A Gesture Recognition Peripheral Using Optical Flow: Week 5

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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

- Bridged Hartley/Pless egomotion equations (2009) with Higgins egomotion equations (1981)
- 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 matix to velocity vector

Relevant Works

Determine Ego-motion

- *A Computer Algorithm for Reconstructing a Scene from Two Projections*
- `H.C. Longuet-Higgins (1981)`
- *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': Cooresponding 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

$$v_i = v_i' = b_k$$

$$x_i = r_k p$$

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

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

Higgins

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

$$u = x' - x = \frac{xt_z - t_x}{X_3 - t_z}$$

$$v = y' - y = \frac{yt_z - t_y}{X_3 - t_z}$$

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

$$(yt_z - t_y)x' + (-xt_z + t_x)y' + xt_y - yt_x = 0$$

$$yt_z x' - t_y x' - xt_z y' + t_x y' + xt_y - yt_x = 0$$

Bridging Hartley and Higgins

Higgins Assumptions

- No rotation ($R = I$)

Equations

$$x' - x = \frac{xt_z - t_x}{X_3 - t_z}$$

$$y' - y = \frac{yt_z - t_y}{X_3 - t_z}$$

Working Toward Higgins [1]

$$X_3 - t_z = \frac{xt_z - t_x}{x' - x}$$

$$X_3 - t_z = \frac{yt_z - t_y}{y' - y}$$

$$\frac{xt_z - t_x}{x' - x} = \frac{yt_z - t_y}{y' - y}$$

$$(xt_z - t_x)(y' - y) = (yt_z - t_y)(x' - x)$$

$$xt_z y' - xt_z y - t_x y' + t_x y = yt_z x' - yt_z x - t_y x' + t_y x$$

$$yt_z x' - t_y x' - xt_z y' + t_x y' + xt_y - yt_x = 0$$

[1] Recall Higgins: $yt_z x' - t_y x' - xt_z y' + t_x y' + xt_y - yt_x = 0$

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):

$$u = \frac{xt_z - t_x}{X_3}, v = \frac{yt_z - t_y}{X_3}$$

- Higgins:

$$u = \frac{xt_z - t_x}{X_3 - t_z}, v = \frac{yt_z - t_y}{X_3 - t_z}$$

- 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 resiliant to variation and noise