**Algorithm EKF_localization**($\mu_{t-1}, \Sigma_{t-1}, u_t, z_t, m$):

$\theta = \mu_{t-1,\theta}$

$$G_t = \begin{pmatrix} 1 & 0 & -\frac{v_t}{\omega_t}\cos\theta + \frac{v_t}{\omega_t}\cos(\theta + \omega_t \Delta t) \\ 0 & 1 & -\frac{v_t}{\omega_t}\sin\theta + \frac{v_t}{\omega_t}\sin(\theta + \omega_t \Delta t) \\ 0 & 0 & 1 \end{pmatrix}$$

$$V_t = \begin{pmatrix} -\frac{\sin\theta + \sin(\theta+\omega_t\Delta t)}{\omega_t} & \frac{v_t(\sin\theta - \sin(\theta+\omega_t\Delta t))}{\omega_t^2} + \frac{v_t\cos(\theta+\omega_t\Delta t)\Delta t}{\omega_t} \\ \frac{\cos\theta - \cos(\theta+\omega_t\Delta t)}{\omega_t} & -\frac{v_t(\cos\theta - \cos(\theta+\omega_t\Delta t))}{\omega_t^2} + \frac{v_t\sin(\theta+\omega_t\Delta t)\Delta t}{\omega_t} \\ 0 & \Delta t \end{pmatrix}$$

$$M_t = \begin{pmatrix} \alpha_1 v_t^2 + \alpha_2 \omega_t^2 & 0 \\ 0 & \alpha_3 v_t^2 + \alpha_4 \omega_t^2 \end{pmatrix}$$

$$\bar{\mu}_t = \mu_{t-1} + \begin{pmatrix} -\frac{v_t}{\omega_t}\sin\theta + \frac{v_t}{\omega_t}\sin(\theta + \omega_t \Delta t) \\ \frac{v_t}{\omega_t}\cos\theta - \frac{v_t}{\omega_t}\cos(\theta + \omega_t \Delta t) \\ \omega_t \Delta t \end{pmatrix}$$

$\bar{\Sigma}_t = G_t\ \Sigma_{t-1}\ G_t{}^T + V_t\ M_t\ V_t{}^T$

$$Q_t = \begin{pmatrix} \sigma_r^2 & 0 & 0 \\ 0 & \sigma_\phi^2 & 0 \\ 0 & 0 & \sigma_s^2 \end{pmatrix}$$

*for all observed features* $z_t^i = (r_t^i\ \ \phi_t^i\ \ s_t^i)^T$ *do*

  *for all landmarks* $k$ *in the map* $m$ *do*

    $q = (m_{k,x} - \bar{\mu}_{t,x})^2 + (m_{k,y} - \bar{\mu}_{t,y})^2$

$$\hat{z}_t^k = \begin{pmatrix} \sqrt{q} \\ \text{atan2}(m_{k,y} - \bar{\mu}_{t,y}, m_{k,x} - \bar{\mu}_{t,x}) - \bar{\mu}_{t,\theta} \\ m_{k,s} \end{pmatrix}$$

$$H_t^k = \begin{pmatrix} -\frac{m_{k,x} - \bar{\mu}_{t,x}}{\sqrt{q}} & -\frac{m_{k,y} - \bar{\mu}_{t,y}}{\sqrt{q}} & 0 \\ \frac{m_{k,y} - \bar{\mu}_{t,y}}{q} & -\frac{m_{k,x} - \bar{\mu}_{t,x}}{q} & -1 \\ 0 & 0 & 0 \end{pmatrix}$$

    $S_t^k = H_t^k\ \bar{\Sigma}_t\ [H_t^k]^T + Q_t$

  *endfor*

$$j(i) = \underset{k}{\text{argmax}} \quad \det\left(2\pi S_t^k\right)^{-\frac{1}{2}} \exp\left\{-\tfrac{1}{2}\ (z_t^i - \hat{z}_t^k)^T [S_t^k]^{-1} (z_t^i - \hat{z}_t^k)\right\}$$

  $K_t^i = \bar{\Sigma}_t\ [H_t^{j(i)}]^T [S_t^{j(i)}]^{-1}$

  $\bar{\mu}_t = \bar{\mu}_t + K_t^i (z_t^i - \hat{z}_t^{j(i)})$

  $\bar{\Sigma}_t = (I - K_t^i\ H_t^{j(i)})\ \bar{\Sigma}_t$

*endfor*

$\mu_t = \bar{\mu}_t$

$\Sigma_t = \bar{\Sigma}_t$

*return* $\mu_t, \Sigma_t$

**Table 7.3** The extended Kalman filter (EKF) localization algorithm with unknown correspondences. The correspondences $j(i)$ are estimated via a maximum likelihood estimator.