Quadcopter Navigation through Obstacles using Potential Field

Visual Navigation for Flying Robots

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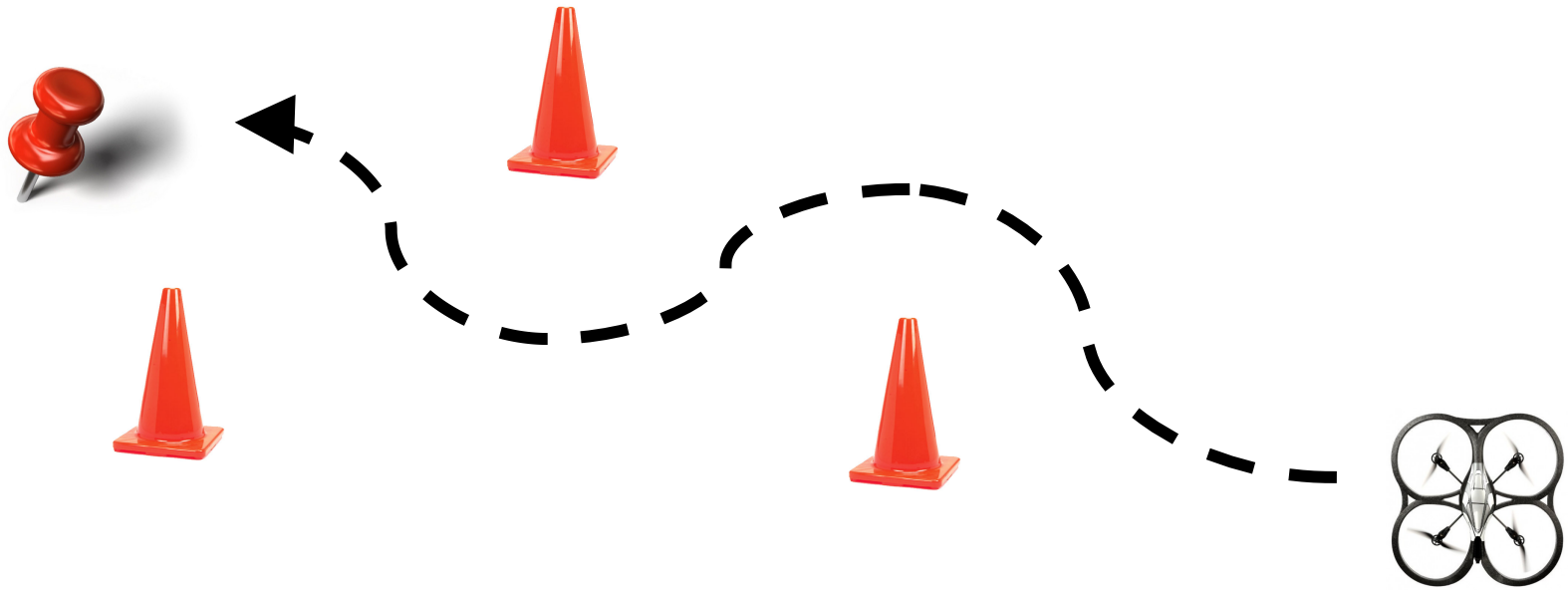
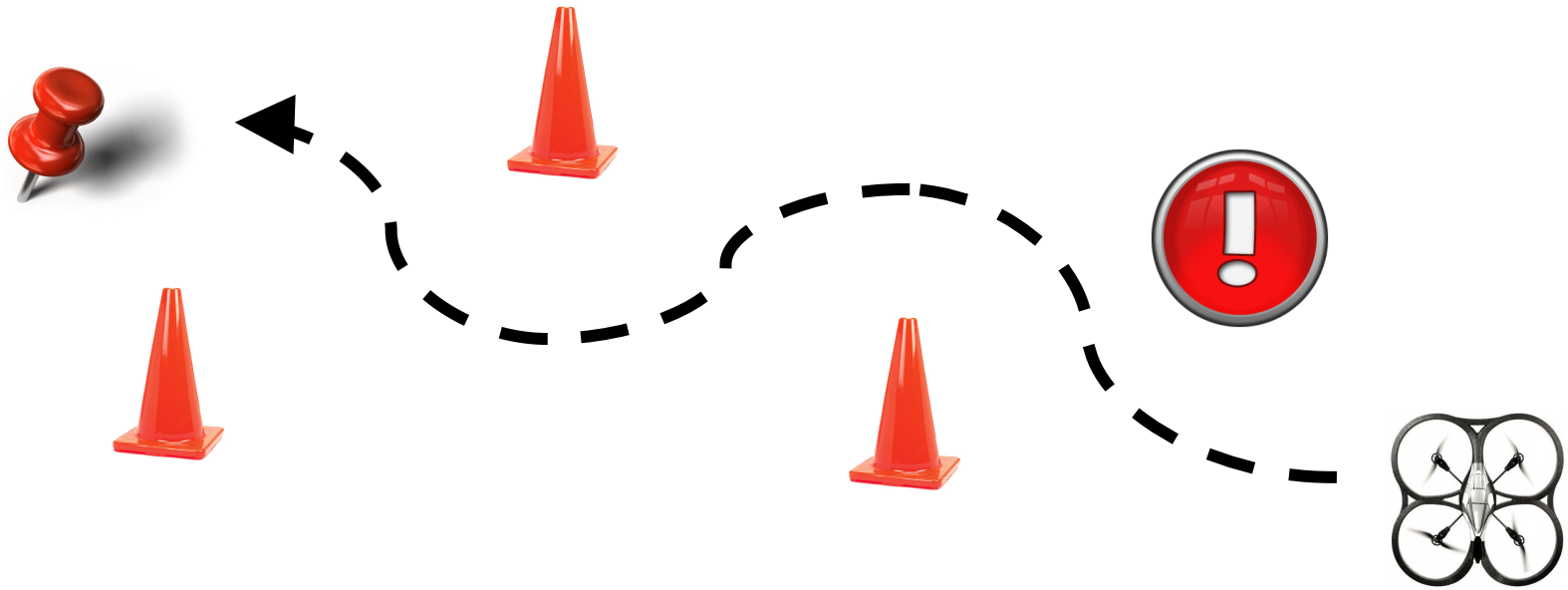
Idea

Navigate the quadcopter **autonomously** to the goal point by **avoiding obstacles** on the path?



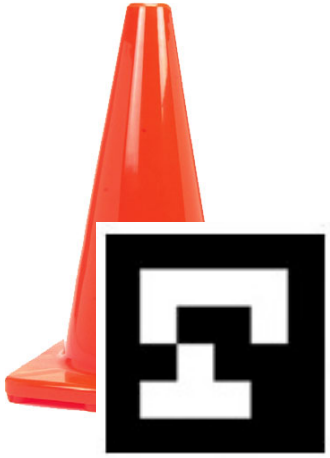
Research Problem

- Obstacles **detection**.
- **Avoiding** those obstacles.
- Finding the **optimal path** to the goal point.



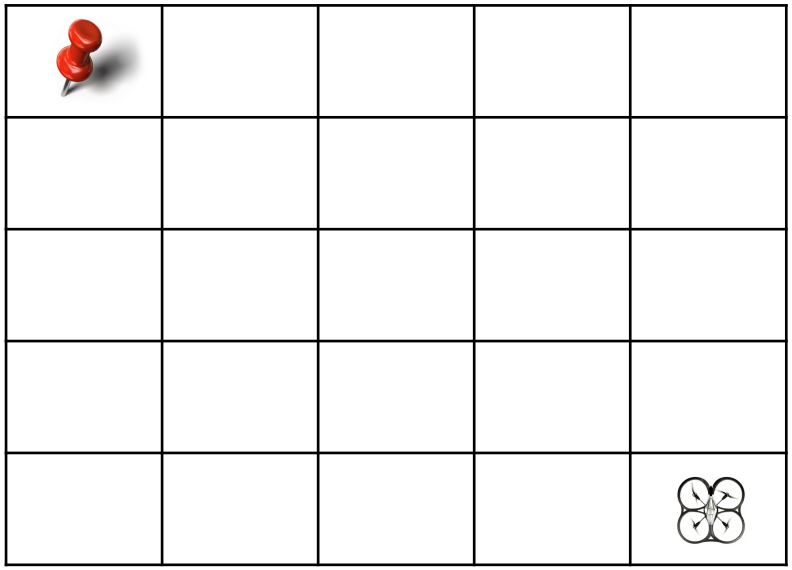
Approach

- Detect obstacles with **markers**.



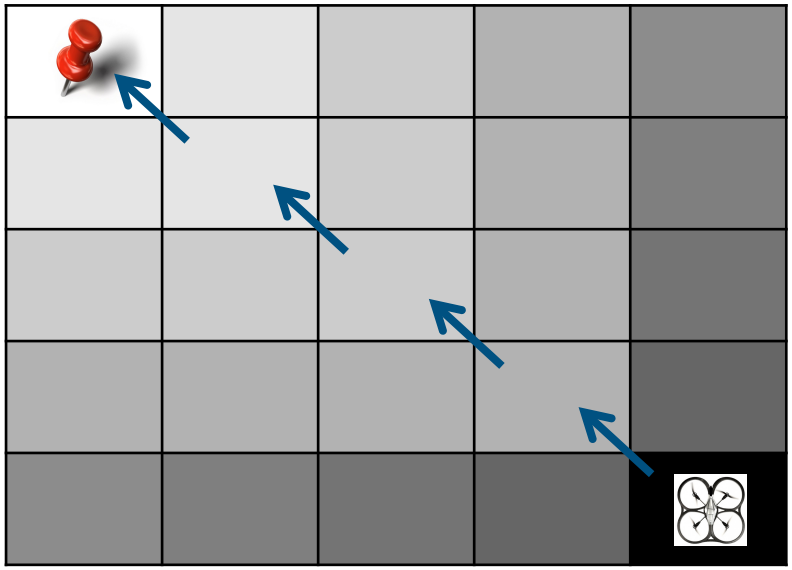
Approach

- Discretization of the environment with **grid**.



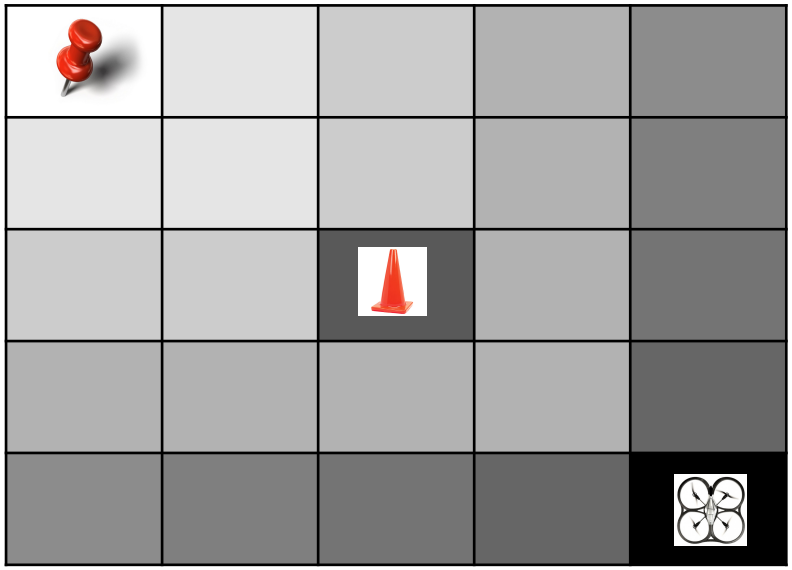
Approach

- Apply **potential field** to the environment grid.
- Potential difference between each block (gradient).



Approach

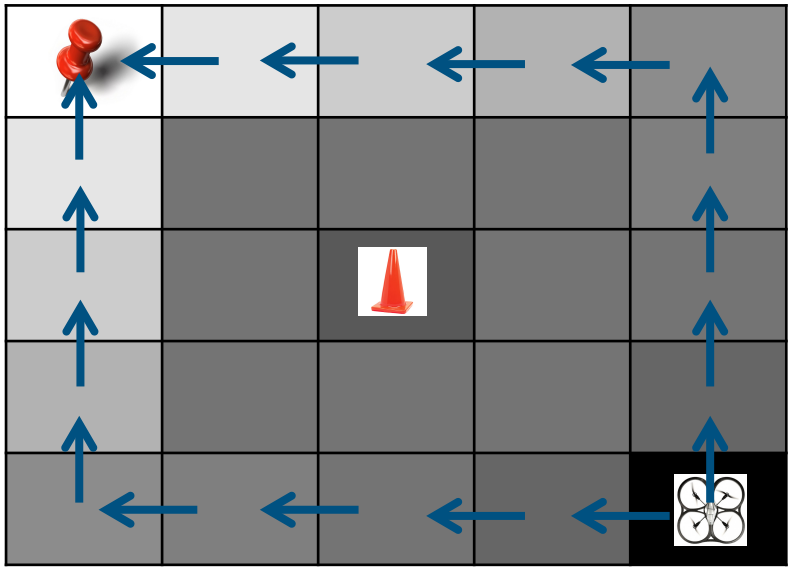
- Higher potential for block with obstacle.



Approach

- **Convolve** the field with **Gaussian** kernel

$$J(x,y) = H * J = \sum_{i=-r}^{+r} \sum_{j=-r}^{+r} e^{-\frac{1}{2}\frac{i^2+j^2}{\sigma}} J(x-i, y-i)$$



Approach

- Position correction using **extended Kalman filter**
  - Motion model

$$\bar{\mu}_t = g(\mu_{t-1}, u_t)$$
$$\bar{\Sigma}_t = G_t \Sigma G_t^\top + Q$$

with $$G_t = \frac{\partial g(\mu_{t-1}, u_t)}{\partial x_{t-1}}$$

  - Sensor model

$$\mu_t = \bar{\mu}_t + K_t(z_t - h(\bar{\mu}_t))$$
$$\Sigma_t = (I - K_t H_t)\bar{\Sigma}_t$$

with $$K_t = \bar{\Sigma}_t H_t^\top (H_t \bar{\Sigma}_t H_t^\top + R)^{-1}$$ and $$H_t = \frac{\partial h(\bar{\mu}_t)}{\partial x_t}$$

Approach

- Control correction using **PID controller**.

$$u(t) = K_P \cdot e(t) + K_I \cdot \int_0^t e(\tau)\,\mathrm{d}\tau + K_D \cdot \dot{e}(t)$$

- Error values for PID are derived from potential field.

Approach

- Detect obstacles with **markers**.
- Discretization of the environment with **grid**.
- Apply **potential field** to the environment grid.
- **Convolve** the obstacles with **Gaussian** kernel.
- Position correction using **Kalman filter**.
- Control correction using **PID controller**.

Future Works

- Three dimensional potential field.
- Obstacle detection without markers.