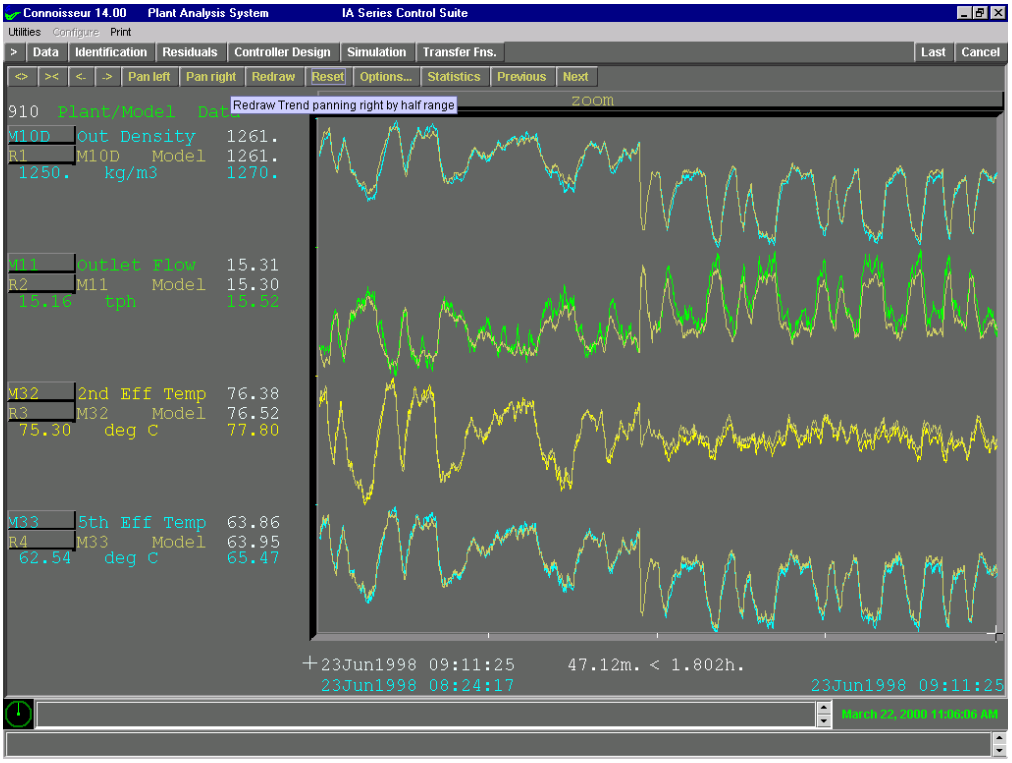
I/A Series® Control Suite Connoisseur™ Toolkit



The Connoisseur Toolkit, a part of the I/A Series Control Suite, is a software tool for process identification and control system design, and off-line simulation of controller/process behavior. The Connoisseur Toolkit also supports on-line Connoisseur model predictive controllers running in I/A Series control processors or in other hosts. It provides a superb analysis tool that allows you to identify, describe, and model the dynamic relationships among process variables.

Process engineers use the Connoisseur Toolkit to collect process data and analyze the dynamic and steady state relationships among groups of process variables. Models of these relationships can be created and various control system designs can be defined and simulated. These model and simulation results are displayed visually. They show the response of a Connoisseur model predictive controller running coupled with the process model derived from actual plant data.

Identical simulation scenarios can be run with different controller designs for comparison purposes. From the Connoisseur Toolkit, controller designs can be downloaded to execute in I/A Series hosts or in I/A Series control processors. The Connoisseur Toolkit can be added to new or existing Foxboro I/A Series systems, or to many other proprietary distributed control system (DCS) and programmable logic controller systems.

THE CONNOISSEUR TOOLKIT

Many real world processes require control systems that are more complex than traditional PID control loops. To manage these processes, engineers have configured advanced regulatory controllers employing feedforward control, sometimes using multiple feedforward signals. These systems become much more difficult to design as the number of feedforward signals used in a loop increases. Each feedforward signal has a dynamic relationship with each controlled variable. In a block-oriented multivariable controller design, many tuning parameters need to be adjusted and readjusted to maintain controller performance. This can be difficult, time-consuming, and expensive both in terms of human resources and lost production. Such control schemes are all too often run manually or must be de-tuned to such an extent as to be ineffective. In such cases, an inadequate control system design may constrain the entire process. Also, it is simply not possible to simulate and test many different sets of tuning parameters or different controller designs using a DCS that is controlling the actual plant process.

To address this difficulty, most process engineers implement multivariable control by using model predictive controllers. Model predictive control schemes are particularly beneficial in processes that exhibit long time delays between actuation and measurement, which have complex process dynamics or in which many variables interact. In any combination of these circumstances, accurate control is often difficult to achieve using conventional control methods. The Connoisseur Toolkit can address these issues, providing a cost-effective solution for the design, tuning, and maintenance of both model predictive and advanced regulatory controllers.

The Connoisseur Toolkit gives process engineers a critical visualization capability, enabling them to analyze the behavior of their process operating with a variety of different controller designs. Connoisseur offers a comprehensive range of facilities for the development, implementation and support of control strategies. The diverse range of technologies required through the whole control design and implementation cycle are uniquely brought together in Connoisseur.

What Is Included?

The Connoisseur Toolkit includes all the components of the Connoisseur model predictive control software. The complete functionality of Connoisseur is included. The only distinction of the “Toolkit” is that the Toolkit software is not licensed for real-time control of a process except during process response testing.

Process Response Testing

The Connoisseur Toolkit provides complete facilities for the acquisition, conditioning and processing of plant data during normal operation and during response testing. Interface software exists to permit communication with a wide range of industrial control equipment, including the most common distributed control systems, historians, and programmable logic controllers. Measurements can be defined with individual sample intervals, scaling, and filtering characteristics.

The response test data is archived and can be viewed in a variety of ways using Connoisseur to permit insight into process behavior. Trend graphics are provided, which present historical signal variation over a defined time span. Other facilities include residual trend diagrams and automatic statistical calculations (mean, standard deviation, range, and so forth) of trended data. Selected historical data can be stored, either automatically or on user request, creating a permanent record of process operation, which can be used for later analysis by Connoisseur or by other software (including Microsoft™ Excel™). This is often useful for a comparison of before and after control performance.

Data acquisition is only one function in the performance of process response tests. In order to obtain a response, the process is normally deliberately perturbed by adjustments to process input signals, which may be either set points of existing regulatory (PID) controllers or direct actuation signals. The perturbations may simply be manual steps. Alternatively, Connoisseur is able to generate automatic process test sequences (known as Pseudo Random Binary Sequences, or PRBS) which possess appropriate statistical properties. By using these low amplitude, high frequency signals, it is usually possible to characterize the process without creating unacceptable transients or moving the process away from an acceptable operating region. During the course of such a test, the acquired data can be examined using cross-correlation analysis. This allows the rapid determination that data of appropriate quality has been obtained to identify the dynamic behavior of the process. Figure 1 shows a Connoisseur display of PRBS sequences and the resulting process response data.

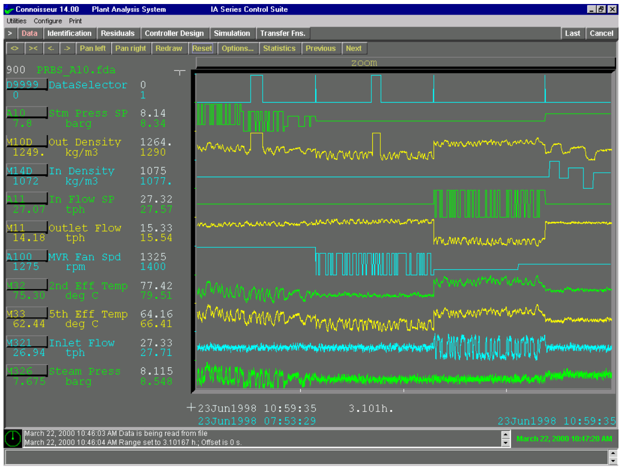


Figure 1. Collected Process Data for Analysis

Data Analysis Using the Connoisseur Toolkit

Effective process modeling requires insight into the process behavior. Connoisseur provides a portfolio of statistical data analysis tools that promote this insight and lead to effective process models. The portfolio includes:

- visual data editing to remove outliers, spikes, noise, or faulty data
- algebraic and statistical transformations to compensate or otherwise characterize raw process plant signals
- cross-correlation and auto-correlation for quantification of input/output dependencies and for the analysis of the statistical properties of the data
- power spectral density analysis to determine appropriate sampling rates and detect aliasing.

Process Identification

Having completed satisfactory process response tests with the Connoisseur Toolkit, the resulting data is used to identify a dynamic model of the process. Connoisseur uses a linear time series sampled-data model with a multi-input, multi-output structure. This model is usually identified from plant data as described below, but can also be imported from existing transfer function or state-space model representations, if these are available.

The model predicts the values of the plant outputs at a defined future instant, based on the present and past values of process inputs and outputs. The user specifies a few simple parameters which dimension the model; the number of input and output signals, the prediction interval, the order of dynamics and any known pure time delays. The model coefficients which multiply each of the input and output samples and which aggregate to form the output predictions are then estimated automatically by Connoisseur.

Process identification is performed using an unbiased recursive least squares technique. This technique seeks to minimize the prediction error of the model in application to the data generated during the plant test.

In order to assess the accuracy of the model, it is subjected to the same pattern of input signal variation as the process itself. The predicted and actual responses are then presented by Connoisseur, both quantitatively and graphically. In order to improve the model accuracy, the engineer is able to revise the model design choices and iterate towards an improved process model. Connoisseur's user interface provides a side-by-side comparison of key model statistics for each model interation. The figure on the cover shows data from a process model plotted against actual plant process history.

The model is able to describe time delay, multivariable interaction and complex dynamic responses. With such a representative process model, a model predictive control system design can be derived which accurately compensates for these characteristics.

Control System Design

The model predictive controller is designed by maximizing an economic performance function which considers weighted contributions of set point error, incremental control effort, and actuation deviation from target over a finite time period. These weights are normalized values, not engineering units, so they can easily be compared with each other. This time period is known as the design horizon and represents a projection of the closed loop control performance into the future. The duration of this horizon is made large enough to ensure that the cost function converges towards a unique solution.

The result of this design process is a fixed set of controller gains, which give optimal control over the design horizon. The Connoisseur control algorithm uses these gains to multiply measurement error, previous incremental control effort and any feedforward changes to compute the control action during each controller period.

The structure of the control algorithm is completely defined by that of the model. The number of input and output signals is the same. The number of gains is determined by the number of coefficients used in the process model.

The controller considers the error of each of the controlled variables from its set point, the actuator movements made by the controller, and any deviations from actuator steady state targets. The user can influence the behavior of the control algorithm by adjusting the appropriate normalized weightings. Increasing a set point error weighting causes a relatively greater contribution to be made by this signal to the total economic performance function. The design procedure seeks to eliminate set point error from this signal preferentially at the expense of other set points and by more aggressive control effort. Similarly, increasing the weighting on an individual, manipulated variable directs the controller to operate more on other actuators, or to allow a longer period of deviation from set point for the lower weighted set points.

Simulation

In order to help assess the characteristics of a control system design, the Connoisseur Toolkit offers the complete off-line simulation facilities of Connoisseur's plant analysis system. A controller design is applied in a closed loop to the process model and set point changes are made at controlled intervals under simulation. The responses are presented in graphical form to provide insight into the likely behavior of the controller when applied in the actual plant. It is normal engineering practice to use the design weightings and the simulation facilities to tailor the closed loop response before deploying the controller on line. Figure 2 shows a Connoisseur display of a typical control system off-line simulation.

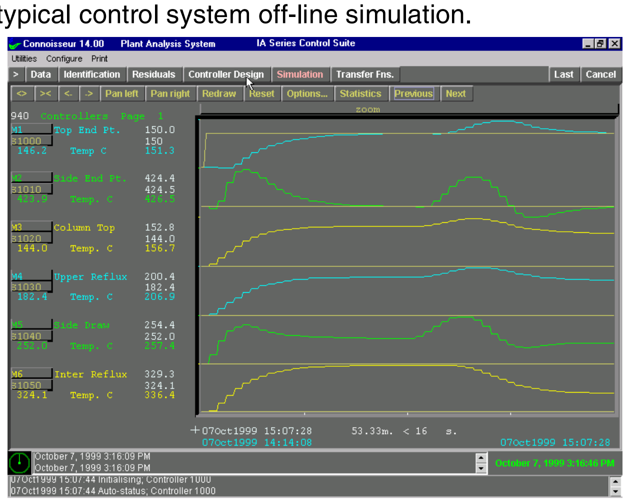


Figure 2. Control System Simulation

Support of On-Line Connoisseur Model Predictive Controllers

Multivariable controllers designed using the Connoisseur Toolkit can be downloaded into the I/A Series Control Processor 60 (CP60). Each of these controllers can support configurations of up to 30 variables (10 controlled, 10 manipulated, 10 feedforward). They operate using Connoisseur's on-line control engine, which is implemented in the I/A Series CP60. The model predictive controller design is downloaded into the CP60 using the Connoisseur Toolkit. Once downloaded, the I/A Series system checkpoints and maintains the controller parameters. At this point, the I/A Series system provides complete support of the on-line operation of the controller. No host computer is required, and the controller can run in fault-tolerant CP60 configuration. All on-line support and monitoring is performed by the control processor and the I/A Series system. The downloaded controller can also include Connoisseur's Linear Programming (LP) optimization and constraint management capabilities.

As needed, a PC or workstation running the Connoisseur Toolkit can download any updates to the controller design coefficients. This relationship between the Connoisseur Toolkit and the I/A Series system is similar to that between single hand-held calibration tool which is used for configuring multiple intelligent sensors.

Supported I/A Series Platforms

Application Workstation 51, Styles B, C, D, E and Application Processor 51, Styles B, C, D, E

- Minimum of 128 MB RAM
- Minimum of 8 GB disk
- Minimum 1 GB spare capacity for Connoisseur
- 9 mm tape drive or CD-ROM
- Solaris™ 2.5.1 or later operating system.

Application Workstation 70

- Minimum of 128 MB RAM
- Minimum of 8 GB disk
- Minimum 1 GB spare capacity for Connoisseur
- CD-ROM
- Windows NT™ 4.x or later operating system.

Supported Network Platforms

Intel™/Windows NT 4.x or later

- Minimum of 128 MB RAM
- Minimum of 8 GB disk
- Minimum 1 GB spare capacity for Connoisseur
- CD-ROM
- Ethernet network communications card.

SPARC/Solaris 2.5.1 or later

- Minimum of 128 MB RAM
- Minimum of 8 GB disk
- Minimum 1 GB spare capacity for Connoisseur
- 9 mm tape drive or CD-ROM
- Solaris 2.5.1 or later operating system.

Interfaces Available For Process Data Collection

Integration with Foxboro I/A Series systems is provided. Integration with other DCS and programmable logic controller systems is supported for the platforms listed below. Interfaces to other DCS and programmable logic controller platforms must be quoted specifically. The following DCS and programmable logic controller interfaces are available:

- ABB MOD300 via Computer Gateway
- ABB MOD300 via Advant platform (integrated system)
- Allen-Bradley DF1 for PLC/2 and PLC/5
- Fisher Provox via Chip interface
- J Bus
- Modbus™ RTU protocol
- Honeywell TDC3000 via either CM50S or CM50N gateway
- Honeywell™ TDC 3000 via AXM
- Rosemount™ System 3
- Beckman RMV9000 via RMT/HOST
- OSI Software PI™ System
- Square D PLC (Symax interface)
- TCS ANSI Binary Protocol
- Texas TI 500 series PLC
- Yokogawa Centum DCS via Centap
- Yokogawa Micro XL.

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MB 021 Printed in U.S.A. 0900

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