Moving Object Detection with an Adaptive Background Model

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ADAPTIVE CHANGE DETECTION

Naive method

$$| \, current - background \, | > threshold$$

doesn't work well in uncontrolled situations

Fix by using:

- Color spaces & shadows
- Kernel density modelling
- Kernel parameter estimation

CHANGE DETECTION ISSUES

If we have a single background, then what about:

- Gradual illumination changes: sun movement
- Rapid illumination changes: lights on
- Background object shadow movement
- Camera jitter
- Halting objects: cars parked

Problem: model out of date
Solution: adapt background model over time

CHROMATICITY COORDINATES

Image: (red,green,blue)=(R,G,B)

Shadows have same color, but are darker

Use chromaticity coordinates

$$(r, g, b) = \left(\frac{R}{R+G+B}, \frac{G}{R+G+B}, \frac{B}{R+G+B}\right)$$

Normalizes for lightness

$r + g + b = 1$ so just use (r,g)

SIMILAR FOREGROUND COLORS

In chromaticity space, grey=white=black

Want to detect lightness changes

Lightness: $s = (R + G + B)/3$

Model pixel at time t as (r_t, g_t, s_t)
Model background as (r_B, g_B, s_B)

If $\frac{s_t}{s_B} < \alpha$ or $\frac{s_t}{s_B} > \beta$ or chromaticity different then foreground else background

(Eg. $\alpha = 0.8, \beta = 1.2$)

CHROMATICITY MODELLING

Using average color has problems with scene and camera jitter: no single pixel value

Instead use non-parametric distribution:

$$Pr(x|\text{ BACKGROUND}) = \frac{1}{N}\sum_{i=1}^{N} K_\sigma(x - b_i)$$

b_i : previous samples from background
Gauss kernel function $K_\sigma(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$

ADDING COLOR INTO MODEL

Chromaticity coordinates have 2 values: (r, g)

Use $\vec{x} = (r, g)$

$$Pr(\vec{x}|\text{BACKGROUND}) = \frac{1}{N}\sum_{i=1}^{N}\prod_{j\in\{r,g\}} K_\sigma(x_j - b_{ij})$$

DETECTING CHANGES I

Maintain background history H $= \{\vec{v}_i\} = \{(r_i, g_i, s_i)\}$ for each pixel
H is the last N pixel values classified as background for this pixel
A different set H for each pixel

At time t for a new pixel value $\vec{x}_t = (r_t, g_t, s_t)$, for each $\vec{b}_i = (r_i, g_i, s_i)$ in the background history H for this pixel

If $\alpha \leq \frac{s_t}{s_i} \leq \beta$ record sample in M ($\alpha = 0.8, \beta = 1.2$)

If $\mid M \mid = 0$
then FOREGROUND
else estimate probability of $\vec{x}_t = (r_t, g_t, s_t)$ being background

DETECTING CHANGES II

Want to estimate $Pr(\text{BACKGROUND}|\vec{x}_t)$

$$Pr(\vec{x}_t|\text{BACKGROUND}) = \frac{1}{|\ M\ |} \sum_{i \in M} \prod_{j \in \{r,g\}} K_\sigma(x_j - b_{ij})$$

$$Pr(\text{BG}|\vec{x}_t) = \frac{Pr(\vec{x}_t|\text{BG}) \times Pr(\text{BG})}{Pr(\vec{x}_t|\text{BG}) \times Pr(\text{BG}) + Pr(\vec{x}_t|\text{FG}) \times (1 - Pr(\text{BG}))}$$

$Pr(\text{BACKGROUND}) = 0.99$ (estimated *a priori* likelihood)
$Pr(\vec{x}_t|\text{FOREGROUND}) = 0.001$ (estimated - all values likely)

If $Pr(\text{BACKGROUND}|\vec{x}_t) < \tau$ then FOREGROUND ($\tau = 0.05$)

UPDATING THE MODEL?

At each pixel i, keep N most recent (r_t, g_t, s_t) background pixel values

Allows slow drift in illumination
Set allows multiple backgrounds due to jitter

(Discard non-background pixels)

$N = 50$ in examples

What We Have Learned

1. Non-parametric background model
2. Chromaticity coordinates