Here we have posterior distribution of velocity and image intensity:

$$P(v|I) \propto P(v)P(I|v) \qquad I(x,y,t) = I(x + v_x\Delta t, y + v_y\Delta t, t + \Delta t) + \eta \tag{1}$$

Note that the image intensity is being subjected to the brightness constraint with noise. This allows us to take the Taylor series expansion:

$$\tilde{I}(x,y,t) \approx \frac{dI}{dx}\frac{dx}{dt} + \frac{dI}{dy}\frac{dy}{dt} + \frac{dI}{dt} \tag{2}$$

$$= I_x v_x + I_y v_y + I_t \tag{3}$$

We propose a prior distribution determined by the previous time step's posterior distribution:

$$P(v|I)_t \propto P(v|I)_{t-1}P(I|v) \tag{4}$$

This distribution is largely determined by the likelihood function, $P(I|v)$. The likelihood function is comprised of component functions calculated at each point in in the stimulus image. At point (x_i, y_i) and time t:

$$P(I(x_i, y_i, t)|v_i) \propto exp\left(-\frac{1}{2\sigma^2}\int_{x,y} w_i(x,y)(\tilde{I}(x,y,t))^2 dxdy\right) \tag{5}$$

With $w_i(x,y)$ being a small Gaussian window centered at (x_i, y_i). This is derived from the Taylor series expansion of (1). At each point in time:

$$P(I(x,y,t)|v) = \int_i P(I(x_i, y_i, t)|v_i) \tag{6}$$

Thus we have our final posterior distribution:

$$P(v|I)_t \propto P(v|I)_{t-1}\int_i P(I(x_i, y_i, t)|v_i) \tag{7}$$

In expanded and discrete form, the equation is given by

$$P(v|I)_t \propto exp\left(log(P(v|I)_{t-1}) - \frac{1}{2\sigma^2}\sum_i \sum_{x,y} w_i(x,y)(\tilde{I}(x,y,t))^2\right) \tag{8}$$