

Control loops: performance and diagnostics

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Summary

The paper aims at presenting an innovative solution for control loop performance assessment and optimization. The software product has been designed to enable process managers to recover profit margins through the systematic monitoring and adjustment of the performance of the basic control system. To achieve this goal, technologies and methods are systematically used that have been developed in research and development laboratories on the basis of the results produced over the past 15 years in the fields of control engineering and information technology.

Keywords: Control performance monitoring, loop tuning optimization, model identification

1 INTRODUCTION

Ever since the early 90s, there has been a renewed and persistent interest in the evaluation of basic control loop performance. Two motivation factors, one academic and the other economic/managerial have simultaneously caused this.

On the one hand, the work of Harris [1], has re-launched a research field that had seemed to be gradually losing ground, presenting a simple and effective method for the objective evaluation of tuning loop performance, based on a measurement that can be compared with the determination of the “*state of shape*” of the loop. At the same time, process owners started to pay increased attention towards the meticulous management of basic control systems, because of the growing awareness about their influence on production processes. This impact works both directly and as a binding condition for the effectiveness and relevant economic return of more sophisticated automation strategies.

Industrial automation suppliers have naturally intercepted the growing demand, and keep on being engaged in developing and marketing products and solutions for loop performances monitoring. The successful application of these products depends on a series of factors that go well beyond the calculation algorithm pure efficiency, including the ability to connect up without disturbing the underlying control system, easy use and configuration and the possibility of translating the inevitably difficult to understand figures into a concise number of precise data useful for control room operators or maintenance engineers.

Nevertheless, even a punctual and accurate diagnostic capacity is often not enough. The drastic reduction of the workforce on production sites does in fact force the professional figures in charge of operations to take on several diverse duties and consequently the need arises not only to identify the nature of the problem but to also be able to solve it with quick, safe and easily implemented remedial measures.

This work intends presenting a number of solutions recently made available to the market in the form of a product that combines monitoring and diagnostic functionalities with tools able to restore quickly and effectively regulatory systems back to optimal operating conditions.

The article is organised as follows: after a short historical digression on the basic principles of control system performance monitoring, section 2 focuses on the requirements, the restraints and the

opportunities which the application of these techniques offers in the field of process automation. Section 3 is dedicated to the description of the salient aspects of the proposed solution, while section 4 supplements the treatise with a short example of application. Finally, section 5 is dedicated to future prospects and scheduled improvements.

2 EVALUATION OF CONTROL SYSTEM PERFORMANCES: STATE OF THE ART

The availability¹ and effectiveness of a control system is clearly essential for managing the process in conditions of safety and maximum performance, ensuring quality of production and its profitability. Over 90% of the process control systems are based on PID type controllers, which represent a basic standard² as regards process tuning (see Figure 1 - Tuning loop with PID diagram for basic nomenclature).

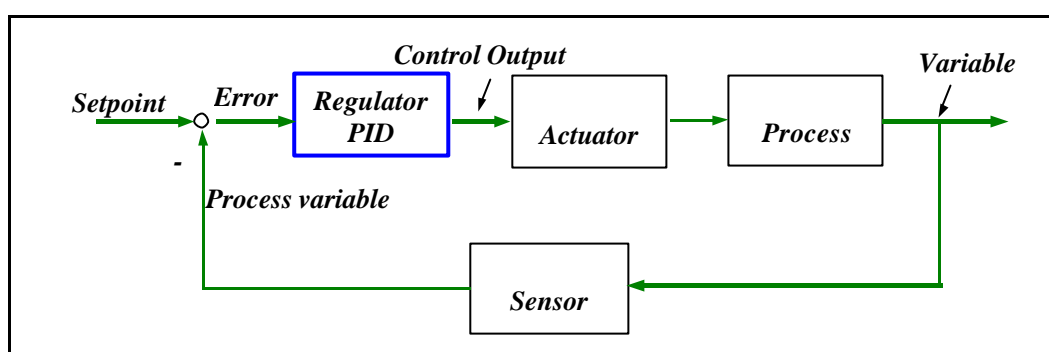


Figure 1 - Tuning loop with PID diagram

These controllers, the basic principle of which is fairly simple, represent the basis of any automation strategy, even when advanced, second-layer systems, such as multivariable controllers or MES (*Manufacturing Execution Systems*) are applied.

The most general expression of the PID controller algorithm consists in the so-called "parallel" expression, in which the three proportional, integral and derivative parts operate in a non-interacting way on the feedback error. Including the possibility of a weight factor on the proportional part and of a derivative action on the process variable or on the error, this can be written as follows:

$$u = K_P (b \cdot r - y) + K_I \frac{1}{s} (r - y) + K_D \frac{s}{1 + T_F s} (g \cdot r - y)$$

where:

u	Manipulated Variable (Controller action)
r	Setpoint
y	Process Variable (Controlled Variable)
K_P	Proportional Gain
K_I	Integral Gain
K_D	Derivative Gain
T_F	Time constant (Filter)

¹By the word *availability* is meant in this case the relation between the time the loop is able to operate in closed loop with appropriate performances compared to the total operating time, including therefore the open loop operating time.

²Notice that, though the PID concept is fairly widespread, its practical implementation in the various control and automation systems is very varied, presenting different variations.

- b Setpoint weight factor in proportional part ³
 γ Setpoint weight factor in derivative part ⁴

The parameters K_P , K_I e K_D represent the "knobs" at the disposal of the control engineer which permit combining the characteristics of the controller with the actual dynamics of the process under consideration, so as to obtain the required responses and behaviours. We thus found ourselves faced with a system with 3 distinct degrees of freedom for which the best value threesome must be pinpointed. Because the overall process performances will depend on the goodness of the tuning done, it follows that this appears as the crucial step in commissioning a plant. For this reason, it is normally entrusted to specialists who enter the optimal values of the three parameters on the basis of empirical rules or principles based on personal and therefore not easily transferable experience.

With the passing of time however, changes in production conditions or normal settling of component parts, sensors and actuators can affect the effectiveness of regulation. These changes can vary from changes in process gain or dynamics, to valve operation problems (*stiction*⁵, hysteresis) to the application of restraints on operating conditions. The moving away from original *tuning* conditions would therefore call for the periodical retuning of the controllers, so as to adapt tuning to changes in operating conditions⁶.

Monitoring and restoring the operation of the complete set of controllers in a plant, is however a pretty onerous business as regards personnel commitment (and related cost). More specifically, such requirement clashes both with the considerable reduction in staff under way for some time now in all production sites, and with the scarcity of people truly expert in the field of control system tuning. The lower availability of time and resources inevitably leads to neglecting major aspects of process management which nevertheless have an impact on the global economical bill. Part of this category are the maintenance requirements of regulating instruments and parts. Persistent temperature fluctuations caused by a valve in hysteresis or a badly tuned controller will have to be offset by the continuous use of hot and/or cold fluids, the cost of which will accumulate in an insidious but not negligible way on the energy bill and consequently on variable production costs [2].

A further contribution to the drop in economic performance also comes from the objective difficulty of tuning procedures. A very high percentage of industrial controllers does in fact lack the derivative part by need rather than by choice. In practice, the decision is made not to use a PID controller not on the basis of a comparative analysis of performances (which at least in the case of processes distinguished by second order or superior dynamics, would be far better) but due to the extreme difficulty of manually tuning a system with three independent parameters [3]. In other words, the lack of mathematical supporting instruments translates into the resigned acceptance of lower performances.

In practice, we are faced with a situation distinguished by [4]:

- from hundreds to thousands of loops
- system complexities (both process and automation)
- multiple and sometimes contrasting control goals
- long maintenance cycles
- low availability of operating and engineering personnel
- severe economic impact

³ For $b=0$ the proportional part acts on the PV while for $b=1$ it acts on the deviation

⁴ For $\gamma=0$ the derivative parts acts on the PV, while for $\gamma=1$ it acts on the deviation.

⁵ The term *Stiction* identifies all those events due to friction on the valves

⁶ It should be noted that this type of problem can in some cases can be completely inherent in the specific type of production and not relate to the history of the unit and *equipment*. This is the case of plants working with *campaign productions* (frequent in fine chemistry) where the load conditions and the type of product can be greatly different from one period to another, leading to the need for personalised tuning for the different production campaigns.

On top of these there is a perception problem on the part of the management, ready to acknowledge the positive economic impact of cutting back the number of staff, but less inclined to accept the actual drop in margins caused by failure to maintain the process at potential efficiency levels. This leads the company management to focus on production efficiency increases tied to cuts in the number of staff, while underestimating the benefits produced by better management of company assets.

Hence the need to have instruments and methods able to keep a check on the performance of controllers, warning and requesting human assistance only when actually required [5].

To cater for this need, in the past 15 years, strong research and development efforts have made it possible to develop a series of methods for monitoring control loop performances essentially based on the evaluation of variance in the controlled variable in the face of stochastic unmeasured disturbances ([6], [7]).

Most of these methods are based on the work of Harris [1], who suggested using data collected in closed-loop to assess controller performances by means of the so-called Minimum Variance Control (MVC) benchmark.

Without going into technical details, which do not fall within the scope of this work (for more details see, among others, the excellent survey provided by [8]), it will be enough to recall that, from a theoretic viewpoint, a minimum variance controller is a controller able to remove all disturbance effects (downstream of the delay time), leaving only a white noise-like disturbance. Given any disturbance frequency, no controller can do a better job in reducing the variance of controlled variables: in other words an MVC controller represents the best theoretical result that can be achieved.

It is its very nature as "asymptotic maximum" that makes it an ideal benchmark for the construction of an objective measurement of the performances of a controller.

Harris' index is nothing more than the relation between the MVC control loop variance and the variance actually measured:

$$\mathbf{I} = \frac{S_{\text{MVC}}^2}{S_{\text{SP-PV}}^2}$$

Harris' index is therefore a number between 0 and 1: the higher the number, the higher the controller performance to the theoretical maximum. It belongs to *stochastic* [8] estimation methods, known by this name because they evaluate the response of the controllers on the basis of their statistical behaviour in the case of non-measured disturbances. It is not therefore able to provide any information on the *determinist* performances such as the response to a step variation in the set-point or disturbance, adjustment time, over-elongation, stability margin, etc.

Among its advantages must be mentioned its capacity to build an objective principle of evaluation of performances, its uniqueness (the σ_{MVC}^2 value is independent of the controller structure) and its relative ease of calculation in standard industrial computers. Harris' index best expresses its potential (and is directly applicable) in the following cases:

- processes without major delay times (for instance in the case of carrying loops);
- processes describable with low-order models;
- processes where non-measurable disturbances are almost stationary

It is however necessary to recall that this is not applicable to processes with variable delay times and that an adequate compromise must be assessed from time to time between the stochastic performances and the determinist performances. To this end, it is therefore necessary that the judgment on the performances of a control loop be properly based on a number of different evaluation parameters [9].

3 AN INNOVATIVE SOLUTION FOR THE INTEGRATED MANAGEMENT OF CONTROL LOOPS

In section 2 we saw how the gradual reduction of plant personnel forces the remaining technicians to take on a growing number of tasks and duties. This results in less and less time and effort being available for monitoring process performances. To try and quantify the efforts required, we should consider that, in typical industrial situations, a control engineer has to maintain on average 4-500 loops at top performance. Considering that the analysis and tuning of a controller requires not less than 2-3 hours, it follows that keeping a control system in shape takes up between 6 and 9 months work of a highly qualified technician.

Luckily, the widespread availability of computers and of large quantities of real time data, permits automating tasks that until a few years ago would have been unachievable without extensive human intervention.

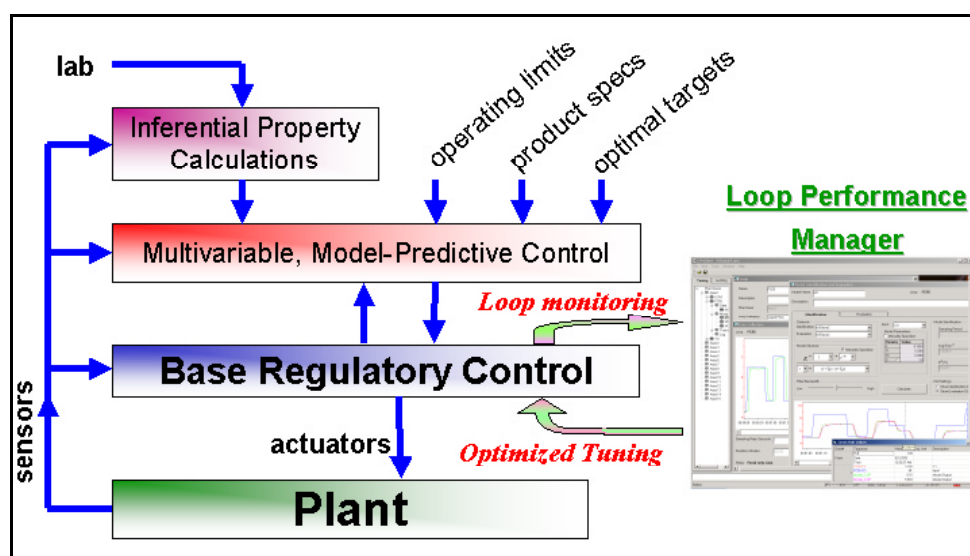


Figure 2 - Typical automatic multi-level structure

It is on the backdrop of this scenario that the authors have been committed for some years in designing and developing new products for the application of the most recent Information Technology solutions in the field of automation. Such development programme, which has already produced innovative software instruments for advanced process control [10], has recently been enhanced with a solution for the optimisation and maintenance of basic control loops.

The product, called Optimize^{IT} Loop Performance Manager (LPM) consists of a system for the systematic evaluation control loops “health” (forthwith identified as *loop auditing*) and of a system for the assisted tuning of the loops themselves (*loop tuning*).

Figure 2 shows the role played by a package such as LPM in the traditional automation architecture for continuous processes. The crucial stages in the application of such a product will be briefly illustrated below.

3.1 Installation and configuration

The main raison d'être of a product like LPM is to reduce the work load for the plant personnel. In view of this, a critical requirement is the absolute ease of connection to the DCS and immediate use. LPM can connect up to any control system by OPC⁷ connection. Special wizards permit automatic search for the OPC Servers available on the local area network and their guided configuration. LPM is able to connect up to a plurality of servers so as to centralise on a single platform the maintenance

⁷ The product is also able to connect up directly, through high-performance proprietor protocols, to some specific DCS.

operations on several DCS units, even of different suppliers: a special library does in fact allows interacting with the numerous implementative variants of the PID algorithms available on the market. To divide out the loops in an orderly way, these are grouped together and displayable according to the areas of operation to which they belong: for instance, in a refinery, it will be possible to classify the loops according to units to which they belong (crude unit, FCC, hydrocracker, utility, etc.).

The configuration of each single loop, a potentially onerous task in terms of time, tedious and most definitely prone to the introduction of trivial typing mistakes, is assisted by a Bulk Configuration utility able to import all the parameters needed from an Excel file derived, for instance, from the control system database.

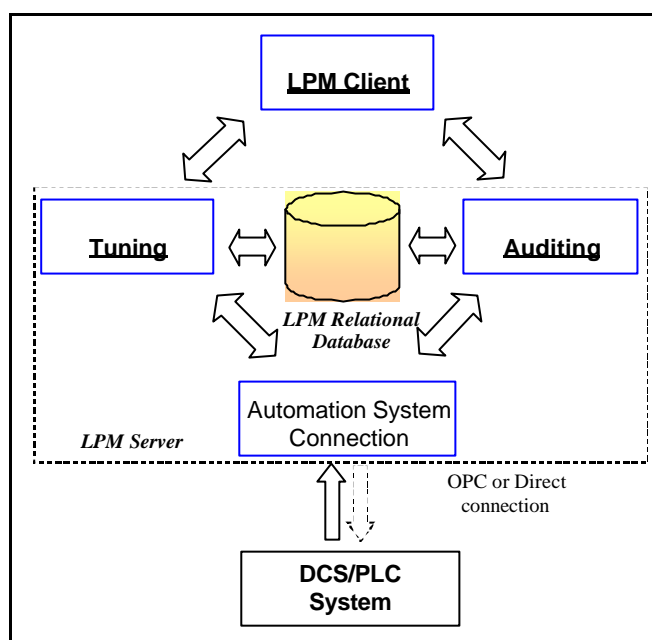


Figure 3 – LPM architecture

Special attention has been given to making the tool intuitive and easy to use by typical control room engineers. A single user interface, structured according to the most modern *Microsoft Windows*[®] standards, does in fact permit accessing both the auditing routines and a sophisticated environment for tuning the basic controllers, which have been identified by the auditing routine, as worth to be returned. Figure 3 shows a simplified diagram of the LPM software architecture.

3.2 Auditing

The fundamental requirements of an automatic performance evaluation system are:

1. **Safety**: ability to interact with the control system in an absolutely safe and non-invasive way;
2. **Autonomy**: ability to manage the various stages (data collection and processing, results generation) in a fully automatic way;
3. **Availability**: the processed data must be stored and made available to the user at request, even after a relevant period of time;
4. **Interactivity**: possibility for the user to perform “on demand” monitoring operations whenever the need arises.

LPM has been designed so that it is able to cater for this need through the following completely automated procedures:

- Collection of periodical data for the loops subject to evaluation (data “batches”)
- Calculation of performance indices
- Archiving of indices

- Execution of statistical tests on indices in order to produce process diagnostics

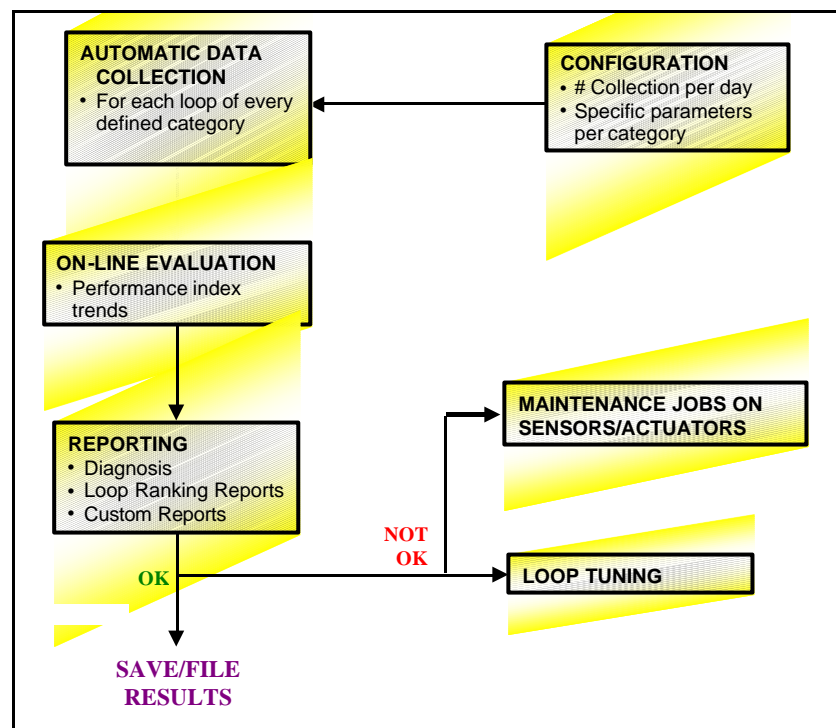


Figure 4 – Loop Auditing Flowchart

A system for evaluating tuning loop performances, which intends using quality KPI such as the previously described Harris index, must be able to provide a reliable value of the s value that a minimum variance controller would obtain in the loop into consideration.

This can be calculated through the use of an auto-regressive model like the one shown in the following expression:

$$\hat{y}(i+b) = a_0 + a_1y(i) + a_2y(i-1) + a_3y(i-2) + \dots + a_my(i-m+1)$$

As we can see, for each controller, the user should provide a series of parameters such as the number of terms to be considered in the model (m), the sampling interval, the extension of the data as a whole (n) and the prediction horizon (b). It is clear that specifying these detailed parameters for hundreds of loops would make the application of these methods impossible from a practical viewpoint [11]. The large-scale application of assessment performance methods is therefore tied to the ability to determine default values sufficiently generic for broad classes of controllers.

LPM permits grouping the controllers into categories (temperature loop, pressure loop, composition loop, etc.) each of which can be distinguished by acquisition parameters (sampling frequency, number and length of single batches, etc.) as best thought fit. According to the date configured by the user, the programme will perform the required number of data collections at pre-defined times, operating in background on up to several hundred loops per server. Some categories are left undefined (the so-called “User-defined Categories”) to allow handling any loops, which badly adapt to the default values of the major categories.

After completing data collection, the program calculates a group of 41 different performance indices and stores these in the auditing database. Of these, 3 are calculated in continuous mode (with sampling every minute for all loop types) as a statistic reference (% of time in auto mode, % of time

in saturation, absolute mean error), while the remaining 38 are processed in batches (i.e. at the end of each data collection) and contain all the most significant details.

Although part of the 41 indices are not directly referable to diagnostic aspects, but represent material useful for specific tests (for instance Boolean status indices or high statistic moments), some have to be intuitively interpreted by the control room and/or maintenance staff. Without entering into detail, we could mention, among the most important:

- Harris index;
- Setpoint "Crossover" Index;
- Oscillation Indices. These include evaluations relating to the amplitude, the period and severity of the oscillation, where this is defined as the relation between the variance due to the oscillation and the overall variance of the signal.
- Operating Mode Index (auto/manual), expressed as % of the samples for which the loop was in automatic out of the total of the batch samples;
- Saturation index, expressed as % of the samples in saturation out of the total of the batch samples.

The indices remain at the disposal of the user, who can check them in configurable time trends (Figure 5).

The reporting function generates weekly and monthly report files in *Microsoft Excel* format, that can be configured by the user. These contain information of both quantitative (the values of the calculated indices) and qualitative nature. The latter relate to diagnostic hypotheses processed on the basis of tests performed on the performance indices themselves. Examples of the available diagnostic hints include:

- The loop tuning is sluggish
- The loop oscillates
- Valve leakage is causing a non-zero flow when closed
- Performance affected by noise
- Controller is saturated
- Overall Performance is acceptable

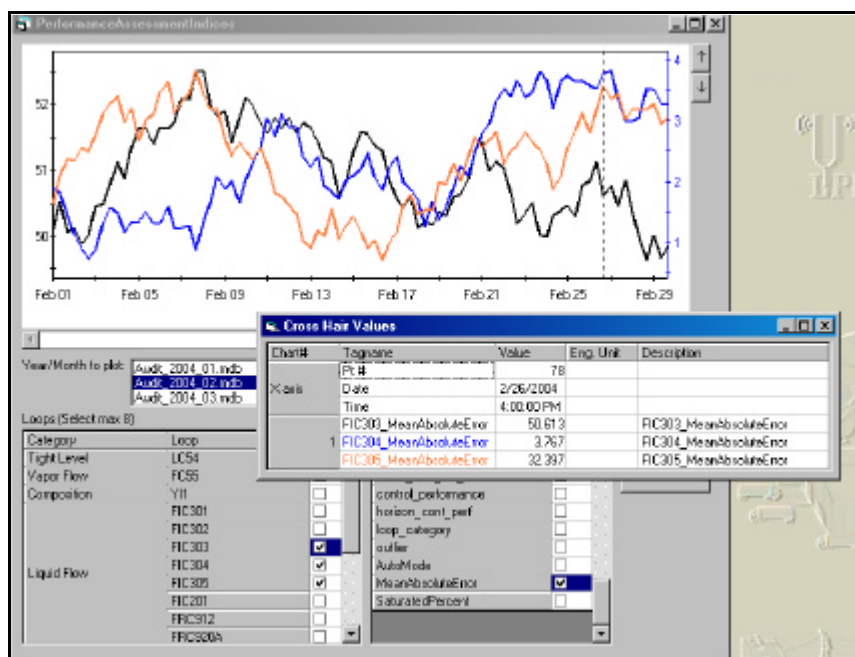


Figure 5 – Example of Trend on evaluation KPI

The user can also interact with the program at any time by configuring and asking for an additional report which will be immediately produced. The reports enable the maintenance technicians to focus on the major control problems and, properly stored, make possible plant performance comparisons over the long period.

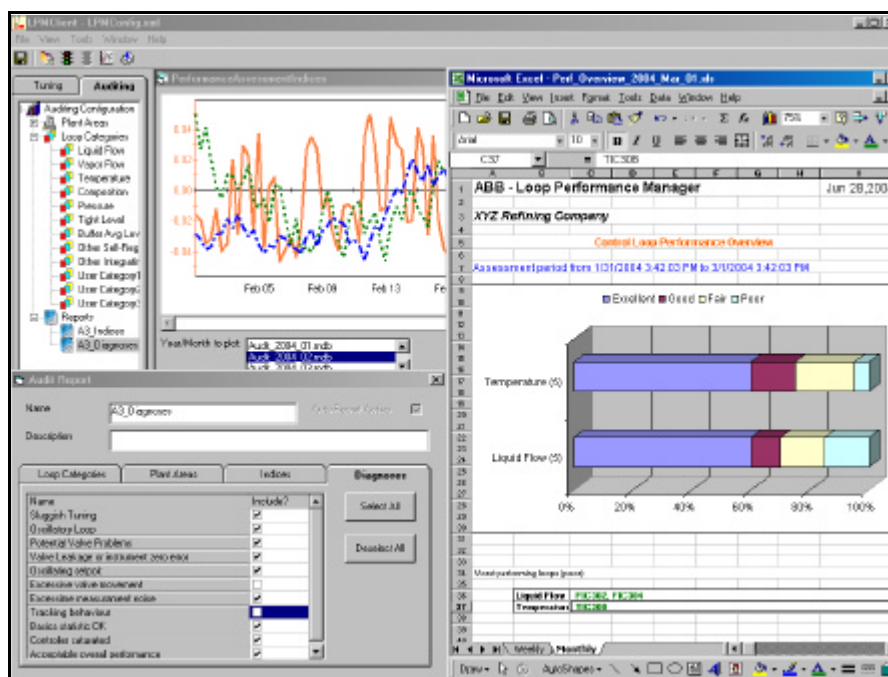


Figure 6 – Example of auditing and reporting

The auditing procedure made available by LPM is distinguished by a number of very interesting features:

- Calculation of numerous indices: literature often emphasises how the detection of faults and malfunctions during control is only possible by the combined analysis of diverse indices [6];
- Conversion into a small number of clear diagnostic suggestions, of many index values, often referring to not trivial statistic-operational aspects;
- Strengthening of the diagnostic results into self-explaining performance categories (excellent, good, etc.). This permits defining a hierarchy among the loops requiring attention;
- Continuous monitoring on diverse time horizons. Entrusting to random samplings can easily completely falsify the evaluation of the state of health of loops operating, for example, in very variable conditions.

3.3 Tuning

As Figure 4 shows, the auditing package is able to detect problems or malfunctions relating both to instruments or equipment, and to the automation system.

While in the former case, normal inspection and maintenance practices are essential, in the latter it is often possible to obtain surprisingly good results through adequate tuning adjustments.

As a natural complement to the "exploration" stage represented by loop auditing, LPM offers a powerful and refined utility for the assisted tuning of base controllers.

The Loop Tuning procedure occurs in the following steps (Figure 7 - Loop Tuning Flowchart):

- Data collection through OPC linkup or direct linkup⁸
- Data processing and storing
- Model identification

⁸ Available for some automation systems

- Evaluation of models obtained
- Calculation of optimal PID tuning parameters
- Evaluation and comparison of the re-tuned controller performance through off-line simulations
- Archiving results and tuning procedures in special *logs*.

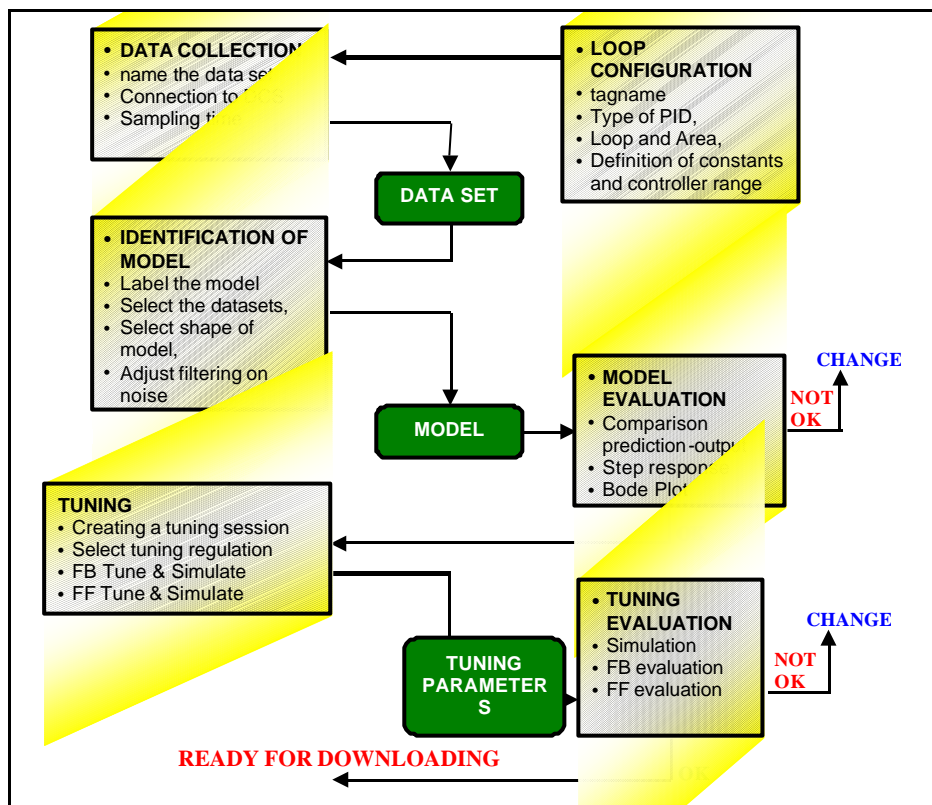


Figure 7 - Loop Tuning Flowchart

The first step of the tuning procedure consists in data collection. Data collection requires an operator to test the process with a series of modest variations such as not to disturb normal system operation. LPM permits collecting data both with open loop (with the controller in Manual) and in closed loop (controller in Automatic).

The robust identification algorithms at disposal allow identifying models of growing complexity including those with reverse or over-dampened response. By selecting a specific flag, models can be identified for integrating processes (level controls). Model identification occurs in separate steps: at first, the software identifies the process delay time, subsequently used to determine the complete transfer function. This approach adds flexibility to the system, allowing the user to manually enter previously known parameters and leaving to the software the task of finding the missing or uncertain ones. The models can be built from among:

- Controller output and Process Variable to be used for feedback tuning;
- Measured Disturbance and Process Variable to be used for feedforward tuning.

Great emphasis is given to the model adequacy evaluation phase: for this purpose, the user can examine both the plot (prediction vs. real data, step response, frequency response) and numerical figures (R^2 , mean quadratic error).

Once an adequate process model has been identified, this can be used for the real tuning phase. LPM makes available the following tuning rules:

- lambda tuning;

- dominant pole placement for PI controllers;
- dominant pole placement for PID controllers;
- Internal Model Control for PI controllers;
- Internal Model Control for PID controllers.

The tuning rules at disposal offer a range of alternatives that successfully cover the various possible occurrences related to continuous process systems. The choice of tuning method is affected by factors such as type of process model, control scenario and design criteria.

For example and without going into detail, it is possible to state that the Internal Model Control and Lambda tuning methods are preferable when the major requirement is about the capacity to closely follow set-point variations (e.g., in the master controller in a cascade configuration), while dominating pole positioning is more successful as regards disturbance rejection.

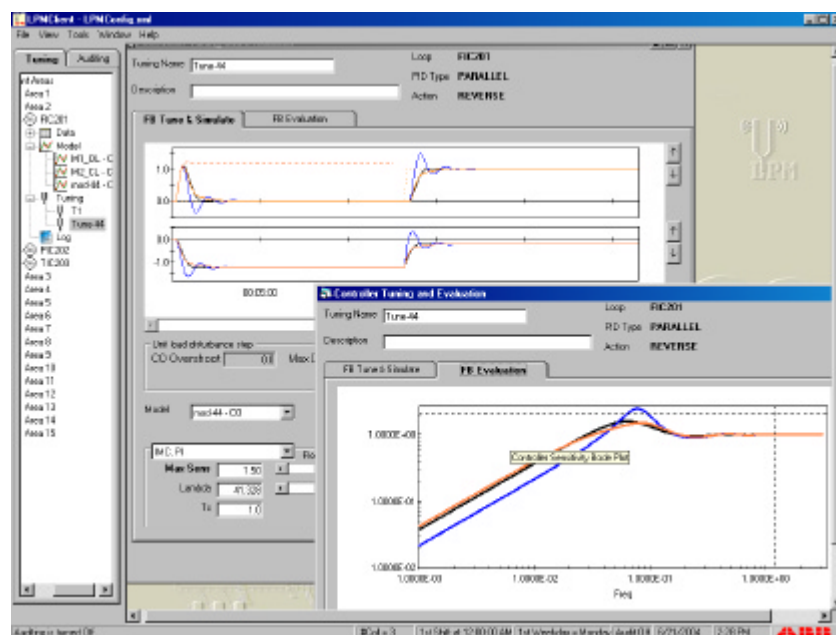
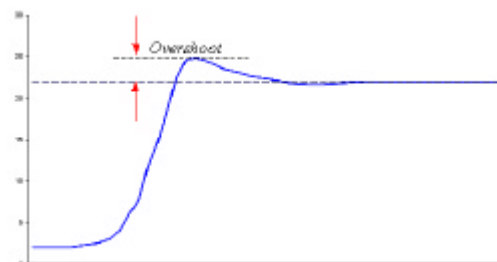


Figure 8 – Example of tuning performed with LPM

An optimisation algorithm calculates the best tuning parameters and presents simulations of the controller response both to input disturbances and setpoint variations. Plot analysis is completed by numerical indices such as the integral of absolute error, the overshoot value⁹ or the settling time. This way the user can select the most effective tuning for his purposes thanks to objective numerical parameters and not just because of his experience or “intangible” impressions.

⁹ Overshoot is the term given to the difference between the peak of the transient response and the final operating value of a process output (PV), with respect to a change made on the process input (CO).

A response with overshoot does not necessarily represent an intolerable behaviour; on the contrary, especially if the peak is short and not pronounced, it can be judged according to the speed the setpoint proximity is reached with this response.

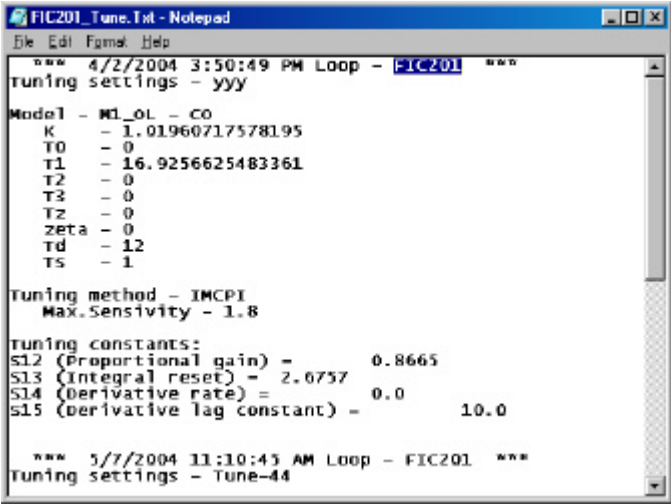


Finally, the user can also perform a final “*fine tuning*”, adjusting the parameters by means of convenient sliders, that allow to comfortably explore the margins of uncertainty and stability of the controllers and find the best trade-off between robustness and speed.

Once the best tuning has been found for the feedback part, the user can use a similar procedure to also tune the contribution of the feedforward part, on the basis of the identified models as described in para. b) above.

Before closing the tuning activity, LPM saves the results of the session in special logs that go to form a sort of historical archive of all the jobs done on the loop. The importance of this “*book-keeping*” function should be not overlooked. Storing over time not just the tuning results, but also the “how” and “why” such results have been achieved, can avoid common dangers deriving from staff turnover and reduces the natural hesitation of younger and less expert personnel to change parameters which are “working, for worse or better”.

A final prominent feature of the product consists of the possibility of performing tuning operations at the same time as normal monitoring functions.



```

FIC201_Tune.Txt - Notepad
File Edit Format Help
*** 4/2/2004 3:50:49 PM Loop - FIC201 ***
Tuning settings - yyy

Model - M1_01 - CO
K - 1.01960717578195
T0 - 0
T1 - 16.9256625483361
T2 - 0
T3 - 0
Tz - 0
Zeta - 0
Td - 12
Ts - 1

Tuning method - IMCPI
Max.Sensitivity - 1.8

Tuning constants:
S12 (Proportional gain) = 0.8665
S13 (Integral reset) = 2.0757
S14 (Derivative rate) = 0.0
S15 (Derivative lag constant) = 10.0

*** 5/7/2004 11:30:45 AM Loop - FIC201 ***
Tuning settings - Tune-44

```

Figure 9 – Example of Tuning Log

4 EXAMPLE OF APPLICATION

One of the most interesting facets, in any advanced application, relates to comparing and gauging the benefits and the practical difficulties its use entails.

A first aspect to be considered is the complementarity between *tuning* and *auditing*, both in the phase of maintenance of existing systems and in the phase of commissioning new applications.

Consider for example a project of loop re-tuning at a polymer production plant where the authors have been involved. In this case, the plant has been running for decades and the field instruments (sensors, valves, pumps, etc.) are pretty old and weary. Loop tuning was first performed when the plant was commissioned and the relevant maintenance was done in a non-systematic way, with the practical result that some loops are still well tuned, updated and performing, while others have tuning parameters dating back years and years.

In a case like this, one possible approach is to perform a *massive and indiscriminate* tuning of the whole loop collection, perhaps split up into units. An activity of this kind would require, for the loop screening activity only, hundreds of hours of work of an expert technician.

An alternative procedure would be to configure the auditing functions and acquire data and information on the *shape status* of the various loops; this way it is easier to identify and categorise the

problems of the various loops, before the tuning activity; this permits anticipating the solution to any problems and makes it possible, through the re-modulation of the activity plan, to maximise overall efficiency. An example of the obtainable benefits can be appreciated by considering the maintenance of a valve affected by malfunctions, one of the main pre-requisite in indiscriminate tuning activities; by operating one loop at a time, a series of problems affecting the actuators is identified and these must be solved before going ahead with further tuning activities. By using the auditing functions, this does not occur because instrument maintenance jobs can be foreseen and anticipated, and consequently carried out *before* tuning.

Consider, for instance, the case of one of the loops retuned in the project, details of which are shown in Figure 10. From a quick examination of the figure, a valve *stiction* problem immediately becomes clear, with the process variable assuming the characteristic "levels" shape, while the control output has a *ramp* movement. This type of problem can only be solved through actions in the field, which require a good level of coordination with the maintenance department; the possibility of an "early warning" therefore represents a major chance to increase efficiency in executing these operations.

A second aspect to be taken into consideration is the simple manner in which the tuning operations can be performed, once hardware problems have been found and solved. For instance, loop tuning can be performed in closed-loop configuration, meaning by performing *step changes* on the setpoint. This capability is much appreciated in the case of critical loops, where we wish to be certain that the process variable will never move away from the setpoint, not even during loop tuning.

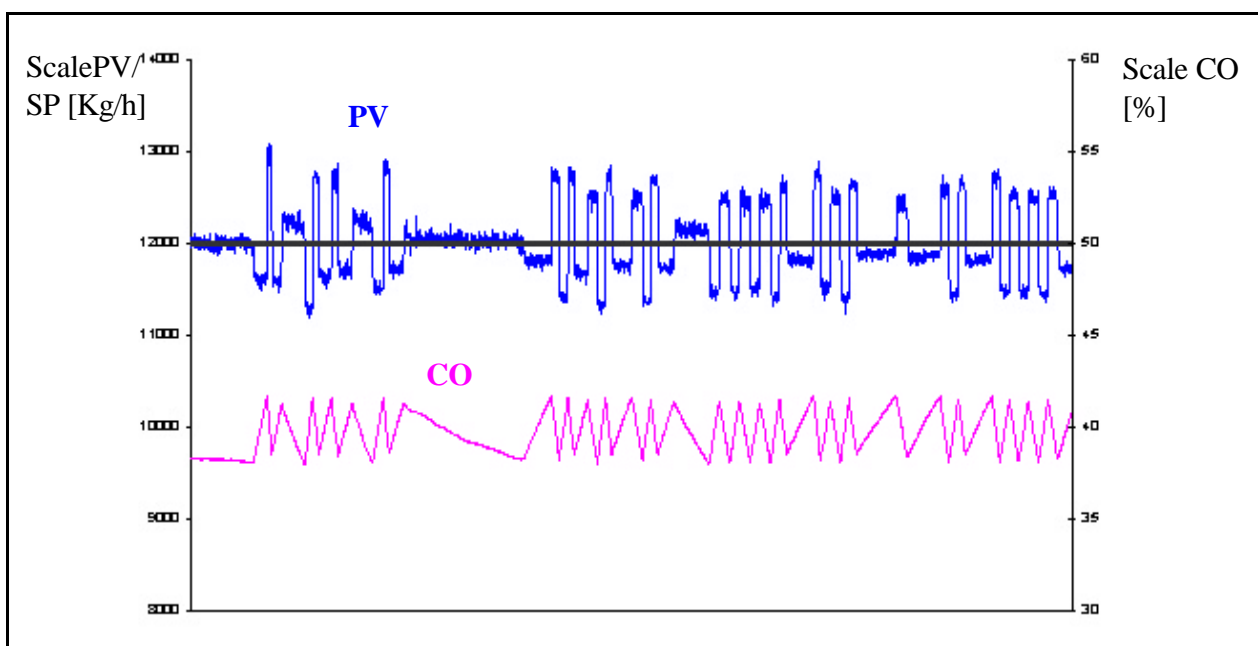


Figure 10 – Example of valve affected by stiction

Figure 11 shows an example of tuning activity performed on a plant loop; this loop features a very quick response that can be assimilated with great accuracy to a first order model (see the green curve shown in green at the bottom of the figure). In the upper part of the figure, the excellent response of the loop after being re-tuned with LPM can be appreciated, both as regards disturbance rejection and the response to a setpoint step-change.

Tuning results are provided by LPM directly in the terms of the configured PID function code parameters and can therefore be directly entered into the DCS, without any further conversion.

Another important and useful aspect from a practical viewpoint is the possibility of exporting the log files and the reports created by LPM into other software applications. The possibility of exporting results makes the creation of activity reports and the management of tuning parameter historical databases much more simple and efficient, simplifying considerably the generation of project documentation.

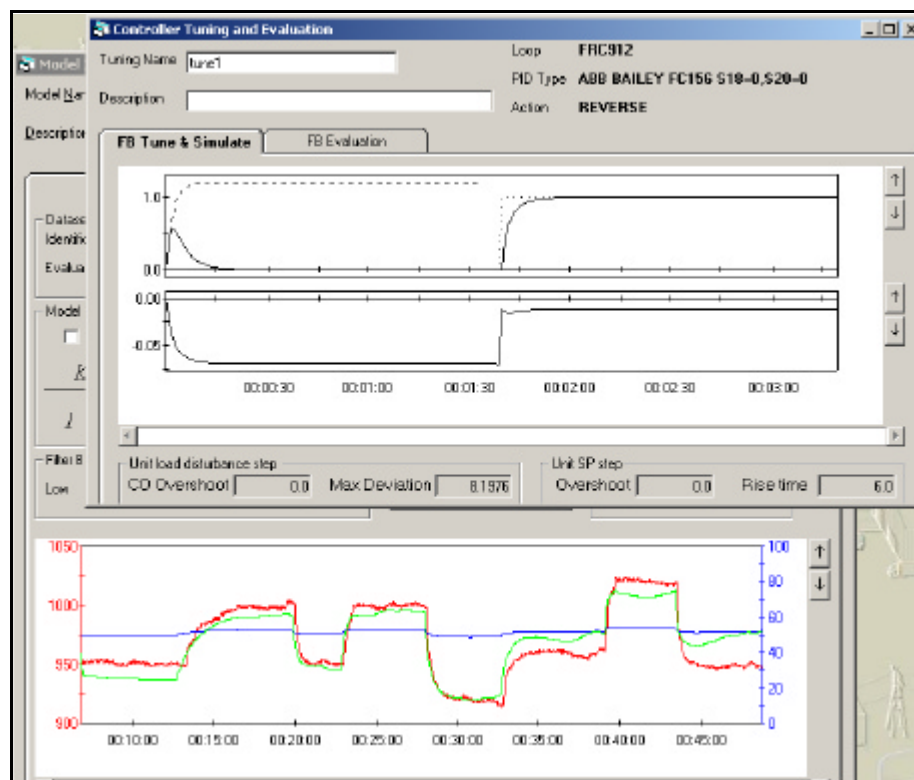


Figure 11 – Carrying loop tuning

5 CONCLUSIONS AND FUTURE PROSPECTS

The solution presented in this paper met with the interest of the market. It is based only on process data collected in standard mode. It does not require specific testing campaigns, or any previous knowledge of process characteristics. The modern software structure gives it powerful computation capacities and at the same time makes it easy to implement and operate, providing information in a concise and effective way.

The possibility of combining, in a single product that is easy to connect and use, both the explorative (auditing) and the executive part (tuning), together with the reliability of its findings, makes it one of the most interesting platforms for conveying, in the process industry, the results which research has produced in the field of basic tuning management.

Encouraged by the feedback coming from end users, the development team is working to extend the above-described functionalities according to a development plan that extends in three main directions:

1. upgrading of basic information technology structures with gradual extension of connection and reporting capacities (remote access, formats compatible with multimedia requirements, special reports for indices featuring biggest variations);
2. introduction of concepts and research methods relating to the root causes of disturbances;
3. gradual inclusion of process performance evaluation.

While the first point concentrates essentially on the creation of a series of functions that make the information provided by LPM even easier to use, points 2 and 3 deserve a few words more.

Once it has been ascertained that a process is no longer operating as expected, the important thing is to be able to determine the root cause of the deviation from expected behaviour. The search for methods able to pinpoint the root cause (*root cause analysis*) has witnessed the expenditure of a great deal of effort over recent years (for more details see for example [12]) and has led to the finding of methods and tools which seems very promising for the process industry.

Control system evaluation methods can provide useful indications not only about the state of the controllers themselves, but also about the components with which these interact. They can for instance underline the suspicion of the presence of leaks or malfunctions of sensors and actuators. The completion of such information with an overall evaluation of the state of the process and of its single hardware components naturally represents the ultimate aim of any monitoring system. The inclusion of powerful statistical methodologies within commercially available products [8], opens up the possibility of realising integrated systems that can cater for all the requirements of a modern plant.

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REFERENCES

- [1] Harris, T.J., (1989), "Assessment of control loop performance", The Canadian Journal of Chemical Engineering, **67**, pp. 856-861
- [2] Hugo, A.J., (2002) "Process controller performance monitoring and assessment", www.controlarts.com
- [3] Isaksson, A.J., Graebe, S.F., (1995), "The derivative filter is an integral part of PID design", Control Theory and Applications **149**, January 2002, pp. 41 - 45
- [4] Harris, T.J., Seppala, C.T., (2001), "Recent Developments in Controller Performance Monitoring and Assessment Techniques", CPC, 2001
- [5] Kinney, T., (2003), "Plant wide performance monitor bridges resource gap", Proc. of ISA 2003, Houston, TX, October 2003
- [6] Horch, A., Heiber, F., (2004), "On evaluating control performance on large data sets", Dycops,
- [7] Li, Q., Whiteley, J.R., Rhinehart, R.R., (2004) "An automated performance monitor for process controllers", Control Engineering Practice **12**, May 2004, pp.537 – 553
- [8] Qin, J.S., (1998) "Control performance monitoring – a review and assessment", Computers and Chemical Engineering **23**, pp.173 – 186
- [9] Grimbale, M.J., (2002) "Controller Performance Benchmarking and Tuning using Generalized Minimum Variance Control", Automatica **12**. pp. 2111 - 2119
- [10] Bonavita, N., Martini, R., Matsko, T., (2003), "Improvement in the Performance of Online Control Applications via Enhanced Modeling Techniques", Proc. of ERTC Computing 2003, Milan, Italy
- [11] Thornhill, N.F., Oettinger, M., Fedenczuk, P., (1999), "Refinery-wide control loop performance assessment". Journal of Process Control **9**, (1999) pp. 109 - 124
- [12] Thornhill, N.F., Xia, C., Howell, J., Cox, J., Paulonis, M., (2002) "Analysis of Plant-wide Disturbances through Data-driven Techniques and Process Understanding", Proc. of 15th Triennial IFAC World Congress, Barcelona, Spain, 2002