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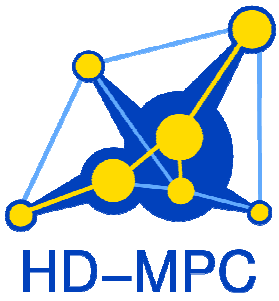

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Executive Summary

The objective of the Benchmark Model-Guide is to help HD-MPC partners to develop benchmark exercises. The Model-Guide will facilitate the proposal and preparation of benchmark exercises and also, it will provide a common format for the description and use of benchmarks.

1 INTRODUCTION

In many cases, new systems are tested using simple simulation models and this, on the one hand, prevents researchers from encountering the complexities that the real world generally imposes and, on the other hand, increases the scepticism of practitioners as to the real applicability of these systems. The creation of benchmarks will be useful for evaluating the real capabilities of different approaches to control systems for real industrial problems. Industry will have chances to test, evaluate, and compare different control solutions at pilot plants or their simulated plants, thus reducing risks and costs of direct experimentation at their actual plants. They will also have a chance to use benchmark capabilities as a medium for communicating specific industrial needs to the research community and also to solution vendors who will be able to show the advantages of their products over common benchmarks.

The research community will also benefit from these activities since the design of a good simulation test bed is often time and resource consuming. Furthermore, it is often subjected to heavy criticism as it either covers only a narrow part of the problem or it is purposely designed to get biased rather than objective performance results. The benchmark examples would effectively overcome these problems by: a) allowing an objective evaluation of control, b) reducing resources and time spent in developing validation models c) giving researchers the possibility to evaluate their proposals in a variety of cases, and d) opening up a forum to compare their performances with those provided by alternative solutions and to discuss the quality of the results.

Benchmarking is going to be used as a mean for testing control technologies developed in HD-MPC Project. It is an excellent means of integration by the execution of joint activities within the consortium centred on common benchmark problems and at the same time fostering excellence through the identification and then adoption of best practices.

Benchmarking enables institutions to improve their performance by identifying critical competencies, strengths and weaknesses, and later using the lessons learnt from best practices to make the necessary improvements. At the same time they are an excellent mean of integration. The first step will be to specify systems, processes and techniques to be studied. Next, Benchmarking partners with superior performance will be identified and studied in order to understand the elements which have led to this superior performance, and to implement improvement plans on this basis. Benchmarking will help HD-MPC Project to find innovative solutions and offer a means of transferring them into business.

2 MODEL-GUIDE OBJECTIVES

The main objective of the Benchmark Model-Guide is to help HD-MPC partners to develop benchmark exercises. The Model-Guide will facilitate the proposal and preparation of benchmark exercises and also, it will provide a common format for the description and use of benchmarks. The Model-Guide will also be used through the web.

For each benchmark case, an exhaustive description of its main technological and operational data as well as of the main performance criteria will be provided. Moreover, best solutions to date and their performance values will also be included. The benchmarks will consist of processes and research infrastructure, simulation models and other tools already existing in the labs of the member. The preparation of the benchmarks will consist of both the preparation of the system (real or simulated) and the preparation of the documentation.

The Model-Guide will cover the main elements of a benchmarking process. They are:

- **Benchmark Proposal and Documentation**: a complete description of the system and the proposed exercises with all the documentation that benchmark's users will need.
- **Benchmark Implementation:** The teams involved in the benchmark exercise will carry this out with a strong activity from the node responsible for the infrastructure.
- **Benchmark Exercises announcement and selection:** How exercises are going to be announced and selected.
- **Performance analysis and evaluation:** How the tests are going to be measured and how the results are going to be disseminated.

3 BENCHMARK PROPOSAL AND DOCUMENTATION

The first step in the benchmarking process is the preparation of the proposals. The proposal will include an exhaustive description of the system and the proposed exercises, that is:

- **Description of the System**: Description of the process, objectives, instrumentation, control architecture, security items, models, etc.
- **Description of the exercises to be performed on a System:** Exercises description and implementation, operating conditions and performance measures.

The Model-Guide web tool will be especially useful at this step. The benchmark developer will be guided with the help of a questionnaire. Next paragraphs give a

detailed explanation of the elements to be described in the proposal and the questionnaire.

3.1 DESCRIPCION OF THE SYSTEM

The first item to be specified in a benchmark case is a complete description of the system, including the process, hardware and software components, sensors, actuators and the different models that can be used in the proposed exercises. Also the control architecture and how the user can access to the system have to be clarified.

3.1.1 THE PROCESS

Benchmark processes can be real or simulated. Both situations need a physical description of the process, with a detailed characterization of components and connections, dimensions, etc., and also a functional description, including the objectives of the process, control aims and operational constraints.

The benchmark processes need to have a special interest from the point of view of control of large, complex and networked systems. These aspects must be emphasised in the proposal.

The variables and disturbances of the process have to be enumerated and described, including:

- Controlled variables: continuous or discrete, constraints, set-points…
- Manipulated variables: continuous or discrete, constraints…
- Other Process Variables: measured disturbances, measured states…
- Possible non measured disturbance: Type, influence…

Also, the dynamics of the process have to be characterized, including type of dynamics, response time, etc.

Finally, previous documentation, as bibliography about the process or control applications to that process, previous experimental results, etc, will be very useful for benchmark users.

3.1.2 INSTRUMENTATION AND CONTROL SYSTEM

A complete description of the control system available in the benchmark installation is also required, including:

- Architecture of the control system: PIDs, PLCs…

- Type and technical characteristics of sensors and actuators used in the process.
- Monitoring and control hardware and software, emphasizing the external connectivity.
- Possibility to add new actuators and sensors, or new closed-loop in the process.

3.1.3 SECURITY

Environmental regulations being each time more complex, the importance of security issues is increasing. Security related costs may be a major criterion for the feasability of many industrial processes in the future years.

In addition, taking into account that the experiment designer will not belong normally to the benchmark installation owner group and sometimes it will be possible to operate the system remotely, the security aspects of the operation must be specially considered.

That includes a description of all the emergency procedures (emergency shutdowns, fast shut downs, how to communicate with an onsite operator...). All the limits of operation must be also defined.

3.1.4 PROCESS MODELS

Models of the systems will very useful in the benchmark process. All existing models of the process and the models developed by benchmark users will be stored in a database and will be made accessible to all groups.

Database will include models with different objectives (mainly control or simulation), types (dynamic or steady-state), modelling the complete process or a part of it, different complexity levels, etc.

A complete description for each one of the models will be provided, including simplifications assumptions, applications constraints, the tool or language used for the implementation and how the validation has been performed.

During the exercises execution, new models can be developed by the benchmark users. For this purpose, if possible, the installation owner group will provide data for validating new models or for identification. The model developer can also propose experiments to calibrate new models.

3.2 EXPERIMENTS

The installation owner group will provide the general operation and implementation conditions that any experiment included in a proposal have to satisfy. Otherwise, the proposal will describe specific aspects of experiments, emphasizing performance measures to evaluate experiments.

3.2.1 GENERAL OPERATING CONDITION

The installation owner must define the operating conditions of the system. It must be specified when the plant is available (days of the week, hours of the day…) for experiment. Also, it should be mentioned whether human supervision is necessary in order to perform the experiments. All procedures related to the plant (as start/stop procedures or manual/automatic switching) must be described.

3.2.2 EXPERIMENT IMPLEMENTATION

Related to the experiment implementation, the installation owner must provide general description about the way the control algorithm can be implemented, that is, software (labview, matlab, C code…) and the required format of control algorithms.

3.2.3 EXPERIMENTS DESCRIPTION

The experiments have to be described in the exercise proposal and documentation. The objectives of the experiment and the control objectives have to be specified. Finally, a complete description of the experiments: steps to be performed input signals...

The technical specifications for the control objectives should be very precisely defined in terms of:

- Rejection of disturbances;
- Speed of convergence of the solutions to the equilibrium;
- Basin of attraction, (local, semi-global, global…);
- Bound on the control variables (e.g. absolute magnitude, maximal energy, rate constraints ...)
- …

3.2.4 PERFORMANCE MEASURES

An important issue in experiment descriptions are the performance measures of the experiments. That includes qualitative and quantitative indexes in relation to control aims, robustness of the control system, facility of the use and operation… The goals of experiments and threshold of the indexes must be defined.

3.3 BENCHMARK QUESTIONNAIRE

The above description has been summarized in a questionnaire. A web tool to use the questionnaire has been implemented and it is described in section 5. The questionnaire is presented now:

1. DESCRIPTION OF THE SYSTEM

a. THE PROCESS

i. Give an overall view of the process: Functionality, operation targets, architecture, …
ii. Physical description of the process (elements, dimensions, scales, ...)
iii. Objectives of the process and specific control aims
iv. Justify the complex or networked aspects of the process.
v. Describe the interest of the process from different points of view: distributed control, hierarchical control, security issues, perturbations rejections, robustness issues, state estimation, identification…
vi. Enumerate and describe the Controlled variables (continuous or discrete, constraints, set-points, …)
vii. Enumerate and describe the Manipulated variables (continuous or discrete, constraints, …)
viii. Enumerate and describe Other Process Variables (e.g., measured disturbances, measured states, …)
ix. Possible non-measured disturbances (type, influence, …)
x. Characterize the dynamic of the process: type of dynamic, response time, …
xi. Is there available bibliography about the process?
xii. Are there available previous experimental results or bibliography about applying any type of control?

b. Control System and Instrumentation

i. Is there a proposed partition of the system for distributed control?
ii. Is there a proposed distributed or hierarchical architecture? If yes, describe the architecture, communication issues,...

iii. Describe the type and technical characteristics of the instrumentation: sensors, actuators. Enumerate and describe the measured / observed variables
iv. Describe the architecture of the basic control systems: PIDs, PLC, securities, ...
v. Description of the basic control system (software and hardware) including Operating system, SCADA, …
vi. Manual/auto, remote operation
vii. Alarm system. What are the alarm messages available?, what are the possibilities of reconfiguration?, what are the degraded modes and the critical modes?
viii. Man machine Interfaces
ix. Data storage
x. Can be configured? Is it possible to inject faults?, Is it possible to command reconfigurations? Is it possible to inject artificial perturbations?
xi. External connectivity: OPC, web, …
xii. Range of admissible sampling periods
xiii. Do there exist saturations (in amplitude, in speed…) in the actuators or in the sensors?
xiv. Can actuators and sensors be added?
xv. Can additional control loops be added, if necessary (e.g. anti-windup schemes)?

c. Security

i. Describe the emergency procedures: emergency shut-downs, fast shut-downs. Are they automated or is it possible to control them (monitoring and supervisory functions)?
ii. Define the limits of operation. How is the controller notified when the operation constraints are no longer verified? Do you know sufficient conditions on the inputs (bounds, maximal speed, algebraic conditions…) so that these limits are guaranteed?
iii. What are the security requirements? What are the properties which have to be verified during the system operation? What are the critical states that the system must never reach?

d. Process Models

i. Is there any available model of the process? If yes,
ii. Specify the objective of the model/s (control, simulation, reliability analysis, security analysis, formal verification …)
iii. Are multiple models of the plant with different degrees of complexity available (e.g. ranging from approximated linear models with few variables to nonlinear detailed models accounting for all the dynamics)?

iv. Describe the model/s: type, simplification assumptions, part of the process modelled, …
v. How are specified modelling errors?
vi. What is the language/tool used to implement the model?
vii. Has it been validated? How?
viii. Is it available any documentation?
ix. What kind of experiments can be performed in order to obtain or calibrate new models? Which part of the model can be easily recalibrated?
x. Is there any available data for identification?

2. *EXPERIMENTS*

a. General operating conditions

i. Specify the plant availability (24 hours/day, only at night, …)
ii. Is it necessary a human supervisor at the site? Why?
iii. If yes, could this supervisor experiments any control strategy or does he need an expert of this control strategy participating to the experiments? Does this expert need some special formation for the operating conditions?
iv. Describe the Start/Stop procedures
v. Manual/automatic switching
vi. Auxiliary equipment needed
vii. Is there an experiment data base?

b. Experiments description

i. Specify the objectives of the experiment, control objectives
ii. Describe the experiments: steps to be performed, input signals, scenarios, …
iii. Can the user suggest a new implementation, new closed-loops, new sensors and actuators to manage some difficulties?
iv. Is it possible to define new experiments by the user? Describe the procedure

c. Experiment implementation

i. Describe the actual control architecture and software in use from the user point of view (labview, matlab, DCS, C code, PLC code…)
ii. Describe the control algorithm implementation format, i.e., what must be done for adding/modifying new control structures.

d. Performance measures

i. Define the indexes to measure the performance of the experiments in relation to the control aims, robustness of the control system, facility of use and operation, economic issues, …
ii. Is it possible to estimate cost of the control strategy in terms of energy, necessity and difficulty of the calibrations, optimality?
iii. Can the goals be reformulated?
iv. Define the threshold of the indexes
v. Is there an experimental result database and statistical tools to compare with previous experiment results?