A Gesture Recognition Peripheral Using Optical Flow: Week 5

Jon Harter

University of Central Florida

June 19, 2009
Short Term Goals

Compare Different Egomotion Models

- Compare egomotion model proposed by Higgins in 1981 to Hartley (2009) and Bruce/Horn (1997)
- Verify implementation of Hartley is correct
- Compare rotation matrices with angular velocity vectors
Current Progress and Challenges

Progress

▶ Compared instantaneous egomotion model to discrete
▶ Fixed an implementation bug of Hartley algorithm

Challenges

▶ Bridge 1997 paper on egomotion (other approach) with Higgins
▶ Accurately convert from rotation matrix to velocity vector
Relevant Works

Determine Ego-motion

- *A Computer Algorithm for Reconstructing a Scene from Two Projections*
- *A linear approach to motion estimation using generalized camera models*
- Hongdong Li, Richard Hartley, Jae-hak Kim (2009)

Contributions

- Higgins proposes "intuitive" function for optical flow, unlike Hartley
Hartley

Definitions

$R$ : rotation matrix

$b_k$ : Camera $k$ center

$r_k$ : Camera $k$ orientation matrix

$x$ and $x'$ : Corresponding points

Initial Equation

$x_i^T [t] x R x_i' + x_i^T R (v_i' \times x_i') + (v_i \times x_i)^T R x_i' = 0$

After Substitution

$v_i = v_i' = b_k$

$x_i = r_k p$

$x_i' = r_k p + r_k \dot{p}$

$(r_k p)^T [t] x R (r_k p + r_k \dot{p}) + (r_k p)^T R (b_k \times (r_k p + r_k \dot{p})) + (b_k \times r_k p)^T R (r_k p + r_k \dot{p}) = 0$
Definitions

\( u \): optical flow \( x \)-component

\( v \): optical flow \( y \)-component

\( t \): translation of system

\( X_3 \): depth

\( x \): image point \( x \)-component

\( y \): image point \( y \)-component

Equations

\[ u = x' - x = \frac{xt_z - tx}{X_3 - t_z} \]

\[ v = y' - y = \frac{yt_z - ty}{X_3 - t_z} \]
Bridging Hartley and Higgins

Hartley Assumptions

- One camera ($b_k = \vec{0}$)
- No rotation ($R = I$)

Equation

$$p^T[t]_x(p + p') = 0$$

Expanded Form

\[
(yt_z - t_y)x' + (-xt_z + t_x)y' + xt_y - yt_x = 0 \\
(yt_zx' - t_yx' - xt_zy' + tx'y' + xt_y - yt_x = 0
\]
Bridging Hartley and Higgins

Higgins Assumptions

- No rotation \((R = I)\)

Equations

\[
\begin{align*}
x' - x &= \frac{xt_z - t_x}{X_3 - t_z} \\
y' - y &= \frac{yt_z - ty}{X_3 - t_z}
\end{align*}
\]

Working Toward Higgins

\[
\begin{align*}
x_3 - t_z &= \frac{xt_z - t_x}{x' - x} \\
x_3 - t_z &= \frac{yt_z - ty}{y' - y} \\
\frac{xt_z - t_x}{x' - x} &= \frac{yt_z - ty}{y' - y} \\
(x_t - t_x)(y' - y) &= (yt_z - ty)(x' - x) \\
x_tz' - xt_zy - t_xy' + t_xy &= yt_zx' - yt_zx - t_yx' + t_yx
\end{align*}
\]

\[yt_zx' - tyx' - xt_zy' + t_xy' + xt_y - yt_x = 0\]

\(^1\)Recall Higgins: \(yt_zx' - tyx' - xt_zy' + t_xy' + xt_y - yt_x = 0\)
Bridging Hartley and Higgins

Other Comparisons

- The case where rotation exists has also been verified
- No comparison under the assumption of multiple cameras
  (Higgins uses one camera)
Another Comparison

Bridge Bruce and Horn Egomotion and Higgins (no rotation)

► Bruce/Horn (instantaneous):

\[ u = \frac{xt_z - t_x}{X_3}, \quad v = \frac{yt_z - t_y}{X_3} \]

► Higgins:

\[ u = \frac{xt_z - t_x}{X_3 - t_z}, \quad v = \frac{yt_z - t_y}{X_3 - t_z} \]

► Approximately equal for small \( t_z \)

Challenge

► Have not verified above comparison with rotation
Future Plans

- Hartley Algorithm must be tested against noise in data
- Filter must be created to ensure only trusted optical flow is used.
- Construct a model for gesture recognition that is resilient to variation and noise