Weighted algorithm for SVD-based orbit correction

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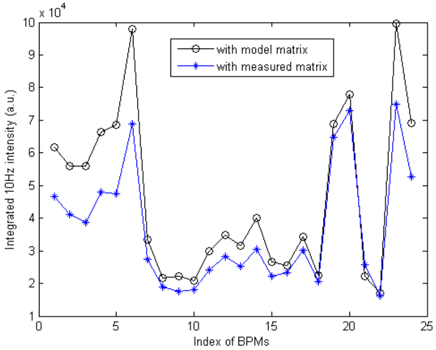
December 7, 2011

Outline

- The motivation
- General algorithm
- Weighted algorithm
- Standard orbit feedback case
- 10 Hz feedback case
- Summary

The motivation

- 10 Hz feedback: further minimize residual oscillations at IP6 (STAR) and IP8 (PHENIX)
- For e-lens and coherent electron cooling: maximize stability of proton beam at IR10/IR2 as a prerequisite for proton/electron beam alignment



General algorithm

Goal

$$\begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{pmatrix} + \begin{pmatrix} x_{1g} - x_1 \\ x_{2g} - x_2 \\ \vdots \\ x_{mg} - x_m \end{pmatrix} = \begin{pmatrix} x_{1g} \\ x_{2g} \\ \vdots \\ x_{mg} \end{pmatrix}$$

Solution

$$\begin{pmatrix} x_{1g} - x_1 \\ x_{2g} - x_2 \\ \vdots \\ x_{mg} - x_m \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} & \cdots & R_{1n} \\ R_{21} & R_{22} & \cdots & R_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ R_{m1} & R_{m2} & \cdots & R_{mn} \end{pmatrix} * \begin{pmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_n \end{pmatrix}$$

SVD algorithm:

Decompsition

$R = USV^T$

Matrix inversion

$R^{-1} = VS^{-1}U^T$

Solution

$\theta = R^{-1}X$

Weighted algorithm

$$\begin{pmatrix} x_{1g}-x_1 \\ x_{2g}-x_2 \\ \vdots \\ f*\begin{pmatrix} x_{ig}-x_i \\ x_{i+1,g}-x_{i+1} \end{pmatrix} \\ \vdots \\ x_{mg}-x_m \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} & \cdots & R_{1n} \\ R_{21} & R_{22} & \cdots & R_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \multicolumn{4}{c}{f*\begin{pmatrix} R_{i1} & R_{i2} & \cdots & R_{in} \\ R_{i+1,1} & R_{i+1,2} & \cdots & R_{i+1,n} \end{pmatrix}} \\ \vdots & \vdots & \ddots & \vdots \\ R_{m1} & R_{m2} & \cdots & R_{mn} \end{pmatrix} * \begin{pmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_n \end{pmatrix}$$

$f(>1)$ is the weights for BPMs in the region of interest, weights for other BPMs are equal to 1

Interface

OCW

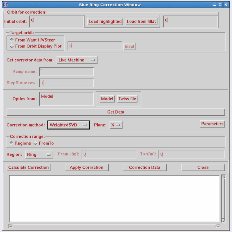


Figure: Orbit Correction Window showing the WeightedSVD algorithm

Weight

SWN	S [m]	Initial	Final	Goal	Diff.	Weight	Status
bo6-bh14	214.26	0.778	0.357	-0.003	-0.360	1.00	OK
bo6-bh16	243.92	0.306	0.063	0.002	-0.061	4.00	OK
bo6-bh18	273.57	-0.259	0.057	0.002	-0.055	4.00	OK
bo6-bh20	303.23	0.347	0.340	-0.003	-0.342	1.00	OK
bo7-bh20	332.89	0.800	0.351	-0.002	-0.353	1.00	OK

Figure: Correction Data Pop-up showing weights of BPMs

Weighted correction

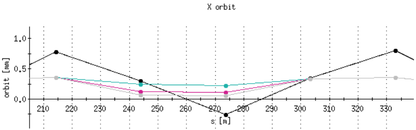


Figure: Weighted orbit correction with different weights for bo6-bh16 and bo6-bh18 (f=1 for Cyan, f=2 for Red and f=4 for Gray)

e-lens orbit

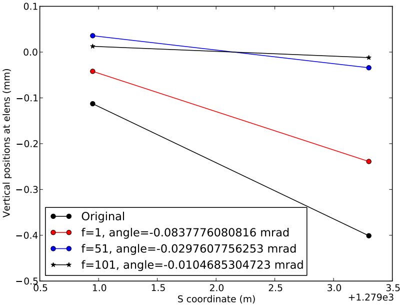


Figure: Local orbit for e-lens with different weights

e-lens orbit

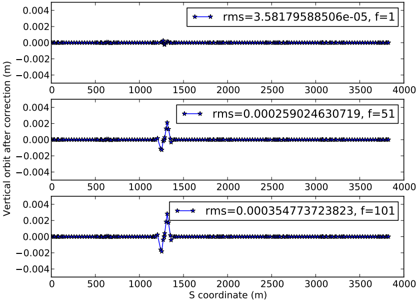


Figure: Close-orbit for e-lens with different weights

10 Hz FB

$$F * \begin{pmatrix} x_{1g} - x_1 \\ x_{2g} - x_2 \\ \vdots \\ x_{mg} - x_m \end{pmatrix} = F * \begin{pmatrix} R_{11} & R_{12} & \cdots & R_{1n} \\ R_{21} & R_{22} & \cdots & R_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ R_{m1} & R_{m2} & \cdots & R_{mn} \end{pmatrix} * \begin{pmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_n \end{pmatrix}$$

$$F = \begin{pmatrix} 1 & 0 & \cdots & 0 & 0 \cdots & 0 \\ 0 & 1 & \cdots & 0 & 0 \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & f & 0 \cdots & 0 \\ 0 & 0 & \cdots & 0 & f \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 \cdots & 1 \end{pmatrix}$$

Matrix manipulation

$$(F*R) = USV^T$$
$$(F*R)^{-1} = VS^{-1}U^T$$

Solution

Multiply beam position vector by $(F*R)^{-1}*F$ instead of R^{-1}

Summary

- Weighted algorithm for standard orbit correction tested off-line
- Weighted algorithm for 10 Hz FB is ready for implementation