High Speed Pole Balancing with Only Spike-based Visual Input

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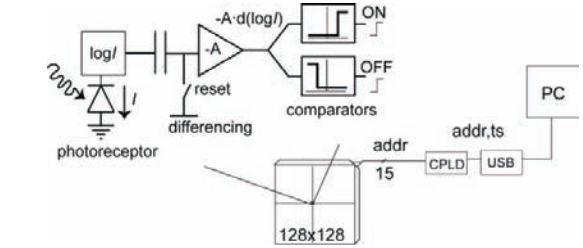
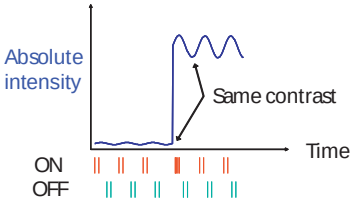
Dynamic Vision Sensor (DVS)

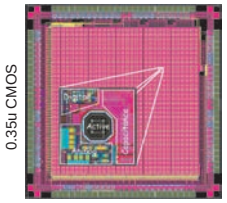
Retina Output Cells respond to relative intensity change (contrast)



DVS pixel and camera architecture (simplified pixel schematics)



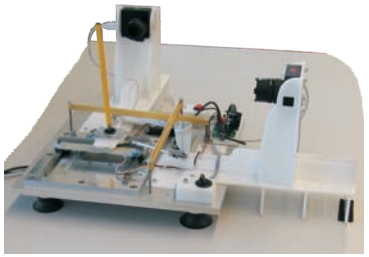
A relative change in illumination causes an event



Photograph of retina chip
128x128 pixels (on/off)
Pixel size $(40u)^2$
1 Meps, 23mW power

Balancer Hardware

2D actuated table, range of motion ~100x100mm



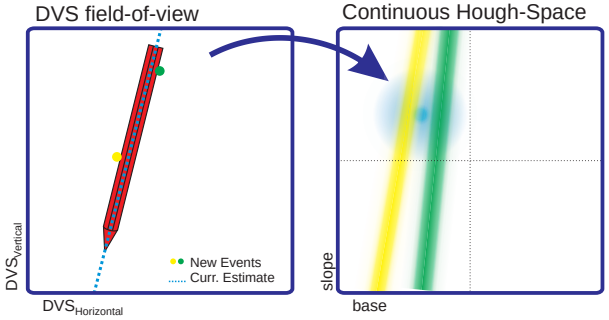
2 orthogonally mounted DVS

Actuated by 2 high-speed Brushless Servo Motors

On-board low-level position control (Microcontroller)

2D Line Tracking Algorithm

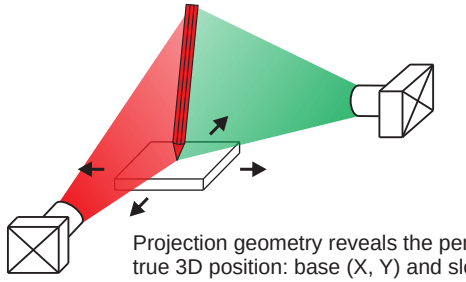
Continuous Hough Transform for each of 2 DVSs individually



Each incoming event (yellow and green) updates the current estimate for the pencil's base and slope, shown as blue line (left in visual space) and blue Gaussian (right in Hough-Space)

3D Pencil Tracking

Combining 2 independent estimates into a 3D-position



Projection geometry reveals the pencil's true 3D position: base (X, Y) and slope ($á_x$, $á_y$)

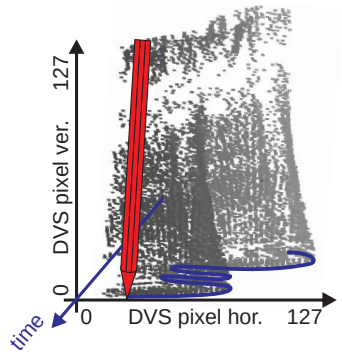
Balancing Controller

Standard PD control at 500Hz update rate

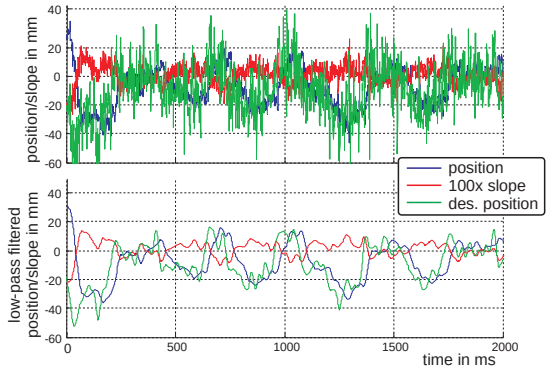
$$X_{des} \quad g_P X \quad g \quad _X \quad g_D \dot{X}$$
$$Y_{des} \quad g_P Y \quad g \quad _Y \quad g_D \dot{Y}$$

$g_P, g\ , g_D : gains$
$X, Y : positions$
$_X\ ,\ _Y : tiltangles$

Balancing Performance



Space-time plot of 54k events (dots) reported from one DVS sensor during balancing in a time window of 240ms. The pencil's base over time and the last tracked position are shown in blue and red.



Recorded traces of position, slope, and desired position.

Upper graph: raw data
Lower graph: low-pass filtered data (3rd order Butterworth, -3dB 30Hz)
Right graph: position histogram