A Multi-Camera Input Device Utilizing Optical Flow for Ego-motion Estimation

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** Equal Contributions*

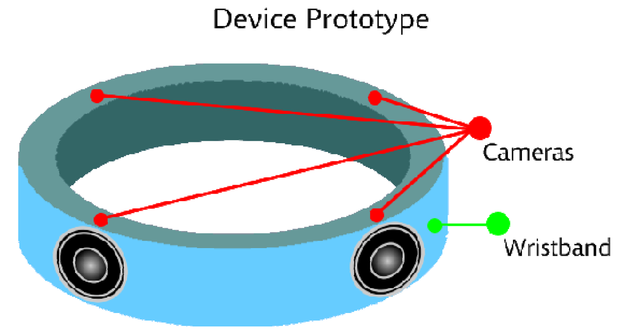
Overview:

- ***Purpose:*** Design a multi-camera input device for electronic media capable of estimating its ego-motion by qualitative analysis of optical flow for gesture recognition *(two methods for ego-motion estimation utilized)*
- ***Method 1:*** Compare optical flow data from each camera to a set of synthetic optical flow data, returning corresponding ego-motion parameters
- ***Method 2:*** Utilize constraints posed by the antipodal regions of the system to estimate the ego-motion for each frame of optical flow

Prototype:

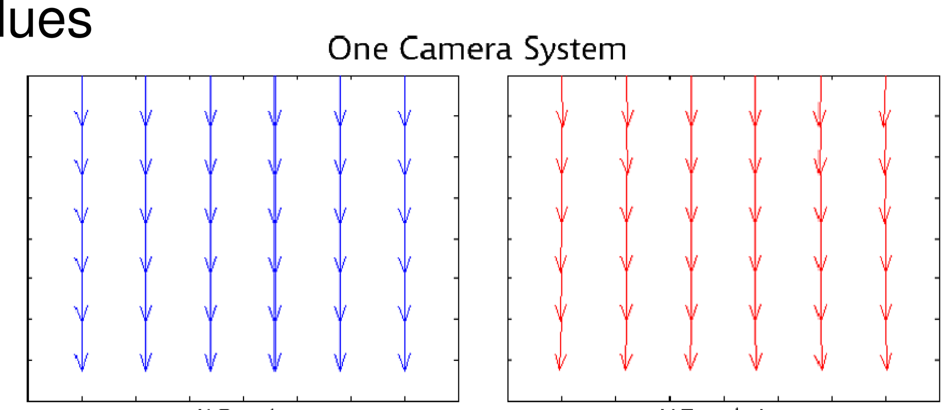
- ***Design:*** Wristband peripheral with four mounted cameras

Device Prototype

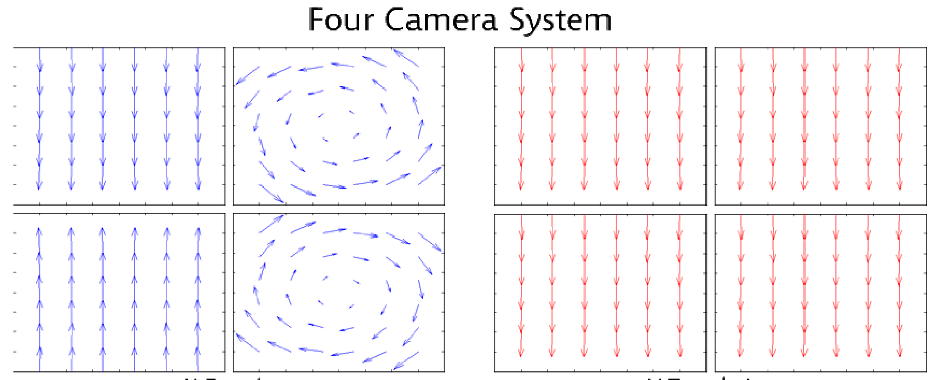


- ***Multi-Camera Advantage:*** Disambiguate optical flow ego-motion clues

One Camera System



Four Camera System



(Current tests use four webcams in a similarly aligned hand-held configuration, arrows denote optical flow)

Gathering Optical Flow

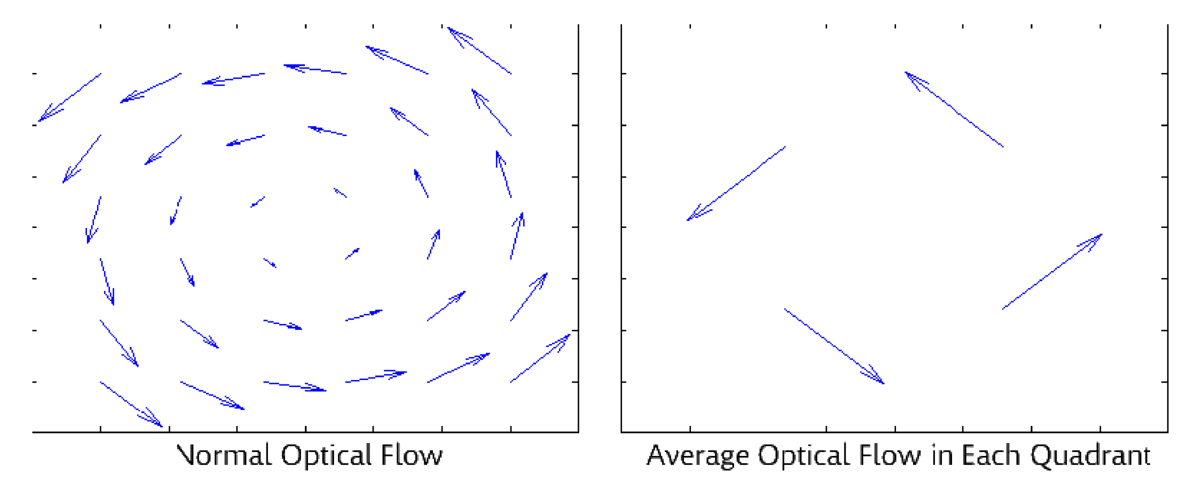
- ***Optical Flow:*** The apparent motion of objects, edges, and surfaces in a visual scene
- ***Data:*** Calculated for each frame of each camera throughout the duration of the gesture
- ***Implementation:*** Standard OpenCV

Method 1

- ***Generate Optical Flow:*** Use modified version of optical flow equations proposed by H. C. Longuet-Higgins [1] .

Algorithm

- Split each frame into four quadrants, calculating the average optical flow in each quadrant



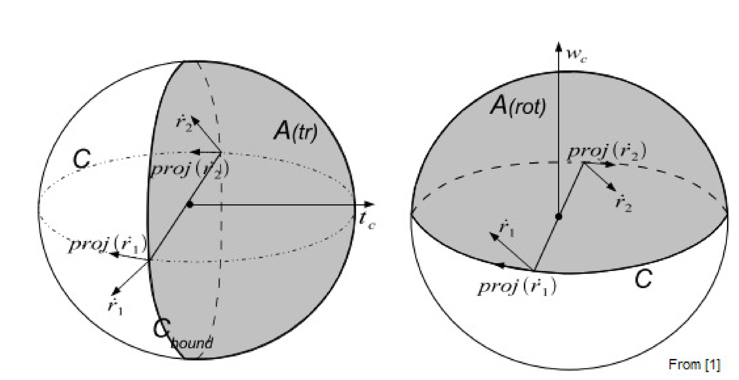
- Compare averaged data to each synthetically generated case.
- Assume the ego-motion parameters used to generate the case that is closest to the averaged data are the best estimation for that data's ego-motion
- Repeat the above steps until enough frames have been analyzed to constitute a gesture (in practice 10-20 frames)

Method 2

- ***Analyzing Antipodal Regions:*** This techniques is based on the work of Lim et al [2].

Algorithm

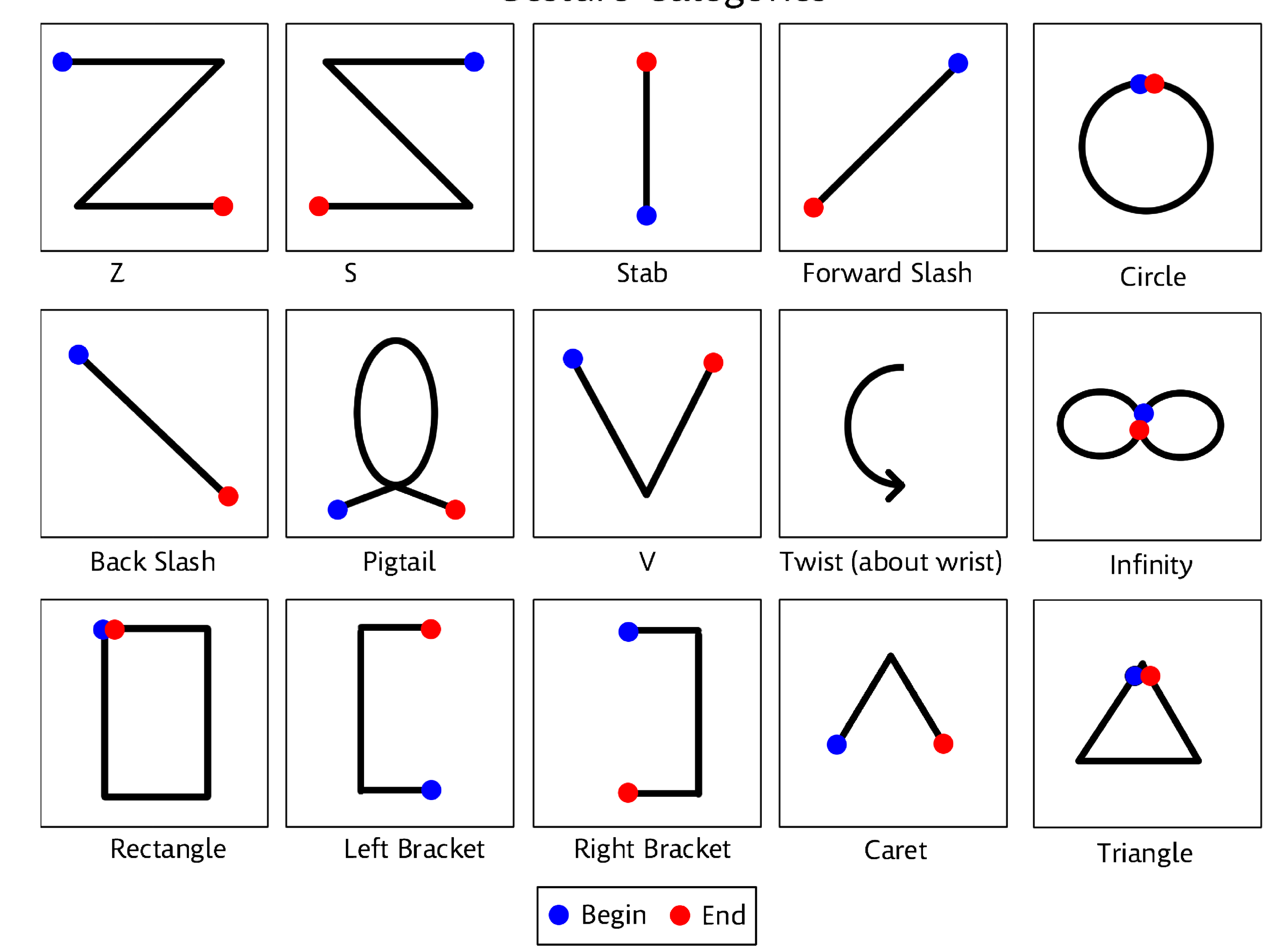
- Split each frame into four quadrants, calculating the average optical flow in each quadrant (same as above)
- Project the optical flow vectors from two antipodal regions onto some predefined great circles



- If the signs of those projections are equal, there is a constraint on the direction of the translation; otherwise, there is a constraint on the axis of rotation
- Ego-motion can be estimated from analyzing the constraints proposed above

Classifying Gestures

Gesture Categories



	BS	Ca	Ci	FS	Inf	LB	P	R	RB	S	St	Tri	Tw	V	Z
B. Slash	20	80	0	0	0	0	0	0	0	0	0	0	0	0	0
Caret	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Circle	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0
F. Slash	0	0	0	90	0	0	10	0	0	0	0	0	0	0	0
Infinity	0	0	0	0	90	0	0	10	0	0	0	0	0	0	0
L. Bracket	0	0	10	0	0	90	0	0	0	0	0	0	0	0	0
Pigtail	0	0	0	0	10	10	80	0	0	0	0	0	0	0	0
Rectangle	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
R. Bracket	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Stab	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Triangle	0	0	0	0	0	0	10	10	0	0	0	80	0	0	0
Twist	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0
V	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
Z	0	0	0	0	20	0	0	0	0	0	0	0	0	0	80

Method 1: 88.67% Accuracy

	BS	Ca	Ci	FS	Inf	LB	P	RB	Rec	S	St	Tri	Tw	V	Z
B. Slash	10	80	0	0	0	0	0	0	0	0	0	0	10	0	0
Caret	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Circle	0	0	90	0	0	0	10	0	0	0	0	0	0	0	0
F. Slash	0	0	0	80	0	0	0	0	0	0	20	0	0	0	0
Infinity	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0
L. Bracket	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Pigtail	0	0	10	0	0	0	80	0	0	0	0	0	0	0	10
R. Bracket	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0
Rectangle	0	0	0	0	0	0	0	0	90	10	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Stab	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Triangle	0	0	0	0	0	0	0	0	0	10	0	80	0	10	0
Twist	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0
V	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
Z	0	0	20	0	10	0	0	0	0	0	0	0	0	0	70

Method 2: 86.67% Accuracy

- Above data calculated from 600 training examples, 40 of each gesture performed in two different locations by two people and 150 testing examples, 10 of each gesture performed in two different locations by a third person

Citations

- [1] A Computer Algorithm for Reconstructing a Scene from Two Projections, H.C. Longuet-Higgins, Laboratory of Experimental Psychology, University of Sussex, Brighton BN
- [2] Directions of Ego-motion from Antipodal Points, John Lim, Department of Information Engineering RSISE; Australian National University, Nick Barnes, NICTA; Canberra, Australia