With respect to the figure, the $M_i$ are the mover positions and the $P_i$ are the points that need to be moved. $M_1$ and $M_2$ are horizontal movers; $M_3$, $M_4$, and $M_5$ are vertical movers. $P_1$ is the entrance to the W protection collimator; $P_2$ is the exit of the undulator; $P_3$ is the center of the upstream drift tube BPM and $P_4$ is the center of the downstream drift tube BPM.

In the horizontal direction,

$$dP_{x_i} = A_{ij}dM_j$$

For $i=1:4$ and $j=1:2$ corresponding to the entrance to the W protection collimator ($P_1$), the exit of the undulator ($P_2$), the center of the upstream BPM in the drift tube assembly
(P3) and the center of the downstream BPM in the drift tube assembly (P4); and M1 and M2 are the horizontal movers.

What we are really interested in is something like:

\[ dM_j = B_{ji} dP_{xi} \]

which tells us how much to mover the mover to adjust the position of the Pi point of interest. Furthermore, we are only interested in the combinations of P1 and P2 or P3 and P4 but not say P1 and P4, etc.

Therefore, I define

\[ dM_j = B_{uji} dP_{xi}, i = 1, 2 \]

and

\[ dM_j = B_{dtji} dP_{xi}, i = 3, 4 \]

where the \( B_{uji} \) are the matrix elements relevant to moving the undulator while ignoring the drift tube motion and the \( B_{dtji} \) are the matrix elements relevant to moving the drift tube while ignoring the undulator motion.

I find,

\[
\overline{A} = \begin{pmatrix}
1.174 & -0.174 \\
-0.025 & 1.025 \\
1.164 & -0.164 \\
0.063 & 0.937
\end{pmatrix}
\]

\[
\overline{Bu} = (\overline{Au'} \overline{Au})^{-1} \overline{Au'} = \begin{pmatrix}
0.855 & 0.145 \\
0.021 & 0.979
\end{pmatrix}
\]

\[
\overline{Bdt} = (\overline{Adt'} \overline{Adt})^{-1} \overline{Adt'} = \begin{pmatrix}
0.851 & 0.149 \\
-0.058 & 1.058
\end{pmatrix}
\]

wherein

\[
\overline{Au} = \begin{pmatrix}
A_{11} & A_{12} \\
A_{21} & A_{22}
\end{pmatrix} \quad \text{and} \quad \overline{Adt} = \begin{pmatrix}
A_{31} & A_{32} \\
A_{41} & A_{42}
\end{pmatrix}
\]
A similar construct is made for the vertical motion, ignoring any coupling between the vertical and the horizontal.

\[ dP_y_i = C_{ij} dM_j \]

For \( i = 1:4 \) and \( j = 1:3 \) corresponding to the entrance to the W protection collimator (P1), the exit of the undulator (P2), the center of the upstream BPM in the drift tube assembly (P3) and the center of the downstream BPM in the drift tube assembly (P4); and the \( dM_j \) correspond to the motions of the vertical movers M3, M4, and M5.

And:

\[ dM_j = D_{ji} dP_y_i \]

which tells us how much to move the mover to adjust the position of the \( P_i \) point of interest. As before, we are only interested in the combinations of P1 and P2 or P3 and P4 but not say P1 and P4, etc. It turns out that there is not a unique set on M3, M4, and M5 motions for any particular desired change in the \( P_i \).

For a parallel vertical change, all three movers can be used together with the same change in setting (i.e. all are change by the same \( \Delta y \)).

For differential motion, I choose to use only M4 and M5, leaving M3 fixed. The corresponding matrices are defined to be

\[ dM_j = Du_{ji} dP_y_i , i = 1,2 \]

and

\[ dM_j = Ddt_{ji} dP_y_i , i = 3,4 \]

where the \( Du_{ji} \) are the matrix elements relevant to moving the undulator while ignoring the drift tube motion and the \( Ddt_{ji} \) are the matrix elements relevant to moving the drift tube while ignoring the undulator motion. And the \( dM_j \) refer to the changes in the M4 and M5 movers.

I find,

\[
\begin{bmatrix}
0.628 & 1.059 & -0.687 \\
0.628 & -0.495 & 0.868 \\
0.367 & 1.176 & -0.543 \\
0.367 & -0.250 & 0.883
\end{bmatrix}
\]
\[ Du = \left( C'u'C' \right)^{-1} C'u' = \begin{pmatrix} 1.500 & 1.187 \\ 0.856 & 1.831 \end{pmatrix} \]

\[ Ddt = \left( C'dt'C' \right)^{-1} C'dt' = \begin{pmatrix} 0.979 & 0.602 \\ 0.277 & 1.303 \end{pmatrix} \]

wherein

\[ C'u = \begin{pmatrix} C_{12} & C_{13} \\ C_{22} & C_{23} \end{pmatrix} \text{ and } C'dt = \begin{pmatrix} C_{32} & C_{33} \\ C_{42} & C_{43} \end{pmatrix} \]