WEPV008

ONLINE AUTOMATIC PERFORMANCE OPTIMIZATION FOR THE ELETTRA SYNCHROTRON

G. Gaio†, S. Krecic, F. Tripaldi, Elettra-Sincrotrone Trieste S.C.p.A., Trieste, Italy

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a

An "all in one" feedback and optimizer

At Elettra a programmable C++ Tango server, called MIMOFB (Multi Input Multi Output Feedback), has been developed to replace legacy applications implementing slow feedback systems and to perform automatic optimization procedures.

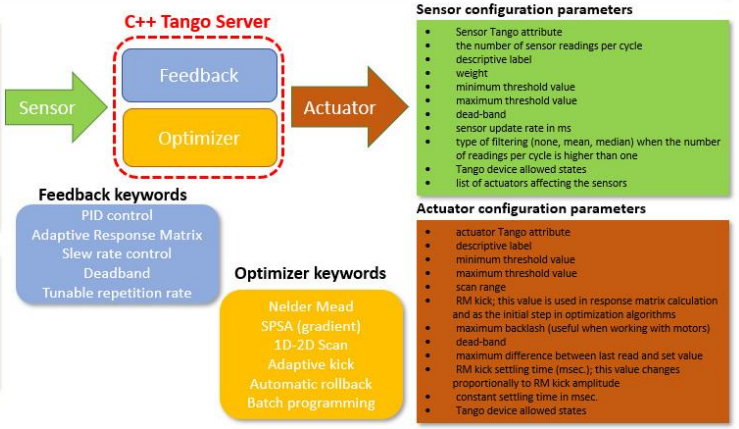
Feedback

The **MIMOFB** implements a correction scheme based on a linear model that link sensors and actuators. This relationship is an approximation that is empirically calculated by measuring the perturbation generated on the sensors by one actuator at a time. The result of this process is a matrix, formally a **Response Matrix (RM)**. The product between the inverse of the response matrix, usually inverted using the **Singular Value Decomposition (SVD) algorithm**, and the error vector returns the values to subtract from actuators to minimize the distance between the sensors and the reference.

Optimizer

The **MIMOFB** implements only model-less optimization schemes. In this case the objective function F is the sum of the normalized distances between N sensor values and corresponding references multiplied by the sensor weights.

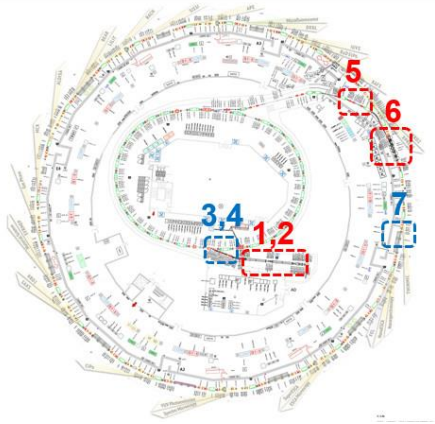
$$F = \sum_{i=0}^{N} w_i * \frac{abs(x_i - x_i^{ref})}{x_i^{max\_thres} - x_i^{min\_thres}}$$



b

Automatic optimized systems

The optimizer is used routinely for tuning booster accumulated current and maximize storage ring injection efficiency. The optimizer is also employed (on demand) in maximizing photon beam flux on a beamline by changing the orbit inside its undulator.



Red: optimization integrated in the automatic injection procedure

Blue: on-demand optimizations

[description];[actuators];[algorithm];[target function]

1. **pre-injector energy; one actuator, pre-injector HV power supply; algorithm scan-1D; booster accumulated current**
2. **pre-injector to booster RF phase matching; one actuator, rf phase shifter; algorithm scan-1D; booster accumulated current**
3. **pre-injector to booster transfer-line orbit; four actuators, corrector magnet power supplies; algorithm Nelder-Mead; booster accumulated current**
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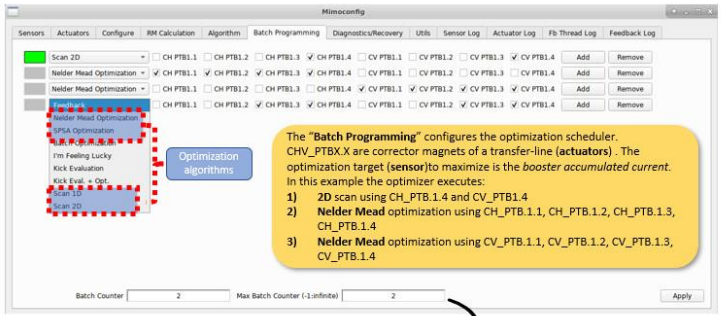
5. **booster to storage ring transfer line orbit; four actuators, corrector magnet power supplies; algorithm Nelder-Mead; injection efficiency**
6. **storage ring injection system; four actuators, HV power supplies; algorithm Nelder-Mead; injection efficiency.**
7. **beamline photon flux; four actuators, position/angle at source point (eight correctors); algorithm Nelder Mead; beamline photodiode**

c

The batch programming for optimization

The optimization algorithm could run one shot or, by means of a programmable optimization scheduler, cycle between different combinations of optimization algorithms and actuators.



The "**Batch Programming**" configures the optimization scheduler. CHV_PTBX.X are corrector magnets of a transfer-line (**actuators**) . The optimization target (**sensor**)to maximize is the *booster accumulated current*. In this example the optimizer executes:

1) **2D** scan using CH_PTB.1.4 and CV_PTB1.4
2) **Nelder Mead** optimization using CH_PTB.1.1, CH_PTB.1.2, CH_PTB.1.3, CH_PTB.1.4
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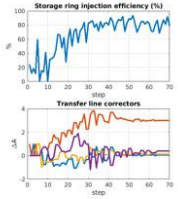
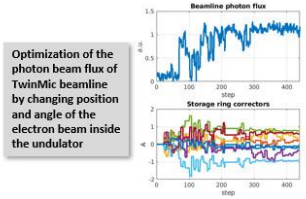
Number of optimization cycles



Optimization of the Elettra injection efficiency by changing the two last correctors of the booster-storage ring transfer line



Optimization of the photon beam flux of TwinMic beamline by changing position and angle of the electron beam inside the undulator

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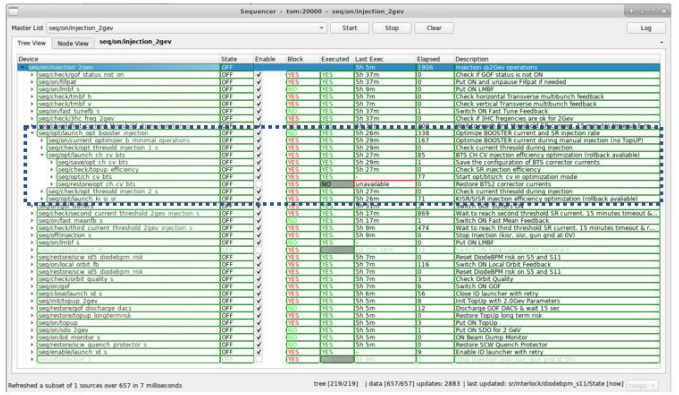
Optimization embedded in the sequencer-based automation framework (WEAL02)

The machine optimization process run unsupervised in the sequencer that injects beam into the storage ring till giving stable beam to the users.



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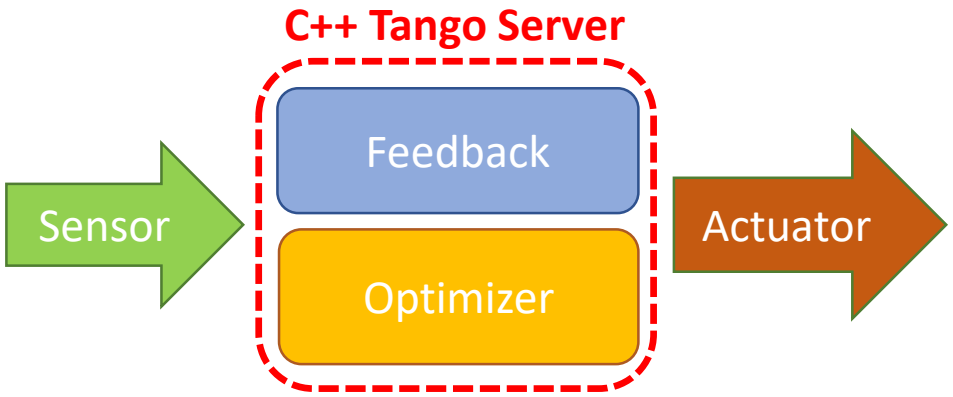

Feedback keywords

PID control
Adaptive Response Matrix
Slew rate control
Deadband
Tunable repetition rate

Optimizer keywords

Nelder Mead
SPSA (gradient)
1D-2D Scan
Adaptive kick
Automatic rollback
Batch programming

Sensor configuration parameters

- Sensor Tango attribute
- the number of sensor readings per cycle
- descriptive label
- weight
- minimum threshold value
- maximum threshold value
- dead-band
- sensor update rate in ms
- type of filtering (none, mean, median) when the number of readings per cycle is higher than one
- Tango device allowed states
- list of actuators affecting the sensors

Actuator configuration parameters

- actuator Tango attribute
- descriptive label
- minimum threshold value
- maximum threshold value
- scan range
- RM kick; this value is used in response matrix calculation and as the initial step in optimization algorithms
- maximum backlash (useful when working with motors)
- dead-band
- maximum difference between last read and set value
- RM kick settling time (msec.); this value changes proportionally to RM kick amplitude
- constant settling time in msec.
- Tango device allowed states

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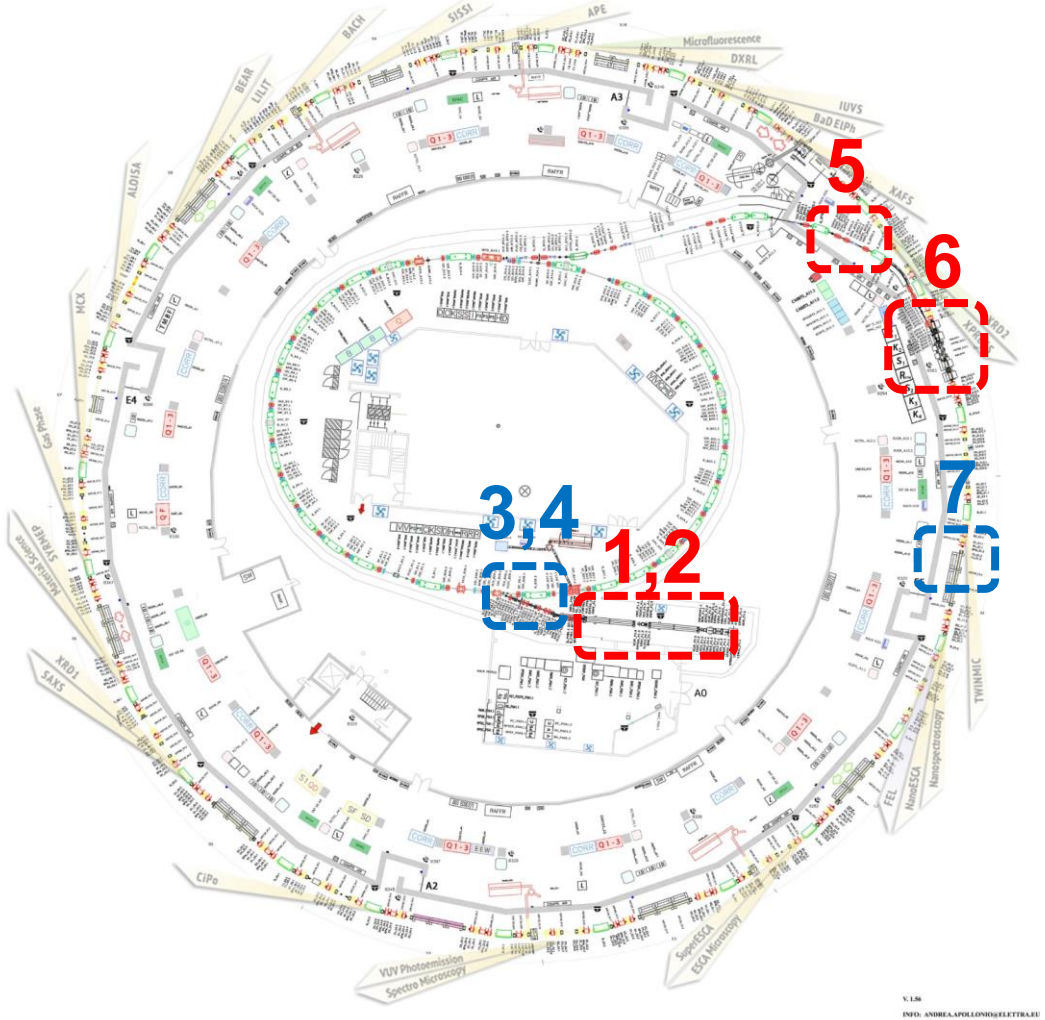

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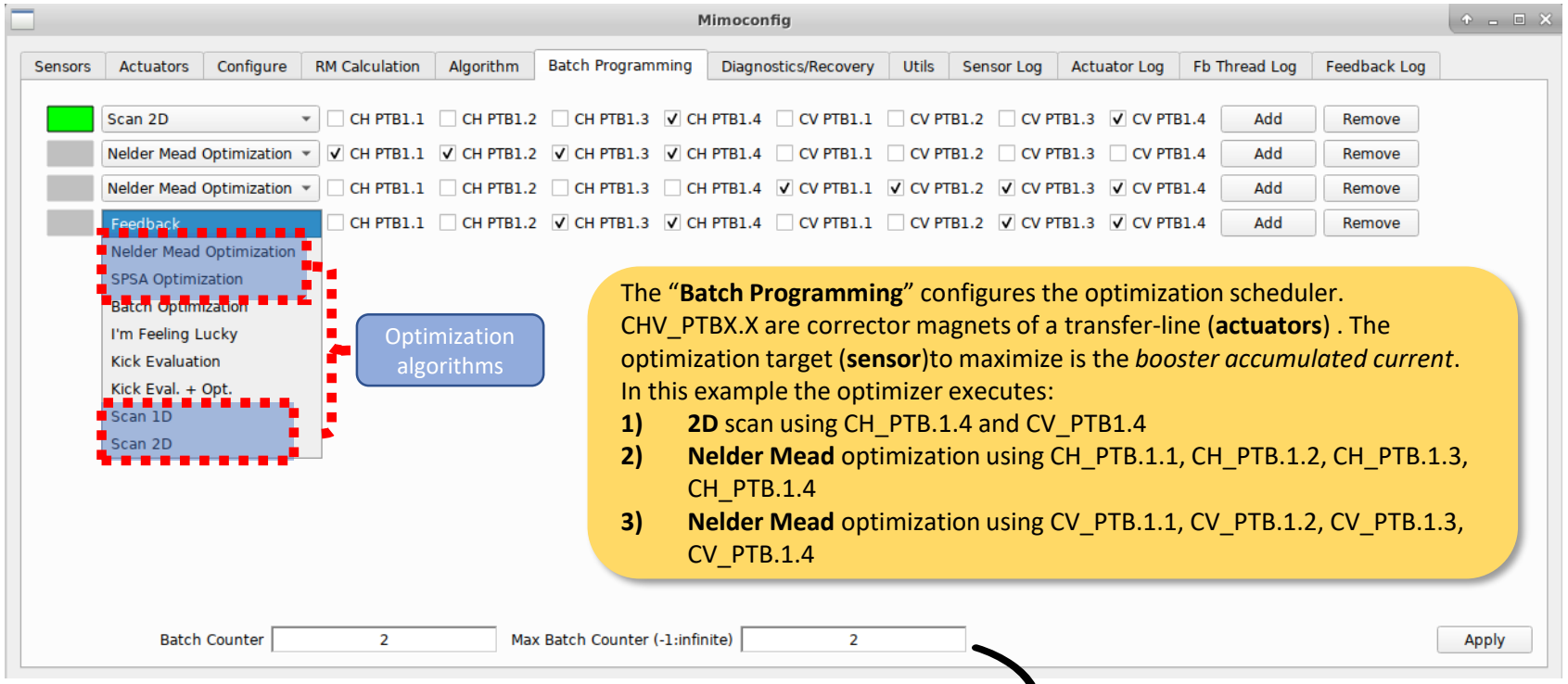

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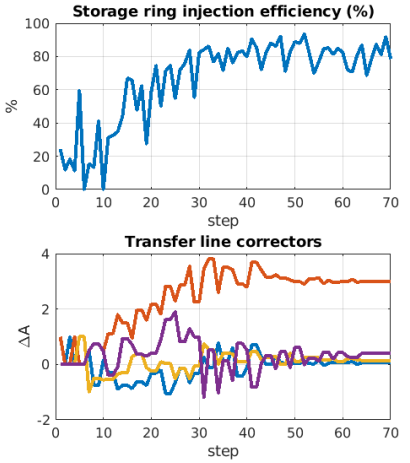

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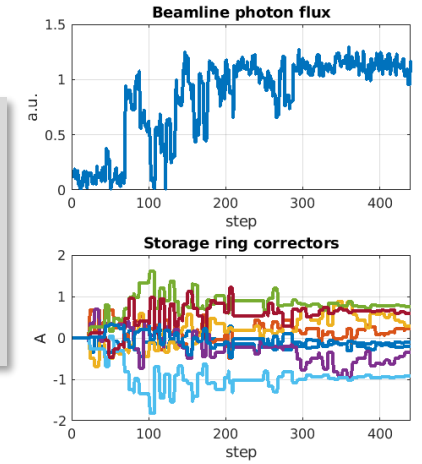

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Sequencer - tom:20000 - seq/on/injection_2gev

Master List: seq/on/injection_2gev — Start | Stop | Clear | Log

Tree View | Node View | seq/on/injection_2gev

Device	State	Enable	Block	Executed	Last Exec	Elapsed	Description
seq/on/injection_2gev	OFF				5h 5m	1906	Injection @2Gev operations
seq/check/gof status not on	OFF	✓	YES	YES	5h 37m	0	Check if GOF status is not ON
seq/on/fillpat	OFF	✓	YES	YES	5h 37m	0	Put ON and unpause Fillpat if needed
seq/on/lmbf s	OFF	✓	NO	YES	5h 9m	0	Put ON LMBF
seq/check/tmbf h	OFF	✓	YES	YES	5h 7m	0	Check horizontal Transverse multibunch feedback
seq/check/tmbf v	OFF	✓	YES	YES	5h 7m	0	Check vertical Transverse multibunch feedback
seq/on/fast tunefb s	OFF	✓	NO	YES	5h 37m	1	Switch ON Fast Tune Feedback
seq/check/3hc freq 2gev	OFF	✓	YES	YES	5h 37m	0	Check if 3HC freqencies are ok for 2Gev
seq/check/first current threshold 2gev injection s	OFF	✓	YES	YES	5h 22m	202	Wait to reach first threshold SR current. 15 minutes timeout &re...
seq/opt/launch opt booster injection	OFF	✓	NO	YES	5h 26m	338	Optimize BOOSTER current and SR injection rate
seq/on/current optimizer b minimal operations	OFF	✓	YES	YES	5h 29m	167	Optimize BOOSTER current during manual injection (no TopUP)
seq/check/opt thresold injection 1 s	OFF	✓	YES	YES	5h 29m	0	Check current thresold during injection
seq/opt/launch ch cv bts	OFF	✓	YES	YES	5h 27m	85	BTS CH CV injection efficiency optimization (rollback avaliable)
seq/save/opt ch cv bts	OFF	✓	YES	YES	5h 29m	1	Save the configuration of BTS corrector currents
seq/check/topup efficiency	OFF	✓	YES	YES	5h 27m	0	Check SR injection efficiency
seq/opt/ch cv bts	OFF	✓	YES	YES	-	77	Start opt/bts/ch_cv in optimization mode
seq/restore/opt ch cv bts	OFF		YES	NO	unavailable	0	Restore BTS2 corrector currents
seq/check/opt thresold injection 2 s	OFF	✓	YES	YES	5h 27m	0	Check current thresold during injection
seq/opt/launch ki si sr	OFF	✓	YES	YES	5h 26m	71	KISR/SISR injection efficiency optimization (rollback avaliable)
seq/on/gof buffers	OFF	✓	YES	YES	5h 31m	2	Switch GOF buffers ON
seq/check/second current threshold 2gev injection s	OFF	✓	YES	YES	5h 17m	869	Wait to reach second threshold SR current. 15 minutes timeout &...
seq/on/fast meanfb s	OFF	✓	NO	YES	5h 17m	1	Switch ON Fast Mean Feedback
seq/check/third current threshold 2gev injection s	OFF	✓	YES	YES	5h 9m	474	Wait to reach third threshold SR current. 15 minutes timeout & r...
seq/off/injection s	OFF	✓	YES	YES	5h 9m	0	Stop Injection (kisr, sisr, qun grid at 0V)
seq/on/lmbf s	OFF	✓	NO	YES	-	0	Put ON LMBF
seq/on/global orbit fb	OFF		YES	NO	0d 20h 34m	42	Switch ON Slow Global Orbit Feedback
seq/restore/scw id5 diodebpm risk	OFF	✓	YES	YES	5h 7m	0	Reset DiodeBPM risk on S5 and S11
seq/on/local orbit fb	OFF	✓	YES	YES	5h 7m	116	Switch ON Local Orbit Feedback
seq/restore/scw id5 diodebpm risk	OFF	✓	YES	YES	5h 7m	0	Reset DiodeBPM risk on S5 and S11
seq/check/orbit quality s	OFF	✓	YES	YES	5h 7m	3	Check Orbit Quality
seq/on/gof	OFF	✓	YES	YES	5h 7m	6	Switch ON GOF
seq/close/launch id s	OFF	✓	YES	YES	5h 6m	56	Close ID launcher with retry
seq/init/topup 2gev	OFF	✓	YES	YES	5h 5m	8	Init TopUp with 2.0Gev Parameters
seq/restore/gof discharge dacs	OFF	✓	NO	YES	5h 5m	12	Discharge GOF DACS & wait 15 sec
seq/restore/topup longtermrisk	OFF	✓	YES	YES	5h 5m	0	Restore TopUp long term risk
seq/on/topup	OFF	✓	YES	YES	5h 5m	3	Put ON TopUp
seq/on/sdo 2gev	OFF	✓	NO	YES	5h 5m	1	Put ON SDO for 2 GeV
seq/on/bd monitor s	OFF	✓	NO	YES	5h 5m	0	ON Beam Dump Monitor
seq/restore/scw quench protector s	OFF	✓	NO	YES	5h 5m	0	Restore SCW Quench Protector
seq/enable/launch id s	OFF	✓	YES	YES	-	9	Enable ID launcher with retry
seq/off/injection s	OFF		YES	NO	5h 9m	0	Stop Injection (kisr, sisr, qun grid at 0V)

Refreshed a subset of 1 sources over 657 in 7 milliseconds — tree [219/219] | data [657/657] updates: 2883 | last updated: sr/interlock/diodebpm_s11/State [now] — tango

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