Moving Object Detection with an Adaptive Background Model

Robert B. Fisher
School of Informatics
University of Edinburgh
Adaptive Change Detection

**ADAPTIVE CHANGE DETECTION**

Naive method

\[ |\text{current} - \text{background}| > \text{threshold} \]

doesn’t work well in uncontrolled situations

Fix by using:

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

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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**Problem:** model out of date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

\[r + g + b = 1 \text{ so just use } (r, g)\]
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:

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

\( b_i \): 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 $|M| = 0$

then FOREGROUND

else estimate probability of $\vec{x}_t = (r_t, g_t, s_t)$ being background
DETECTING CHANGES II

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

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

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

$P r(\text{BACKGROUND}) = 0.99$ (estimated $a \ priori$ likelihood)

$P r(\vec{x}_t | \text{FOREGROUND}) = 0.001$ (estimated - all values likely)

If $P r(\text{BACKGROUND} | \vec{x}_t) < \tau$ 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