia, W. Colmenares: Hybrid control of a mixed continuous-batch process. *European Symposium on Computer Aided Process Engineering*, ESCAPE 14 ISBN, 0-444-51694-8, Elsevier, pp. 739-744, Lisbon, Portugal, May 2004

[a16.3] C. de Prada, D. Sarabia, S. Cristea: NMPC of a hybrid continuous-batch process European Conference on Mathematics for Industry, *ECMI2004, Minisymposium on Nonlinear Model Predictive Control* M-37 Eindhoven, Holanda, May. 2004, ref. 215

[a16.4] D. Sarabia, C. de Prada, S. Cristea: A mixed continuous-batch process: implementation of hybrid Predictive controllers. *7th Symposium on Advances in Control Education ACE2006*, IFAC Madrid, Jun. 2006, accepted, Paper Number: 148a

[a16.5] O. Stursberg, T.H Tran: Algorithmic and Abstraction-Based Design of Discrete Controllers for Hybrid Automata. *at - Automatisierungstechnik*, vol. 54(9), 2006, pp. 450 - 458.

[a16.6] T.H Tran, O. Stursberg, S. Engell: Reconfiguration of Discretely Controlled Hybrid Systems for Changing Specifications. Accepted for: *1st IFAC Workshop on Dependable Control of Discrete Systems (DCDS)*, Paris, France, 2007.

[b] Software:

An EcosimPro simulation and a real time control system based on the MPC platform HITO is available

[c] Experimental results:

The case study has been solved with good results, both in simulation in the EcosimPro environment and in real-time MPC control of the pilot plant

WP4b	Verification of control logic of an evaporator	Responsible: Christian Sonntag <c.sonntag@bci.uni-dortmund.de>

No.	Problem	HYCON added value	Model used	Methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
17	Verification of the control logic of an evaporation system	Provision of a large-scale, industrially motivated case study that leads to large hybrid models described by DAE systems and discrete dynamics; constitutes a challenging verification task.	Hybrid automaton with nonlinear DAE-dynamics, timed automata	Optimization-based safety analysis, verification by theorem proving	Matlab		Hybrid model developed in cooperation with Bayer Technology Services (BTS)	UNIDO	[a17.1], [a17.2]

Publications

[a17.1] A. Völker, C. Sonntag, S. Lohmann, and S. Engell: Optimization-Based Safety Analysis of an Industrial-Scale Evaporation System with Hybrid Dynamics. Accepted for: *8th International Symposium on Dynamics and Control of Process Systems (DYCOPS)*, Cancun, Mexico, 2007.

[a17.2] A. Völker, C. Sonntag, S. Lohmann, and S. Engell: Analyzing Large-scale Hybrid Systems by Optimization: A Case Study from the Process Industries. *Hybrid Systems: Computation and Control,* Poster Presentation, Pisa, Italy, 2007.

[b] Software:

A Matlab-based simulation model is available.

WP4b	Verification of control logic of a fuel cell	Responsible: Carlos Bordons Alba <bordons@esi.us.es>

No.	Problem	HYCON added value	Model used	Methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
18	Verification of the control logic of a fuel cell system	Real-world benchmark for controller verification.	nonlinear DAE system, PWA approximation	Reachability analysis using zonotopes, model-predictive control		Possible inclusion as a benchmark example (currently under investigation)		US	[a18.1], [a18.2]

Publications

[a18.1] M. Fiacchini, T. Alamo, C. Albea, and E. F. Camacho: Adaptive Model Predictive Control of the Hybrid Dynamics of a Fuel Cell System. Accepted for: *IEEE Multi-Conference on Systems and Control*, Singapore, 2007.

[a18.2] M. Fiacchini, T. Alamo, and E. F. Camacho: Piecewise Affine Model of a Fuel Cell for Safety Verification. Accepted for: *American Control Conference*, New York, USA, 2007.

WP4c	Throttle valve control: a case study of platform-based design	Responsible: Andrea Balluchi <balluchi@parades.rm.cnr.it>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
19	Functional and architectural exploration in the design of automotive embedded systems	Adoption of hybrid system modeling for plant, controller and implementation platform description and closed-loop system behavior evaluation	Hybrid models for the electronic throttle valve, the candidate controllers and suitable abstractions of candidate implementation platforms	Randomized algorithms for controller and implementation platform parameter exploration	InterCIDe		Magneti Marelli Powertrain	PARADES UAQ UNIPI CNR	[a19.1]-[a19.3] [b19.1]

[a] Publications:

[a19.1] A. Agostini, A. Balluchi, A. Bicchi, B. Piccoli, A. Sangiovanni-Vincentelli, and K. Zadarnowska, "**Randomized algorithms for platform–based design**" in Proc. of the 44th IEEE Conference on Decision and Control, and the 2005 European Control Conference, (Seville, Spain), pp. 6638–6643, December 2005

[a19.2] A. Balluchi, L. Benvenuti, A. Ferrari, and A. Sangiovanni-Vincentelli, "**Hybrid systems in automotive electronics design**" International Journal of Control, vol. 79, pp. 375–394, May 2006. Special issue on "Advanced design methodologies in automotive control".

[a19.3] L. Paniconi, "**Platform-based design of Idle Speed Control system in automotive applications**", Master Thesis, Advisor: Prof. M. D. Di Benedetto, Co-advisor: A. Balluchi, April 17, 2007.

[b] Software:

[b19.1] InterCide, a tool under development by the HYCON partners involved, which supports functional and architectural exploration in the design of automotive embedded systems. InterCIDe is written in Matlab. The procedures developed for functional and architecture evaluations are based on randomized techniques and hybrid system modeling techniques. Requested closed-loop performance criteria are tested for the control algorithms over parameters spaces both via randomized algorithms, i.e. letting the parameters vary according to a given probability distributions, and stochastic algorithms, i.e. letting the parameters evolve in time according to a random coefficient stochastic differential equation.

[c] Experimental results.

WP4c	Automotive Applications 1 (2 new case studies!!)	Responsible: Alberto Bemporad <bemporad@dii.unisi.it >

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
20	Control of magnetic automotive actuators	Demonstration of hybrid control tools to industry	Linear Constrained, HYSDEL/ MLD/PWA + nonlinear simulation model	Linear MPC, Hybrid MPC, Explicit MPC	Hybrid Toolbox		Ford (USA)	UNISI	[a20.1]-[a20.4] [b20] [c20]
21	Control of a direct-injection-stratified-charge (DISC) engine	Demonstration of hybrid control tools to industry	HYSDEL/MLD/PWA + nonlinear simulation model	Hybrid MPC, Explicit MPC	Hybrid Toolbox		Ford (USA)	UNISI	[a21.1]-[a21.2] [b21]
22	Control of advanced suspension systems	Demonstration of hybrid control tools to industry	Linear constrained, linear distributed, HYSDEL/MLD/PWA + nonlinear simulation model	Linear MPC, Hybrid MPC, Distributed linear MPC	Hybrid Toolbox		Ford (USA)	UNISI	[a22.1]-[a22.3] [b22]
23	Design of controllers for electromechanical actuators in camless engines NEW!!!!	Adoption of hybrid system modeling for plant and controller, and closed-loop system behavior evaluation	Hybrid models for the electromechanical valves for camless engines, and for the dynamic controller used to track desired reference trajectories and reject disturbances	Lyapunov-like techniques, in the framework of the regulator theory.	Simulink and Simnon		Ford, Aachen, (Germany)	UNIAQ	[a23.1]-[a23.5]
24	Comparative assessment of PWA-MPC controllers for automotive control NEW!!	Comparison and assessment of various hybrid control methods and tools to practitioners and to industry, interaction with other HYCON partners (UNISI, ETHZ), use of methods and software tools developed by other HYCON partners	Constrained PWA / MLD / hybrid / linearized prediction models and hybrid/nonlinear simulation models	Linear and nonlinear MPC, hybrid PWA/MLD MPC (implicit and explicit), adaptive PID	MPT toolbox, Matlab, cplex (Tomlab)		TNO Automotive (Helmond, NL)	TUD, UNISI	[a24.1]-[a24.3] [b24] [c24]

[a] Publications:

[a20.1] S. Di Cairano, A. Bemporad, I.V. Kolmanovsky and D. Hrovat, "**Model predictive control of mechatronic systems: an application to a magnetically actuated mass spring damper**", in *2nd IFAC Conference on Analysis and Design of Hybrid Systems, 2006, Alghero, Italy*.

[a20.2] S. Di Cairano, A. Bemporad, I.V. Kolmanovsky and D. Hrovat, "**Hybrid MPC of magnetic automotive actuators**", to appear in *American Control Conference, New York, NY, 2007*.

[a20.3] S. Di Cairano, A. Bemporad, I.V. Kolmanovsky and D. Hrovat, "**Model predictive control of magnetically actuated mass spring dampers for automotive applications**", to appear in *International Journal of Control*, Special issue on Automotive Systems and Control, *2007*.

[a20.4] S. Di Cairano, A. Bemporad, I.V. Kolmanovsky and D. Hrovat, "**Hybrid modeling and control of a multibody magnetic actuator for automotive applications**", submitted to 46th Conference on Decision and Control, *2007*.

[a21.1] N. Giorgetti, A. Bemporad, I.V. Kolmanovsky, and D. Hrovat, "**Explicit hybrid optimal control of direct injection stratified charge engines**", in Proc. IEEE Int. Symp. on Industrial Electronics, Dubrovnik, Croatia, 2005, pp. 247-252.

[a21.2] N. Giorgetti, G. Ripaccioli, A. Bemporad, I.V. Kolmanovsky, and D. Hrovat, "**Hybrid model predictive control of direct injection stratified charge engines**", IEEE/ASME Transactions on Mechatronics, vol. 11, no. 5, Aug. 2006..

[a22.1] N. Giorgetti, A. Bemporad, H. E. Tseng, and D. Hrovat, "**Hybrid model predictive control application towards optimal semi-active suspension**", in Proc. IEEE Int. Symp. on Industrial Electronics, Dubrovnik, Croatia, 2005, pp. 391-398.

[a22.2] N. Giorgetti, A. Bemporad, H. E. Tseng, and D. Hrovat, "**Hybrid model predictive control application towards optimal semi-active suspension**", International Journal of Control, vol. 79, no. 5, pp. 521-533, 2006.

[a22.3] A. Bemporad F. Maggi, "**Decentralized hybrid control of semiactive suspensions**", Technical report, University of Siena, 2007.

[a23.1] C. Acosta Lua, B. Castillo Toledo, M. D. Di Benedetto, and S. Di Gennaro, "**Output Feedback Regulation of Electromagnetic Valves for Camless Engines**", American Control Conference 2007, New York, USA, 2007, to appear.

[a23.2] C. Acosta Lua, B. Castillo Toledo, M. D. Di Benedetto, and S. Di Gennaro, "**Output Feedback Regulation of Electromagnetic Valves for Camless Engines**", European Control Conference 2007, Kos, Greece, USA, 2007, to appear.

[a23.3] C. Acosta Lua, B. Castillo Toledo, M.D. Di Benedetto, S. Di Gennaro, "**Nonlinear Control of Electromagnetic Valves for Camless Engines**", Technical Report R.06-93, Dept. of Electrical and Information Engineering, 2006. http://www.diel.univaq.it/tr/web/web

[a23.4] S. Di Gennaro, B. Castillo Toledo, and M. D. Di Benedetto, "**Nonlinear Regulation of Electromagnetic Valves for Camless Engines**", Proceedings of the 45th IEEE Conference on Decision and Control – CDC 2006, San Diego, California, USA, pp. 3577-3582, 2006.

[a23.5] S. Di Gennaro, B. Castillo Toledo, and M. D. Di Benedetto, "**Nonlinear Control of Electromagnetic Valves for Camless Engines**", International Journal of Control, Special Issue on Automotive Systems and Control, 2006, to appear.

[a24.1] D. Corona and B. De Schutter, "**Adaptive cruise controller design: A comparative assessment for PWA systems**", Proceedings of the 2nd IFAC Conference on Analysis and Design of Hybrid Systems (ADHS'06), Alghero, Italy, pp. 253-258, June 2006.

[a24.2] D. Corona, M. Lazar, B. De Schutter, and M. Heemels, "**A hybrid MPC approach to the design of a Smart adaptive cruise controller**", Proceedings of the 2006 IEEE International Conference on Control Applications (CCA 2006), Munich, Germany, pp. 231-236, Oct. 2006.

[a24.3] D. Corona, I. Necoara, B. De Schutter, and T. van den Boom, "**Robust hybrid MPC applied to the design of an adaptive cruise controller for a road vehicle**", Proceedings of the 45th IEEE Conference on Decision and Control, San Diego, California, pp. 1721-1726, Dec. 2006.

[b] Software:

[b20] - [b21] - [b22] All case studies have been simulated in Matlab/Simulink using the Hybrid Toolbox

[b24] The case studies and controllers have been simulated and designed using the Matlab/Simulink and the MPT Toolbox

[c] Experimental results.

[c20] A laboratory experiment has been built at Automatic Control Laboratory, Università di Siena

[c24] The data for the benchmark correspond to a real-life set-up at TNO Automotive

WP4c	Hybrid Modeling of HCCI engine	Responsible: Rolf Johansson <Rolf.Johanson@control.lth.se>

No.	Problem	HYCON added value	Model used	Methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
25	Homogenous Charge Compression Ignition (HCCI) combustion process is controlled by chemical kinetics, which depends on the several engine operating conditions. In order to reduce the number of tests, which are time consuming and very expensive; a model with a very short computational time to simulate the HCCI combustion over the whole engine operating range is needed.	Hybrid system modeling for HCCI controller and closed-loop system behavior evaluation	Hybrid models involving chemical kinetics, engine operation, ignition, engine mode switching	System Identification			Volvo Powertrain Renault Ford	LTH, INRIA, UCAM	[a25.1]-[a25.3] [c25.1]

[a] Publications:

[a25.1] J. Bengtsson, P. Strandh, R. Johansson, P. Tunestål and B. Johansson, "**Hybrid Control of Homogeneous Charge Compression Ignition (HCCI) Engine Dynamics**", *International Journal of Control*, Vol. 79, No. 5, pp. 422–448, 2006.

[a25.2] J.-B. Millet, F. Maroteaux, P. Emery, M. Sorine, "**A Reduced Model of HCCI Combustion in View of Application to Model Based Engine Control Systems**", SAE Paper 06FFL18-284, 2006

[a25.3] S. Karagiorgis, K. Glover, N. Collings, A. Petridis, "**Hybrid modeling for switching between SI and HCCI combustion modes**", To be submitted to the ACC07.

[b] Software:

[c] Experimental results.
[c25.1] See [a25.1], [a25.3].

WP4c	Automotive Applications 2	Responsible: Thomas Besselmann <besselmann@control.ee.ethz.ch>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
26	Hybrid Gain-Scheduling Model Predictive Control for lateral vehicle stabilization	Demonstration of hybrid control tools to industry	Linear, hybrid, hybrid parameter-varying and fully nonlinear model	Linear MPC, Hybrid MPC, HPV-MPC, Nonlinear MPC	YALMIP, MPT		Ford	ETHZ	[a26.1] [b]
27	A Hybrid Approach to Control of Mechanical Systems with Backlash	Demonstration of hybrid control tools to industry	HYSDEL/PWA	Explicit MPC, Linear MPC, Hybrid MPC, LQ control	YALMIP, MPT	Proposed as benchmark problem in WP2		ETHZ	[a27.1] [b] [c27.1]

[a] Publications

[a26.1] Th. Besselmann, Ph.Rostalski and M. Morari, "**Hybrid Parameter-Varying Model Predictive Control for Lateral Vehicle Stabilization**", Accepted for *European Control Conference, 2007.*

[a27.1] Ph.Rostalski, Th. Besselmann, M. Barić, F. van Belzen and M. Morari, "**A Hybrid Approach to Modeling, Control and State estimation of Mechanical Systems with Backlash**", *International Journal of Control*, 2007, to appear

[b] Software:

All case studies have been simulated in Matlab/Simulink using MPT and YALMIP

[c] Experimental results

[c27.1] See [a27.1]. A laboratory backlash system has been constructed at the Automatic Control Laboratory, ETHZ, as an experimental benchmark for hybrid control. Experiments can be carried out online at http://control.ee.ethz.ch/~backlash

WP4d	Hybrid control of multi-robot systems	Responsible: Karl H. Johansson <kallej@ee.kth.se>

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
28	Hybrid control of multi-robot systems	Explore hybrid systems tools to analyze fundamental limitations and opportunities on distributed estimation and multi-agent control induced by the need of exchanging information across finite bandwidth links	Hybrid automata, switched graph models, consensus models, models of mobile robots	Hierarchical control, stability analysis, verification, mixed-integer linear program, Kalman Filtering	Simulink/Stateflow, TrueTime	Definition of a test case is being considered	FOI, ABB, Ericsson	INRIA, KTH, UCL, UNIPI , LTH	[a28.1]-[a28.25] [b28.1]-[b28.2] [c28.1]-[c28.2]

[a] Publications:

[a28.1] A. Speranzon, "Coordination, Consensus and Communication in Multi-Robot Control Systems", PhD Thesis, School of Electrical Engineering, Royal Institute of Technology, Sweden, 2006.

[a28.2] K.-E. Årzén, A. Bicchi, S. Hailes, K. H. Johansson, and J. Lygeros, "On the design and control of wireless networked embedded systems," IEEE International Symposium on Computer-Aided Control Systems Design, Munich, Germany, 2006.

[a28.3] R. Carli, F. Fagnani, M. Focoso, A. Speranzon and S. Zampieri, "Symmetries in the coordinated consensus problem" In P.J. Antsaklis and P. Tabuada, Ed., NESC: Networked Embedded Sensing and Control, Lecture Notes in Control and Information Sciences, Springer, 2005

[a28.4] B. Johansson, A. Speranzon, M. Johansson, and K. H. Johansson, "Distributed model predictive consensus," MTNS, Kyoto, Japan, 2006.

[a28.5] R. Carli, F. Fagnani, A. Speranzon and S. Zampieri, "Communication constraints in coordinated consensus problems," American Control Conference, Minneapolis, Minnesota, USA, 2006.

[a28.6] K. H. Johansson, A. Speranzon, and S. Zampieri, "On quantization and communication topologies in multi-vehicle rendezvous,". IFAC World Congress, Prague, Czech Republic, 2005.

[a28.7] A. Danesi, A. Fagiolini, L. Pallottino, I. Savino, R. Schiavi, G. Dini, and A. Bicchi. "A scalable platform for safe and secure decentralized traffic management of multiagent mobile systems". In ACM Workshop on Real-World Wireless Sensor Networks, 2006.

[a28.8] L. Pallottino, V.G. Scordio, E. Frazzoli, and A. Bicchi. "Decentralized and scalable conflict resolution strategy for multi-agents systems". In Int. Symp. on Mathematical Theory of Networks and Systems, 2006.

[a28.9] L. Pallottino, V.G. Scordio, E. Frazzoli, and A. Bicchi. “Probabilistic verification of a decentralized policy for conflict resolution in multi-agent systems”. In Proc. IEEE Int. Conf. on Robotics and Automation, 2006.

[a28.10] L. Pallottino, V. G. Scordio, E. Frazzoli, and A. Bicchi. “Decentralized Cooperative Conflict Resolution for Multiple Nonholonomic Vehicles”. In Proc. AIAA COnf. on Guidance, Navigation and Control, 2005.

[a28.11] L. Pallottino, V. G. Scordio, and A. Bicchi. “Decentralized Cooperative Conflict Resolution Among Multiple Autonomous Mobile Agents”. In Proc. IEEE Int. Conf. on Decision and Control, pages 4758-4763, 2004.

[a28.12] Changbin Yu, Julien M. Hendrickx, Baris Fidan, Brian D. O. Anderson, Vincent D. Blondel, Three and higher dimensional autonomous formations: rigidity, persistence and structural persistence, Automatica, 43:3, pp. 387-402, 2007.

[a28.13] Julien M. Hendrickx, Brian D. O. Anderson, Jean-Charles Delvenne,Vincent D.Blondel, Directed graphs for the analysis of rigidity and persistence in autonomous agents systems. To appear in: International Journal of Robust and Nonlinear Control.

[a28.14] J.-C. Delvenne, Vincent D. Blondel, Complexity of control on finite automata, IEEE Transactions on Automatic Control, 51:6, pp.977- 986, 2006.

[a28.15] Vincent D. Blondel, Julien M. Hendrickx, Alex Olshevsky, and John N. Tsitsiklis, Convergence in Multiagent Coordination, Consensus, and Flocking, Proceedings of the 44th IEEE Conference on Decision and Control, Seville, Spain, 2005.

[a28.16] Peter Alriksson, Anders Rantzer: "Distributed Kalman Filtering Using Weighted Averaging". In Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems, Kyoto, Japan, July 2006.

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[a28.18] A. Bicchi, A.Marigo, and B. Piccoli, ““Feedback encoding for efficient symbolic control of dynamical systems”, IEEE Transaction on Automatic Control, Volume 51, Issue 6, June 2006 Page(s):987 – 1002.

[a28.19] B. Ricasso, and A. Bicchi, “On the Stabilization of Linear Systems Under Assigned I/O Quantization”, submitted in the IEEE Transactions on Automatic Control, 2007.

[a28.20] G. Ferrari-Trecate, A. Buffa, and M. Gati. Analysis of coordination in multi-agent systems through partial difference equations. IEEE Trans. on Automatic Control, 51(6):1058--1063, 2006

[a28.21] G. Ferrari-Trecate, M. Egerstedt, A. Buffa, and M. Ji. Laplacian sheep: A hybrid, stop-go policy for leader-based containment.control. In J.P. Hespanha and A. Tiwari, editors, Proc. 9th International Workshop on Hybrid Systems: Computation and Control, volume 3927 of Lecture Notes in Computer Science, pages 212--226. Springer-Verlag, 2006.

[a28.22] M. Ji, M. Egerstedt, G. Ferrari-Trecate, and A. Buffa and. Hierarchical containment control in heterogeneous mobile networks. Proc. Mathematical Theory of Networks and Systems, Kyoto, Japan, pages 2227--2231, 2006.

[a28.23] P.-A. Bliman and G. Ferrari-Trecate. Average consensus problems in networks of agents with delayed.communications. Proc. 44th IEEE Conference on Decision and Control and European Control Conference 2005, pages 7066--7071, 2005.

[a28.24] G. Ferrari-Trecate, A. Buffa, and M. Gati. Analysis of coordination in multi-agent systems through partial difference equations. Part I: The Laplacian control. 16th IFAC World Congress on Automatic Control, 2005.

[a28.25] G. Ferrari-Trecate, A. Buffa, and M. Gati. Analysis of coordination in multi-agent systems through partial difference equations. Part II: Nonlinear control. 16th IFAC World Congress on Automatic Control, 2005.

[b] Software:

[b26.1] TrueTime [http://www.control.lth.se/~dan/truetime/]

[b26.2] Matlab/Simulink-based simulator for real-time control systems

[c] Experimental results:

[c26.1] A scalable platform for safe and secure decentralized traffic management of multi-agent mobile systems [UNIPI]

[c2.2] Control of mobile robot with inverted pendulum using an ad hoc wireless network [LTH]

WP4d	Distributed and hybrid control of resources in wireless networks for control applications	Responsible: Fortunato Santucci <santucci@ing.univaq.it> Marika Di Benedetto

No.	Problem	HYCON added value	Model used	methods	Tools (WP3 links)	Benchmark (WP2 links)	Industrial involvement (WP6 links)	Partners involved	HYCON results
29	Joint design and adaptive tuning of control algorithms and underlying ad-hoc wireless networking protocols	Explore hybrid systems methods and tools in order to develop an adaptive framework for joint optimization of control performance (control over network) and network operations (control of networks) under constraints (e.g. safety and stability)	Hybrid automata, timed automata, Swiched, Uncertain, Piece Wise Affine, Time Delayed, Linear Model w/ stochastic disturbances + mode switches, HYSDEL/MLD/PWA	Hierarchical control, stability analysis, safety analysis, model predictive control, robust control, optimal control, Linear Matrix Inequalities, Constrained Finite Time Optimal Control, Gain Scheduling, Networked hybrid MPC, Kalman Filtering, Networked hybrid MPC	Simulink/Stateflow, Hybrid toolbox, OmNet, Matlab, NS2, LabView	Definition of a test case is being considered	Thales, Selex, Ericsson, ABB	UPAT, UAQ, UNIPI UNISI, PARADES	[a29.1]-[a29.15] [b29.1]-[b29.3] [c29.1]-[c29.6]

[a] Publications:

[a29.1] M.D. Di Benedetto, A. D'Innocenzo, G. Pola, C. Rinaldi, F. Santucci, "Modeling of Adaptive Behaviours in Control over Wireless Networks", invited session on "distributed decision-making over ad-hoc networks", 17th International symposium on Mathematical Theory of Network and Systems (MTNS'06), Kyoto, July 24-28, 2006.

[a29.2] P. Caravani, E. De Santis, F. Graziosi, E. Panizzi, "Communication and Control for Highway Automation and Driving Assistance in Heavy Traffic and Scarce Visibility", IEEE Transactions on Intelligent Transportation Systems, Volume 7, Dec. 2006 Page(s):448 - 460

[a29.3] M.G. Di Benedetto, G. Giancola, M.D. Di Benedetto, "Introducing Consciousness in UWB networks by Hybrid Modelling of Admission Control", ACM/Springer Journal on Mobile Networks and Applications, Special Issue on Ultra Wide Band for Sensor Networks, November 2005

[a29.4] C. Fischione, F. Graziosi, K. H. Johansson, F. Santucci, "Distributed Cooperative Processing and Control over Wireless Sensor Networks", International Wireless Communication and Multimedia Conference 2006, Vancouver, July 2006.

[a29.5] A. Bonivento, C. Fischione, A. Sangiovanni-Vincentelli, F. Graziosi, F. Santucci, "Seran: A semi random protocol solution for clustered wireless sensor networks", IEEE MASS 05, November 2005, best application paper award.

[a29.6] G. Nikolakopoulos, A. Panousopoulou, A. Tzes and J. Lygeros, "Multi-Hoping Induced Gain Scheduling for Wireless Networked Controlled Systems", accepted for publication in Asian Journal of Control, special issue on Time Delayed Systems .

[a29.7] Panousopoulou, G. Nikolakopoulos, A. Tzes and J. Lygeros, "Recent Trends on QoS for Networked Controlled Systems", Accepted for publication at the Mediterranean Journal of Computer Networks.

[a29.8] A. Panousopoulou, G. Nikolakopoulos, A. Tzes and J. Lygeros, "Recent Trends on QoS for Networked Controlled Systems", in the proceedings of the CITSA 2005 conference, Orlando, Florida.

[a29.9] G. Nikolakopoulos A. Panousopoulou, A. Tzes and J. Lygeros, "Multihoping Induced Gain Scheduling for Wireless Networked Controlled Systems", in the proceedings of the Control and Decision Conference, Seville, 2005, invited paper.

[a29.10] G. Nikolakopoulos A. Panousopoulou and A. Tzes, "MANET-Issues and their Effects on Control Applications", in the proceedings of the 10th IEEE International Conference on Emerging Technologies and Factory Automation, Catania, Italy, 19-22 September, 2005.

[a29.11] G. Nikolakopoulos, L. Dritsas, A. Tzes and J. Lygeros, "Adaptive Constrained Control of Uncertain ARMA-Systems based on Set Membership Identification", accepted for publication in the 2006 Mediterranean Control Conference, Ancona, Italy.

[a29.12] A. Panousopoulou, G. Nikolakopoulos, A. Tzes and J. Lygeros, "Experimental Evaluation of a Mobile Ad-Hoc Networked (MANET) Controlled System", accepted for publication in the 17th International Symposium on Mathematical Theory of Networks and Systems (MTNS'06), invited paper.

[a29.13] L. Dritsas, A. Tzes, and G. Nikolakopoulos, "Constrained Finite Time Control of Networked Systems with Uncertain Delays", accepted for publication in the 2006 Mediterranean Control Conference, Ancona, Italy.

[a29.14] L. Dritsas, G. Nikolakopoulos, and A. Tzes, "Constrained Optimal Control Over Networks with uncertain delays", submitted for publication in the Control and Decision Conference, 2006.

[a29.15] S. Di Cairano, A. Bemporad, and A. Caldelli, ``**Moving target detection and tracking in wireless sensor networks**", *EuropeanControl Conference, 2007, Kos, Greece.*

[a2916] A. Bemporad, S. Di Cairano, E. Henriksson, and K.H. Johansson `` **Hybrid Model Predictive Control Based on Wireless Sensor Feedback: An Experimental Study**", submitted to *46th Conference on Decision and Control*.

[a2917] C. Belta, A. Bicchi, M. Egerstedt, E. Frazzoli, E. Klavins, and G. J. Pappas, "Symbolic Planning and Control of Robot Motion: State of the Art and Grand Challenges", published in the Robotics and Automation Magazine, 2007.

[a2918] M. Lindhé, K.H. Johansson and A. Bicchi, "An experimental study of exploiting multipath fading for robot communications", published in Proc. Robotics: Science and Systems, 2007.

[a2919] Fagiolini, L. Pallottino, and G. Dini, "Decentralized Intrusion Detection In Multi-agent Systems", poster presented at HSCC'07.

[a2920] Fagiolini, G. Valenti, L. Pallottino, G. Dini, and A. Bicchi, "Decentralized Intrusion Detection For Secure Cooperative Multi-Agent Systems", submitted to CDC'07.

[a2921] F. Pasqualetti, A. Bicchi, and F. Bullo, "Distributed Intrusion Detection for Secure Averaging Computations", submitted to CDC'07.

[a2922] L. Pallottino, A. Bicchi, and E. Frazzoli, "Probabilistic verification of decentralized conflict resolution policies of multi-vehicle systems", accepted at ACC07.

[a2923] P. Alriksson, J. Nordh, K.-E. Arzen, A. Bicchi, A. Danesi, R. Schiavi, L. Pallottino, "A component-based approach to localization and collision avoidance for mobile multi-agent systems", accepted for ECC'07.

[a2924] K. E. Arzen, A. Bicchi, G. Dini, S. Hailes, K. H. Johansson, J. Lygeros, and A. Tzes", "A component-based approach to the design of networked control systems", published in the European Journal of Control, 2007, and invited paper at ECC'07.

[a2925] Fagiolini, L. Greco, B. Piccoli , and A. Bicchi, "Symbolic Control for Underactuated Differentially Flat Systems", in the proceedings of the IEEE International Conference on Robotics and Automation, pages 1649-1654, 2006.

[a2926] L. Greco, A. Fagiolini, B. Piccoli, and A. Bicchi , "Steering Dynamical Systems with Finite Plans and Limited Path Length", accepted at ECC'07.

[a2927] G. Dini, and I. M. Savino, "An efficient key revocation protocol for wireless sensor networks," in Proceedings of IEEE WOWMOM'06, Niagara-Falls, Buffalo-NY, 26–29, June 2006.

[a2928] Santucci, F., Graziosi, F. and Tennina, S., "Location service design and simulation in ad hoc wireless sensor networks", Int. J. Mobile Network Design and Innovation, Vol. 1, Nos. 3/4, pp.208-214, 2006.

[a2929] L. Di Paolo, C. Fischione, F. Graziosi, F. Santucci, S. Tennina, "Performance Evaluation of Distributed Source Coding and Packet Aggregation for Wireless Sensor Networks", in Proc. of IEEE Globecom 2006, San Francisco, US, November 2006.

[a2930] L. Di Paolo, C. Fischione, F. Graziosi, F. Santucci, S. Tennina, "Loss Factor of Distributed Source Coding with Packet Aggregation inWireless Sensor Networks", in Proc. Of ICTSM 2006, 14th International Conference on Telecommunication Systems – Modelling and Analysis, October 2006.

[a2931] M. D. Di Benedetto, A. D'Innocenzo, C. Rinaldi, F. Santucci, E. Serra, "Modelling and design of control algorithms over wireless networks", to appear in Proc. of 2007 IEEE Multi-conference on Systems and Control, Singapore, October 2007.

[a2932] Di Benedetto, M.G., Di Benedetto, M.D., Giancola, G., and De Santis, E., Analysis of Cognitive Radio Dynamics, *Springer Journal on Mobile Networks and Applications*, Springer, "Cognitive Wireless Communications Networks," Vijay Bhargava and Ekram Hossain Eds., Springer, to appear.

[a2933] Di Benedetto, M.-G. , Giancola, G. , De Santis, E., Di Benedetto, M.D. , Hybrid Modelling of Ultra Wide Band Self-organizing Networks, *2006 Second International Symposium on Communications, Control and Signal Processing* (ISCCSP 2006), Marrakech, Marocco, 13-15 March 2006.

[a2934] C. Fischione, A. Bonivento, A. Sangiovanni-Vincentelli, F. Santucci, K. H. Johansson, "Performance Analysis of Collaborative Spatio-Temporal Processing for Wireless Sensor Networks", in Proc. of IEEE CCNC 06, IEEE Consumer Communications and Networking Conference, January 2006

[b] Software:

[b291] Matlab. The Mathwork's Matlab and its toolboxes has been utilized in order to develop and simulate the proposed control algorithms.

[b292] LabView. The National Insteument's LabView has been selected as the software platform for developing all the test-beds, and integrating the utilized hardware.

[b293] NS2, OmNet++ and TOSSIM have been utilized for simulating the behavior of various wireless networks.*

[b294] Component-based architecture for safe and secure decentralized traffic management of mobile multi-agent systems, with implementation of the collision avoidance component, the visual localization component, and the security component.

[c] Experimental results:

[c291] A gain scheduler based on Linear Matix Inequalities for a wireless networked controlled system over GPRS that would be tolerable to time delays have been designed and experimentally tested [UPAT]
[c292] A QoS mechanism for controlling the network's resources over a wireless networked controlled system over IEEE 802.11b has been developed and experimentally tested [UPAT].
[c293] A Robot assisted target localization mechanism with wireless sensor networks have been designed and implemented [UPAT]
[c294] Adaptive distributed processing algorithms (e.g. positioning) have been developed and implemented over a WSN: current work is on integration of adaptive control for user sensitive light intensity control and remote control of mobile teams [UAQ].
[c295] A testbench for the moving target detection and tracking problem is planned at UNISI and is based on a wireless sensor networks of about 20 Telos motes
[c296] A model of a production line to be controlled by Networked hybrid MPC through a wireless networks of Telos motes has been built at UNISI
[c297] Migration from TinyOS to Contiki operating system, integration of UNIPI platform in the RUNES platform (KTH, LTH, Patras).
[c298] A middleware platform for handling heterogen