Kalman filtering of Intrinsic Parameters

The objective is to integrate intrinsic camera parameters over time. The full set of camera parameters are:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} s_x & a & u_0 \\ 0 & -s_y & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1/f & 0 \end{bmatrix} \begin{bmatrix} \mathbf{R} & \mathbf{T} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

The first two matrices on the right hand side represent the intrinsic parameters, so we have $s_{y,x}$ which are the scale factors, and u_0, v_0 represents the off-center bias, and f is the focal length. When a is computed it represents the skewness. In total we have to represent 5-6 parameters.

For the temporal filter a simple model is to use a Kalman filter, i.e.,

$$x_{t+1} = \mathbf{F}x_t + \mathbf{G}u_t$$

As there is no deterministic input to the system we can leave out the input u_t. If we for a minute assume the factors are uncorrelated we can represent the autonomy part of the system as time-invariant and uncorrelated. Then $\mathbf{F}$ would be the identity matrix. The measurement equation would be similar

$$p_t = \mathbf{H}x_t$$

where p is the parameter and $\mathbf{H}$ is the identify matrix. The two noise matrices $\mathbf{Q}, \mathbf{R}$ define the confidence in the estimate. $\mathbf{Q}$ is the process noise and specifies how much we think the intrinsics change over time, so the noise matrix could be set to a low value. The matrix can be diagonal initially. $\mathbf{R}$ specifies how much noise there is in the per image estimate. My expectation would be that the measurement noise is 5-10 times larger than the process noise. It would at least be a good initial estimate. You can directly use the Kalman filter implementation in OpenCV. No need to implement it yourself, i.e.

```
cv::KalmanFilter kf(stateSize, measSize, contrSize, type);
```