Online Model

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Work very much in progress building upon the efforts and realisations of many people in past years and on the advice and wisdom of many colleagues…

Definition

An online model is a mathematical model which tracks and mirrors a plant or process in real-time, and which is implemented with some form of automatic adaptivity to compensate for model degradation over time.

To be addressed

- Model (vs Reality)
- Online (vs Offline)
- Mathematics
- Tracking and Mirroring
- Real Time
- Automatic adaptivity
- Degradation over time

Previous Incarnations

PAC'07: Agapov et al. "LHC On-line Model"

"The goal is not to provide a real-time interactive system to control the LHC, but rather a way to speed-up interaction with […] MAD-X and to facilitate off-line analysis […]."

"… aimed mainly at evaluating potential settings and providing simulations in the control room environment rather than monitoring the current machine status."

"For security reasons the on-line modelling software should be separated from the control applications."

Online vs offline.

MAD-X as underlying mathematical engine, but NOT exclusively.

No monitoring, mirroring or tracking.

Previous incarnations

LTC March 2008: W. Herr
"MAD-Online Model - Application to Operation"

Make beam dynamics calculations available in the CCC

- Provide representation of the machine for high level applications
- Provide high level applications
- Simulate behaviour of live or design machine
- Simulate effect of changes to live machine
- Provide input for real time applications (optics model, knobs)

Very ambitious program, going all the way to tracking, simulation of collective effects (beam-beam), bunch to bunch…

Good points on aperture model or simulation of measurements.

Can use engines other than MAD-X

Previous Incarnations

IPAC’10:

K. Fuchsberger et al. “JMAD – integration of MADX into the Java world.”

C. Alabau Pons et al. “The Online Model for the LHC”

and many papers in following conferences…

Setting the basis for the Online Model that we have now.

Mature architecture with integration into LSA.

- JMAD hides the MAD-X details from the rest of LSA
- JMAD provides models and calculated parameters to other clients (aperture meter…)

Existing Features

G. Mueller, “Online Model Training”, Sept. 2010

- What does the Online Model do for you?!
  - execute MadX (Methodical Accelerator Design) scripts in the CCC (Cern Control Center)
  - display Optic Information from
    - defined Optics in LSA (LHC Software Architecture) Database
    - output of MadX
    - output of JMad (Jave API for MadX)
  - display Beam Process Information
  - display theoretical Aperture including 1 Hz measured Collimator Jaw Positions
  - display Beam Envelope around Orbit Trajectory
  - create Knobs from MadX scripts and upload to LSA
  - define a Optics Model to use in JMad
  - generate/upload optics to LSA
  - retrieve Power Converter settings from LSA (on Strength level)
    - for Optic simulations in MadX / JMad
    - to display the current settings for verification
  - import Orbits from YASP orbit logging files

Existing Features

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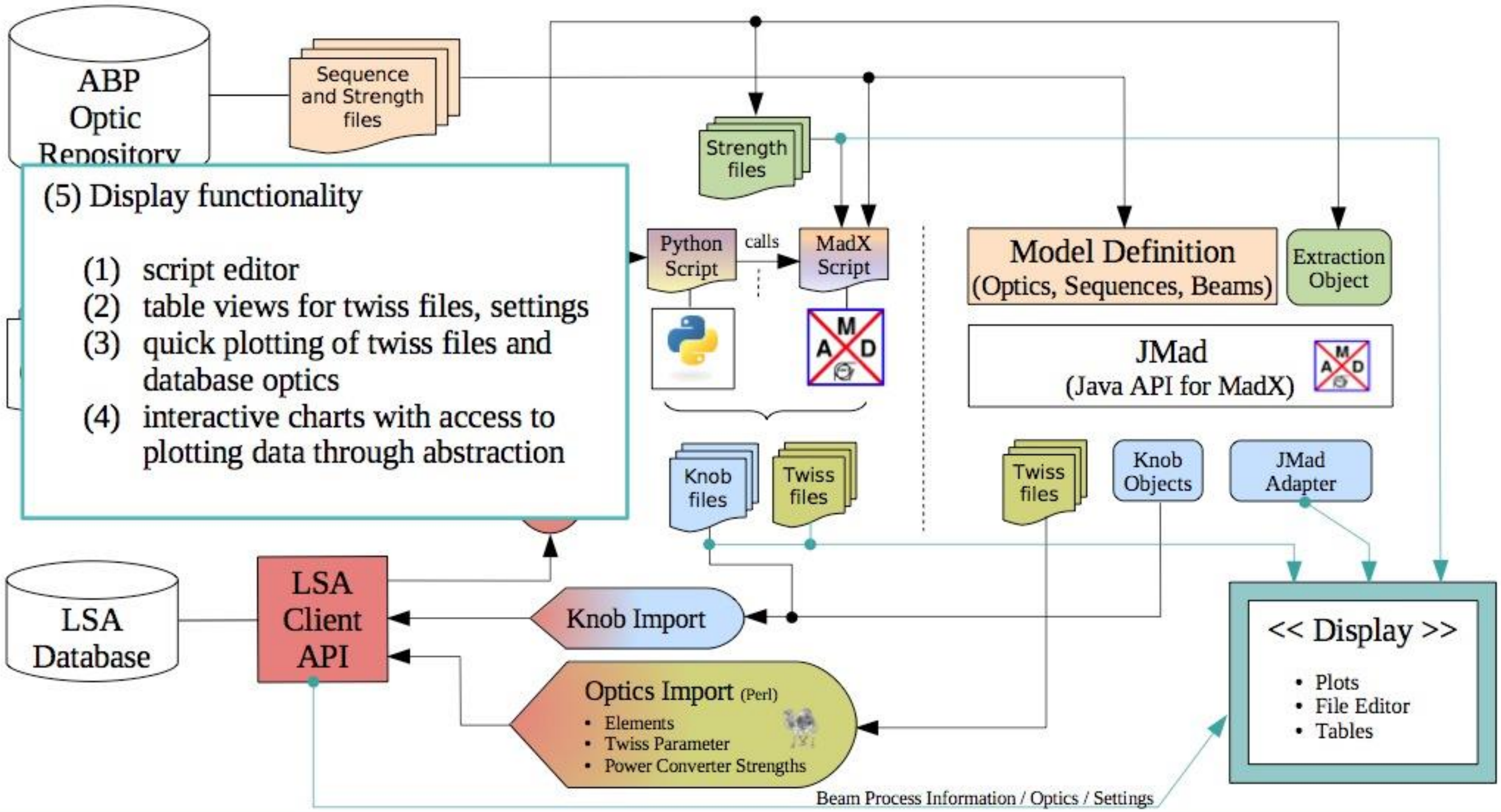
➢ How does it work? ⇨ Online Model System Overview



JMAD

- Model Definition is :
  - Sequence file
  - Strength files…
  - Beam files

Imported from ABP repos.
Used to load optics in LSA

  - Knobs
  - Errors (?) and Corrections (!)

Model

- Many important elements are already available online to model and drive the LHC, e.g. Aperture, magnetic model (FiDeL)

- Model can and will improve as optics measurements and corrections keep improving.

- Model will also improve as we keep adding bits and pieces scattered e.g. syst. b2 components, but also PC limitations etc…

- Identification of sources of errors can lead to a fix
  and then the error (and eventual correction) can simply disappear.
  c.f. errors on magnetic precycle or calibration curves causing beta-beating.

- Identification of sources of errors can lead to a correction
  and then the model has to care about the error, its correction
  and the interplay.

Model

- There are also residual, non attributable errors.
  e.g. an orbit deviation coming from random misalignments.
  If the orbit excursion is reproducible, it can be corrected out with a set of calculated corrector strengths, leaving only a small residual.

- On the LHC, non attributable errors and correction trims cancel and all is well… to first order in this error
  e.g. measure Q' and trim Q' knob until proper value is measured.

- But how do we handle this in the Online Model ?
  - Ignore both the errors and the correction trims, assuming they cancel perfectly, forgetting about the residuals .
  - Ignore both the errors and correction trims, but try to simulate the residuals appropriately.
  - Simulate the full non attributable error set, such that the correction trims superimposed leave only the residuals as observed.

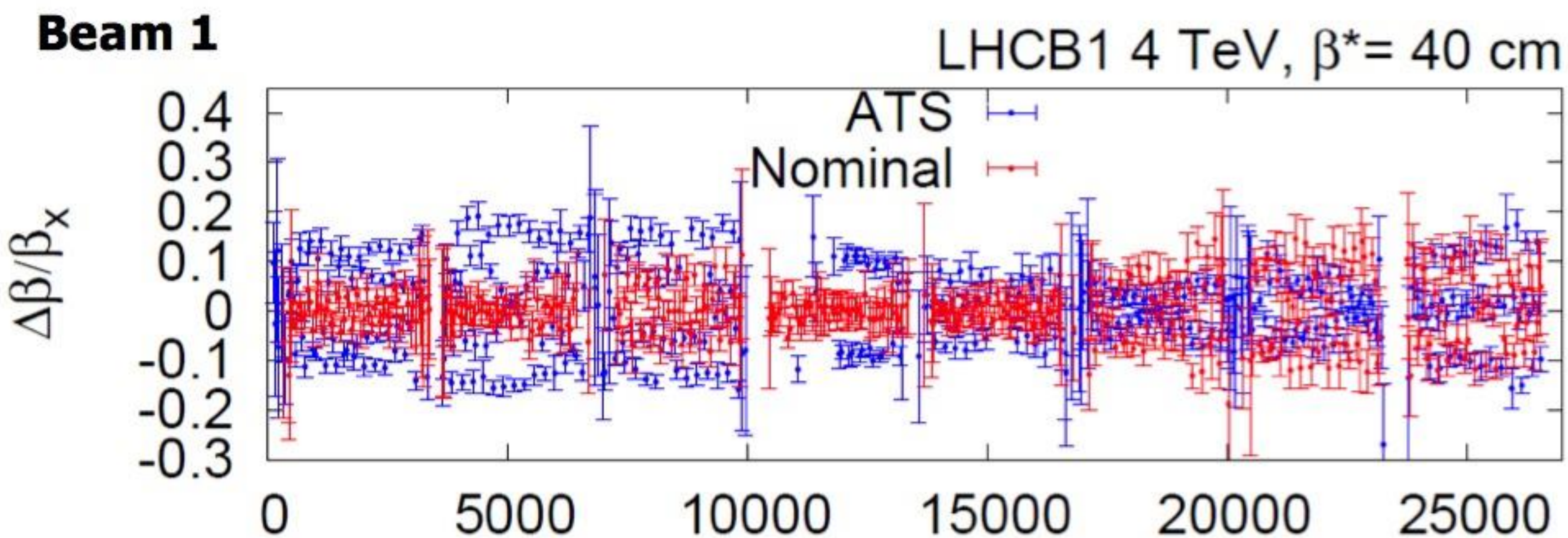
How do we simulate the error set, either the residuals or the full set ?

- In every detail ?

  Reproducing as closely as possible the residual orbit or the beating pattern.

- wrt some figure of merit ?

  Reproducing the residual sigma value for an orbit or the average beating.



Model

This is important if we want to get at higher orders.

Detailed simulation will provide best model for feed-down studies

See E. Maclean: example of feed-down to Q’ of MO powering in presence of orbit offsets from missing correctors.

Detailed simulation might quickly become involved…

Unless some bright student can finally attribute the error… (GOTO 10)

It is important to nail down the lower orders before addressing higher orders because of the effect of feed down.

A lot of this can be done off-line provided we can extract all relevant data (optics files, measurements, etc…) from the control system.

“Some things are better done quietly in your office and not online!”

Probably M. Zuckerberg

Online Model

Personal views here:

- The Online Model is best used for threading on known territory, for online checks that the actual machine and our best model agree, and to spot any deviation, indicative of a perturbation.
- Threading on known territory includes calculating and trying out new knobs, checking optics parameters in MD or special sessions, commissioning new beam processes or new optics, calculating “feed-forward” corrections, etc.
- A sophisticated application, necessary for optics loading and knob generation is certainly neecssary
- Simple pre-configured displays coud also be kept alive for the crews to check parameters and cross-check measurements with predictions. (e.g. betastar “measurement", tune diagram, Q(deltap)…)
- Most of this relies on running Twiss commands…

Some ideas heard here and there…

- Anything that can be done on the LHC itself should also be applicable to the Online Model.

- The Online Model tracks everything happening on the LHC (trims, events…), simulates on the fly and in real time, and presents results to the crew alongside actual measurements.

- This includes all foreseen non-linearities, collective effects, including bunch to bunch…

- At the flip of a button, the console switches from LHC to Model, sending trims and commands to the Online Model and receiving simulated parameters that can be displayed alongside actual measurements. Switch back to LHC and the commands and trims are now sent to the accelerator hardware…

More realistic

- Provide a model in the CCC that is as close as possible to the actual machine, including known errors and set of “probable” errors that can justify the trims and corrections implemented.

- Provide a way of extracting the machine settings at a given time with full set of knobs, trims and environmental conditions.
  - Good for special studies, MD, beam measurements, etc…

- Integration of some measurements. (K modulation…)
  - Can we actually drive the hardware ?

- Grand unification with aperture meter, OMC, and measurements is probably not desirable, lest the Online Model become a monster.
  - But applications should use JMAD as model provider.

Development

Perl scripts used to load optics

- Now being replaced by appropriate code. (Delphine)

Tighter integration into LSA

- Code review and cleanup.
- Integration is key to long term survival.
- Requires resources. (to be properly evaluated)

Underlying engine

- Online Model needs a MADX session to run for some time.
- Garbage collector has fixed an issue with memory leaks.
- MAD-X is evolving… but basic functionalities are available.

Outlook

- **<u>Online</u>** Model exists, is based on JMAD, and is here to stay
  - Must be integrated more tightly in control system
  - Review existing features and consolidate
  - Add limited set of basic features (export, displays…)
  - Investigate real needs for ONLINE aspects
    - Customers ?

- **Model** needs consolidation and some TLC
  - Much information collected and available
  - Data gathering and consolidation essential
  - Build up quality of the model with time and provide trust

Outlook

- The LHC is a very reproducible machine which is better known than we could imagine, in part because there was some fear that it would be completely driven by non-linearities.
  - Magnet design, measurement, sorting…
  - Large set of corrector magnets
- The LHC Control System and Beam Instrumentation are also contributing a lot to the ease of operation.
- The Online Model is a great tool for up or down loading optics to/from the Control System; it provides strong and proven engines for optics calculations and preparation of appropriate settings, but also any physical or observable quantity.
- The Online Model is also a tool to make sure we keep our knowledge of the machine under check and that any deviation is easily identified and properly addressed, whether online or offline.

LHC Online Model

The LHC Online Model is a tool providing in the CCC a physical and mathematical model which can track and mirror the beam operation in the LHC in close-to-real-time, and which is implemented with the features to detect and address deviations from the model or degradation over time.

Any help is welcome,
even if only for providing ideas and opinions.