基于贝叶斯方法的火焰识别

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Overview

Assumptions

Assumption 1

Fire is evidently brighter than ordinary objects. (not enough)

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Assumption 2

Fire is chaotic, randomly spread to its surrounding, i.e. each fire pixel is spread from its position to its neighborhood ball following uniform distribution.

A Template for Fire Generation

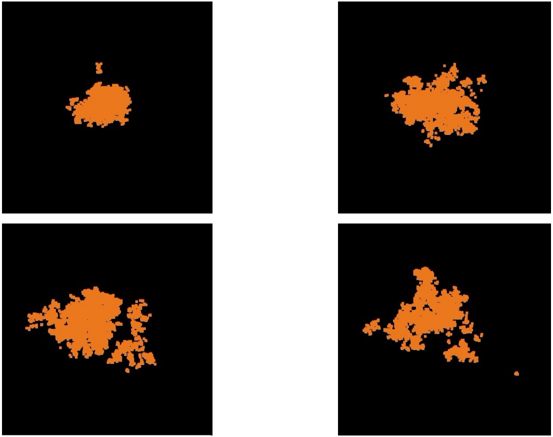

Figure: 火焰生成算法效果

Algorithm

算法 1 Flame generation Algorithm

```
procedure FLAME-GENERATOR(M_i)            ▷ InputM_i, Output next frameM_{i+1}
    M_{i+1} ← 0
    for i = 1 to n do
        for j = 1 to m do
            Choose (ξ_i(i, j), ξ_j(i, j)) randomly in N_b(0, 0)
            M_{i+1}(i, j) ← M_i(i + ξ_i(i, j), j + ξ_j(i, j))
        end for
    end for
    return M_{i+1}
end procedure
```

Detection Scheme

1. Fire Case
2. Non-fire Case
3. Overall Guess

Speculation error:

$$
\begin{aligned}
& \mathbb{P}\left(I_t' | I_t = M(x+\Delta x,\ y+\Delta y)\right) \\
= & \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(I_t' - M(x+\Delta x,\ y+\Delta y))^2}{2\sigma^2}\right)
\end{aligned}
$$

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$$
\begin{aligned}
&\mathbb{P}(I'_t|\text{Flame}) \\
= &\sum_{(\Delta x,\Delta y)\in N_b(0,0)} \mathbb{P}(I'_t|I_t = M(x+\Delta x,\ y+\Delta y)) \\
&\mathbb{P}(I_t = M(x+\Delta x,\ y+\Delta y)|\text{Flame}) \\
= &\frac{1}{|N_b(0,0)|} \sum_{(\Delta x,\Delta y)\in N_b(0,0)} \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(I'_t - M(x+\Delta x,\ y+\Delta y))^2}{2\sigma^2}\right)
\end{aligned}
$$

where $|N_b(0,0)|$ is the number of blocks in a single neighborhood.

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$$
\begin{aligned}
& \mathbb{P}(I'_t|\overline{\text{Flame}}) \\
= \ & \mathbb{P}(I'_t|I_t = M(x + V_x,\ y + V_y))\mathbb{P}(I_t = M(x + V_x,\ y + V_y)|\overline{\text{Flame}}) \\
= \ & \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{(I'_t - M(x + V_x,\ y + V_y))^2}{2\sigma^2}\right)
\end{aligned}
$$

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By Bayes' Formula,

$$\frac{\mathbb{P}(\text{Flame}|I'_t)}{\mathbb{P}(\overline{\text{Flame}}|I'_t)} = \frac{\mathbb{P}(I'_t|\text{Flame})\mathbb{P}(\text{Flame})}{\mathbb{P}(I'_t|\overline{\text{Flame}})\mathbb{P}(\overline{\text{Flame}})}$$

$\mathbb{P}(\text{Flame}) := 0.01$ is set manually, according to empirical test.

Markov Model Optimization

In our previous discussion, only two adjacent frames are considered. In order to improve robustness of the algorithm, we may consider Markov Model as an optimization.

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Recall:

Assumption 2

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Assumption 2'(Markov Chain Property)

Each frame in a video containing fire only depends on its prior frame.

Detection Scheme

$$
\begin{aligned}
& \frac{\mathbb{P}(\text{Flame}|I_n, I_{n-1}, \ldots, I_1, I_0)}{\mathbb{P}(\overline{\text{Flame}}|I_n, I_{n-1}, \ldots, I_1, I_0)} \\
= \quad & \frac{\mathbb{P}(I_n, I_{n-1}, \ldots, I_1|I_0, \text{Flame})\mathbb{P}(I_0, \text{Flame})}{\mathbb{P}(I_n, I_{n-1}, \ldots, I_1|I_0, \overline{\text{Flame}})\mathbb{P}(I_0, \overline{\text{Flame}})} \\
= \quad & \frac{\mathbb{P}(I_n|I_{n-1}, \text{Flame})\mathbb{P}(I_{n-1}|I_{n-2}, \text{Flame}) \ldots \mathbb{P}(I_1|I_0, \text{Flame})\mathbb{P}(\text{Flame}|I_0)}{\mathbb{P}(I_n|I_{n-1}, \overline{\text{Flame}})\mathbb{P}(I_{n-1}|I_{n-2}, \overline{\text{Flame}}) \ldots \mathbb{P}(I_1|I_0, \overline{\text{Flame}})\mathbb{P}(\overline{\text{Flame}}|I_0)}
\end{aligned}
$$

where $\mathbb{P}(\text{Flame}|I_0)$is estimated by brightness ofI_0(recall assumption 1).
$n = 10$is used in actual algorithm.

Outcome

OpenCV, C++ open library.

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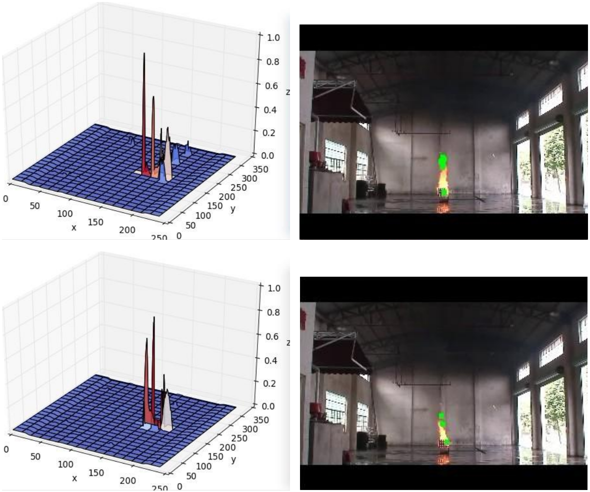
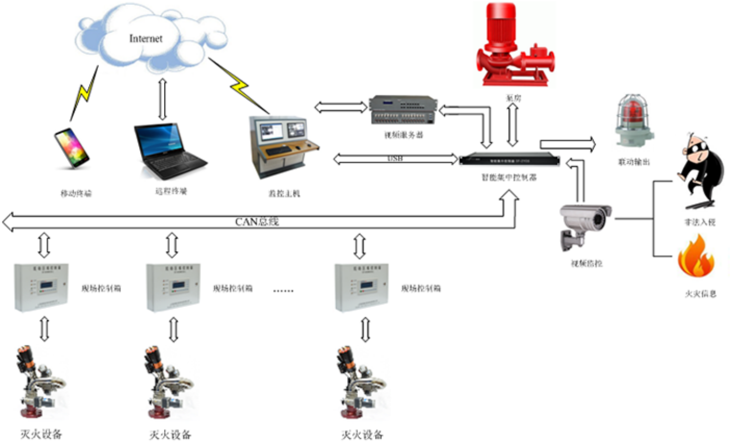


Figure: $\mathbb{P}(\text{Flame})(n = 10)$ vs video output

Application

Early alarm of fire-fighting equipment in basement, factory, theater,etc.



(Image from *http://www.safor-tec.com*)

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Thanks for diligent work of relevant professors and students in the Science Innovation Center.

Outcome

OpenCV, C++ open library.

The End