Video Mensuration using a Stationary Camera

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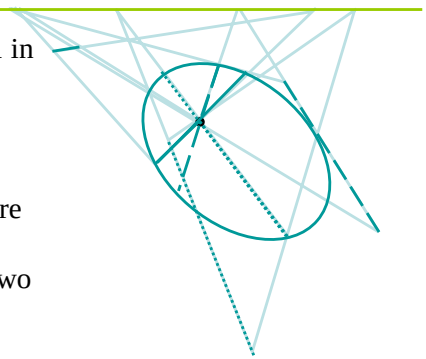
Mensuration Algorithm

Assumption: The vanishing line is given

Problem: Given the reference length $||MN||=1$ in multiple frames as m_in_i and a probe line segment ST also in multiple frames as s_jt_j, measure $||ST||$.

Fact: If for all frame i, M_i are same, then N_i are distributed in a unit circle centering at M_i. Furthermore, if $S_j=M_i$, then T_j and N_i are on two concentric circles respectively.

Example



Solution

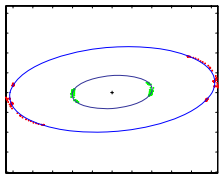
- Arbitrary select point o and parallel move m_in_i to op_i, s_jt_j to oq_j. World points P_i are on a circle C_p and Q_j on a concentric circle C_q

$$C_p = C_0 - \boldsymbol{r}_p^2 \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \qquad C_q = C_0 - \boldsymbol{r}_q^2 \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

C_0 is the circle centering at O with zero radius.

$$H^{-1} \propto \begin{pmatrix} \times & \times & \times \\ \times & \times & \times \\ L(1) & L(2) & L(3) \end{pmatrix}$$

L is the vanishing line



p_i and q_j are on two concentric ellipses centering at o

$$E_{p,q} = E_0 - \boldsymbol{r}_{p,q}^2 L \qquad L = H^{-T}\boldsymbol{diag}(0,0,1)H^{-1}$$

$$E_0 : \boldsymbol{a}_0(x-x_0)^2 + \boldsymbol{b}_0(x-x_0)(y-y_0) + \boldsymbol{c}_0(y-y_0)^2 = 0$$

Finally $\boldsymbol{a}_0(x_p-x_0)^2 + \boldsymbol{b}_0(x_p-x_0)(y_p-y_0) + \boldsymbol{c}_0(y_p-y_0)^2 - \alpha_p(L\boldsymbol{p}_i)^2 = 0$

$\boldsymbol{a}_0(x_q-x_0)^2 + \boldsymbol{b}_0(x_q-x_0)(y_q-y_0) + \boldsymbol{c}_0(y_q-y_0)^2 - \alpha_q(L\boldsymbol{q}_i)^2 = 0$

$(\boldsymbol{a}_0 \quad \boldsymbol{b}_0 \quad \boldsymbol{c}_0 \quad \alpha_p \quad \alpha_q)^T$ can be solved by Singular Value Decomposition (SVD)

The ratio between the two radii $\boldsymbol{r} = \sqrt{\alpha_p / \alpha_q}$

Objective & Contribution

An automated system for wheelbase measurement of moving vehicles

Wheelbase Detection

Key: Use the intensity difference between the wheel covers and the tires

the Vanishing Line Estimation

Represent the vanishing line as $(-\sin\phi\sin\theta, \cos\phi\sin\theta, -\boldsymbol{f}\cos\theta)$

θ: elevation angle ϕ: rotation angle f: focal length

Minimize the variance of $\cos^2(\theta) = -\dfrac{\cos^2\phi - \boldsymbol{r}^2\sin^2\phi - 2\boldsymbol{c}_\alpha\cos\phi\sin\phi + \boldsymbol{c}_\alpha^2\sin\phi}{\sin^2\phi - \boldsymbol{r}^2\cos^2\phi + \boldsymbol{c}_\alpha\cos\phi\sin\phi + \boldsymbol{c}_\alpha^2\cos\phi}$

$$\boldsymbol{r} = \left|\frac{\delta x_2\delta y_1 - \delta x_1\delta y_2}{\delta x_1^2 - \delta x_2^2}\right| \qquad c_\alpha = \frac{\delta x_1\delta y_1 - \delta x_2\delta y_2}{\delta y_1^2 - \delta y_2^2} \qquad \delta x_i = x_{i1} - x_{i2} \qquad \delta y_i = y_{i1} - y_{i2}$$

Mensuration Result