MACHINE HISTORY VIEWER FOR THE INTEGRATED COMPUTER CONTROL SYSTEM OF THE NATIONAL IGNITION FACILITY*

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ABSTRACT

The Machine History Viewer (Fig. 1) is a recently developed module of the Integrated Computer Control System (ICCS) software to the National Ignition Facility (NIF). This software introduces the capability to analyze machine history data to troubleshoot equipment problems and to predict future failures. Flexible time correlation, text annotations, and multiple vertical axis scales will help users determine cause and effect in the complex machine interactions at work in the NIF. Report criteria can be saved for easy modification and reuse. Integration into the already-familiar ICCS GUIs makes reporting easy to access for the operators. Reports can be created that will help analyze trends over long periods of time that lead to improved calibration and better detection of equipment failures. Faster identification of current failures and anticipation of potential failures will improve NIF availability and shot efficiency. A standalone version of this application is under development that will provide users remote access to real-time data and analysis allowing troubleshooting by experts without requiring them to come on-site.

The architecture and functionality of the Machine History Viewer will be presented along with examples.

BACKGROUND

The NIF [1,2] control system includes about 40,000 individual devices, including over 10,000 motors. Many of these devices leave a record of their actions and readings in the machine history database. Examples include motor position and velocity, binary output commanded position and temperature sensor readings. As a whole, NIF presently has over 300 million rows of machine history data, and the archive grows by over 14 million rows each month. This data is valuable for understanding the behavior of the system, for troubleshooting, prediction of problems before they occur, and system optimization. The challenge is to enable the users to access this data in a convenient fashion, and to present the results in a useful, easy-to-understand display.

TERMINOLOGY

Individual providers of machine history (e.g. motors) are called *Subjects*. Each Subject has one or more *Attributes* (e.g., position and velocity for the motor). The *Value* of the attribute may be a number or text (or soon to be image). A *Timeline* (Fig. 2) is an ordered list of time

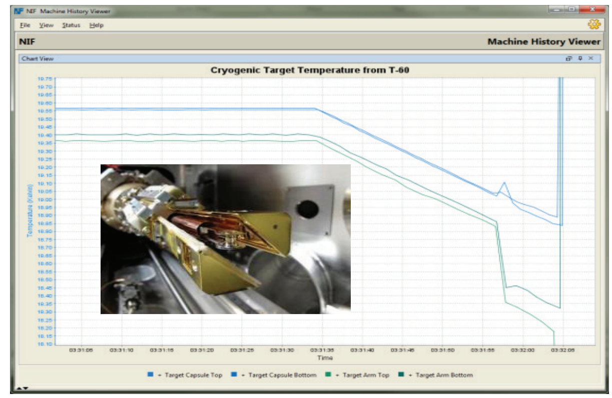

Figure 1: Chart showing temperature of NIF target for 60 seconds prior to shot. Shroud (inset photo) opened at T-8 seconds, causing rise in temperature, compensated for by lowering temperature of the target holder.

stamps and Values for a specific Source Name and Attribute. For example, the list of all motor positions for a specific motor for the past hour would be a Timeline. *Timeline Sources* represent a data store (e.g. a particular database table, or file saved on disk), and are identified with unique *Source Names*.

USE CASES

The Machine History Viewing Tools are used by system operators, scientists, engineers and technicians. System operators gain situational awareness from recent history (e.g., temperature or position plots). Scientists can improve system alignment accuracy by identifying interferences such as heat from chamber illumination sources. Engineers and technicians can troubleshoot

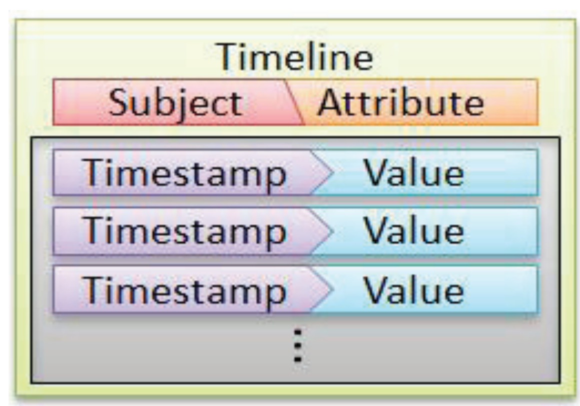

Figure 2: Timeline structure.

ISBN 978-3-95450-139-7

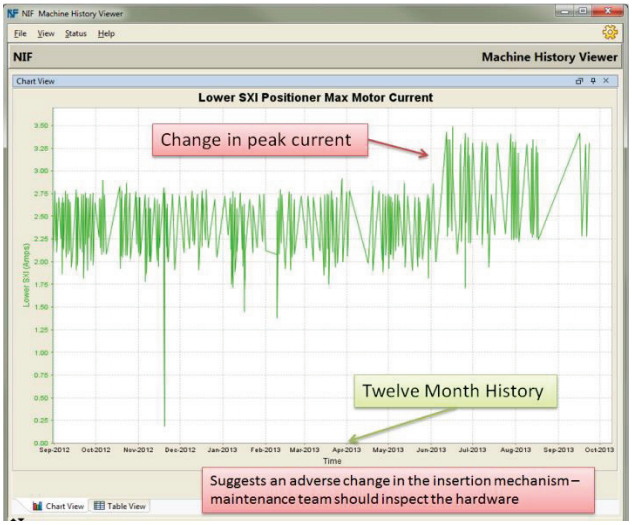

Figure 3: Chart showing maximum motor current per move, for one year, for the Lower Static X-ray Imager insertion motor.

system problems and design efficiency improvements for future upgrades. Engineers can also observe trends in system behavior which will allow repairs or service to be performed before a system failure occurs (Fig. 3).

USER PRESENTATION

Strip Chart

The Machine History Viewer uses a strip chart display as its primary presentation. This is a standard view for time-based data, and is particularly useful when correlating different device behavior over the same period. The chart view allows multiple timelines on the same display. It also allows live updating with horizontal scrolling (much like an analog strip chart device). The strip chart allows zooming, panning, and auto-scaling, all with mouse movements. Clicking the legend for specific timelines will hide or show that timeline on the chart. Hovering over any data point will show a tooltip with the date/time and value for the point.

Table View

Also available is a table-view, showing the timeline values in an Excel-like grid. The table view is better for seeing specific data values, or series of values. The table can be sorted on any column and can contain both numeric and text values. Users can also export the table data to an Excel file. The export contains an initial sheet of the combined data, and then individual sheets for each timeline. The combined sheet usually contains many blank cells, since it's time-correlated and not all devices archive history at the same time. The individual sheets don't have gaps, which simplifies their use in Excel for plotting or sorting.

MULTIPLE VERTICAL SCALE

A problem in simple strip chart displays is that if multiple timelines are shown on the same chart, the timeline with the greatest range of values dominates the scale. For example, if the chart shows a motor with a range 0 to 7000 mm, and the same chart shows a brake (on/off) with a range of 0 to 1, the brake will appear as a straight line, because the vertical scale will be 0 to 7000. The Viewer solves this problem by supporting multiple vertical scales. Now the chart can have two scales, one for the motor and one for the brake, and the changes to each will be clear (Fig. 4). The Viewer is flexible in that any timeline can be assigned to any scale. So if there are multiple devices sharing a similar range of values, they can be plotted against a shared scale. Scales can be depicted on the left, or right, or both sides of the chart. Manual selection of the minimum and maximum axis values can effectively shift timelines to place them in a more meaningful location (see Fig. 5).

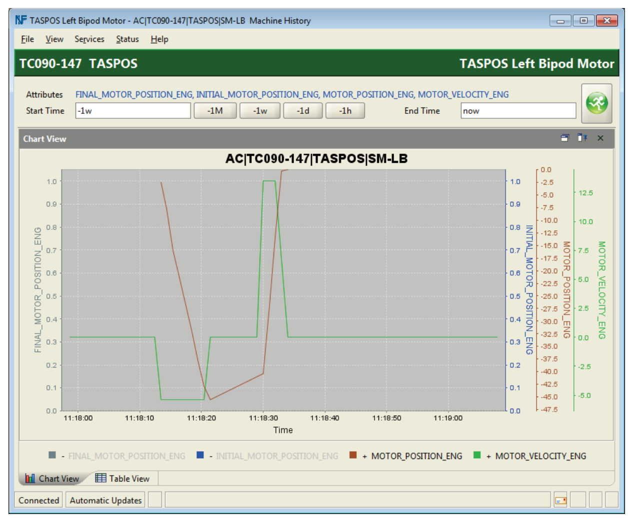

Figure 4: Chart generated using the Target Alignment Sensor left bipod motor Device Control Panel. All attributes for the devices are shown by default, but the user has clicked to hide the first two attributes in this example.

SPECIFYING REPORT CRITERIA

Multiple interfaces are available to view NIF machine history.

Device Control Panel

Each NIF device has a maintenance or control panel. For example, there is a GUI which can be used to control each of the NIF motors. The ICCS control system has a rich navigation system to access the device control panels, and the system operators are very comfortable finding the control panels. The control panel framework now has a menu option to show the machine history for that device. The history panel (Figure 5) prompts the user for the time frame, but otherwise already knows the

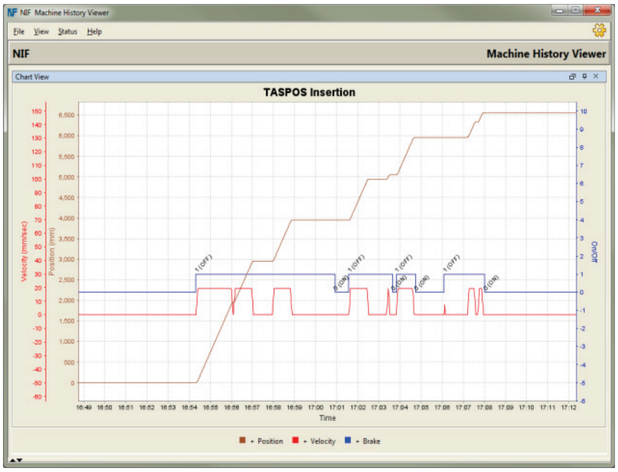

Figure 5: Chart with multiple Y-scale. In this chart, all the following are visible: the motor's position, velocity, and the position of the parking brake. The motor range is 7000 mm, the velocity 150 and the brake zero to one. In the Machine History Viewer, the user has full control over all scales, labels and colors on the chart.

source name, and automatically displays the timelines for all attributes for that source.

To correlate timelines from multiple devices, the operator can open the control panel history for another device, and drag a timeline from one chart to another.

History Report Wizard

For full control over the report, a report wizard tool is available. This provides an editor where users specify which vertical scales they want, and which timelines should be assigned to each scale. Timeline and scale legends and colors may all be specified through the wizard, but defaults are provided for all. Once the report is generated, the editor can be used to modify or extend the report.

Report Criteria Files

Users can save any report setup (without the timeline data itself) to a report criteria file (Fig. 6). This file contains the full report specification, with time range, source names, attribute names, scales and legends, etc. This file can be drag/dropped onto the standalone report writer to quickly re-run any saved report. These files can also have relative time ranges. For example, a report could show NIF target temperatures for the past 24 hours. These text files are stored in YAML format [3], which is computer-readable but also easy for people to read and modify with a text editor.

TIMELINE SOURCES

Multiple Sources

Timeline Sources can pull data from various sources. The implementation details of this process are encapsulated within the concrete classes to provide the greatest flexibility.


```
!panel
title : &title TASPOS Insertion
size :
  width : 200
  height : 100
charts:
- title : *title
  start_time: 9/12/2013 00:00:00
  end_time: 9/16/2013 23:00:00
  scales :
  - name : Position
    minimum : 0
    maximum : 6600
    units : mm
    color : brown
    placement : left
    timelines:
    - subject_name :
          "AC|TC090-147|TASPOS|SM-Z-COARSE"
      attribute_name : "MOTOR_POSITION_ENG"
      color    : brown
      label    : Position
```


Figure 6: Sample Report Criteria File. This file is computer parse-able and human readable.

A particular Subject/Attribute pair can come from multiple sources. If data exists from more than one source, the *Timeline Repository* takes care of stitching the data together into one Timeline.

One interesting use case for this feature is annotations. One of the ICCS tables records string values for a given Subject/Attribute pair. When the software encounters a string and a numeric value, it inserts the text alongside the value on the graph. This is particularly useful for binary values that can be labeled, e.g. shutter open or shutter closed. This can also be used for identifying important events that occur associated with a value that changes over time.

Persistent Data

Many of the ICCS devices write data out to persistent sources such as a database or files on the file system. This data is generally very large. Due to resource constraints, this data is not loaded into memory until queried. This means queries are slower but initialization is fast.

There is also generic support for many tables and files formatted as Comma Separated Values (CSV). When database tables or CSV files follow a common format, these tables can automatically be analyzed and included in searches for Timeline data. Additional Timeline Sources could be created to support any number of generic or specific persistent data types.

Transient Data

Not all data comes from persistent sources. The Machine History Viewer supports Timeline Sources that gather data from live software. When a request is made, a Timeline is provided that can be refreshed as new live data is available. This data is categorized as *transient*. Transient data displays differently on the chart and can be drawn alongside persistent data. Transient data will share the same color but will be shown as a dashed line.

ISBN 978-3-95450-139-7

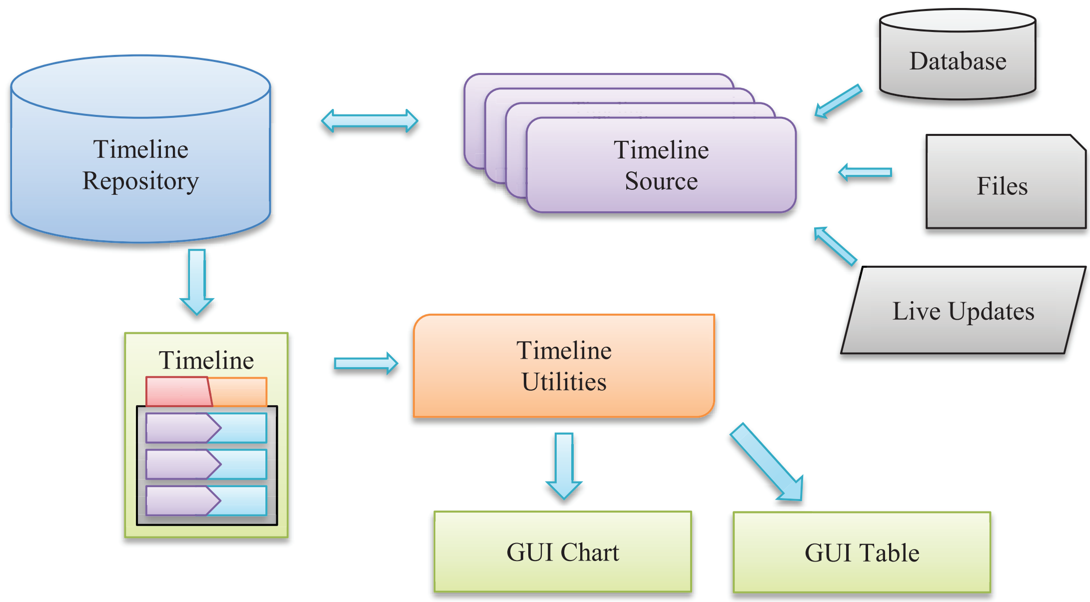

Figure 7: Machine History high level design, showing independence of timeline sources and GUIs. The timeline repository is a gateway to the data sources, but does not mirror the data.

The distinction is important to indicate to the user that if the query is run again at a later time from another instance of the software, the transient data will not be displayed in the same way. Persisted data will be displayed in a deterministic way no matter when it is queried.

The current version of ICCS software does not collect data from live sources, but there are plans to implement this feature in the near future. The same mechanism that publishes data to ICCS GUIs would be used to collect data for the Timeline Sources.

Generated Data

A unique Timeline Source has been developed that outputs generated data. This is used for regression testing of the charting GUI, but also can be used in conjunction with real data to create bounds and other guides drawn simultaneously with real data.

SYSTEM ARCHITECTURE

The system is designed (Fig. 7) to accept history data from virtually any source, and to allow it to be displayed in any fashion. Specific modules are implemented to read from the NIF machine history tables and other history text files.

Utility methods are provided to repackage timeline data, to simplify the work in the GUIs. For example, the strip charts are implemented using JFreeChart [4], which has its own data structures. A utility method is provided which will convert a set of timelines into a JFreeChart object, ready for display.

The design makes it easy to add support for new data sources without any changes to the GUIs, and to add new GUIs or other consumers without making changes to the Timeline Sources.

SUMMARY

The NIF Control System Machine History Viewer tool is a new capability which should provide many benefits to the operation and maintenance of the NIF system. Immediate history helps operators understand present context of the devices. Recent history helps scientists and engineers troubleshoot problems discovered during operations. Long-term history helps predict failures before they occur, so maintenance and repairs can be performed without impacting the shots.

By building with a flexible architecture, the system can be extended at minimal cost. New timeline sources can be added without changing the GUIs, and new GUIs can be added without affecting the timeline sources.

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[1] E. Moses, et al., “The National Ignition Facility: Path to Ignition in the Laboratory,” Fourth International Conference on Fusion Sciences and Applications,” Biarritz, France, September 2005.

[2] The National Ignition Facility Web site, https://lasers.llnl.gov

[3] YAML web site, http://www.yaml.org/

[4] JFreeChart web site, http://www.jfree.org/jfreechart/

*This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. #LLNL-ABS-631632.

ISBN 978-3-95450-139-7