Quadcopter Navigation through Obstacles using Potential Field

Visual Navigation for Flying Robots

Summer Semester 2013

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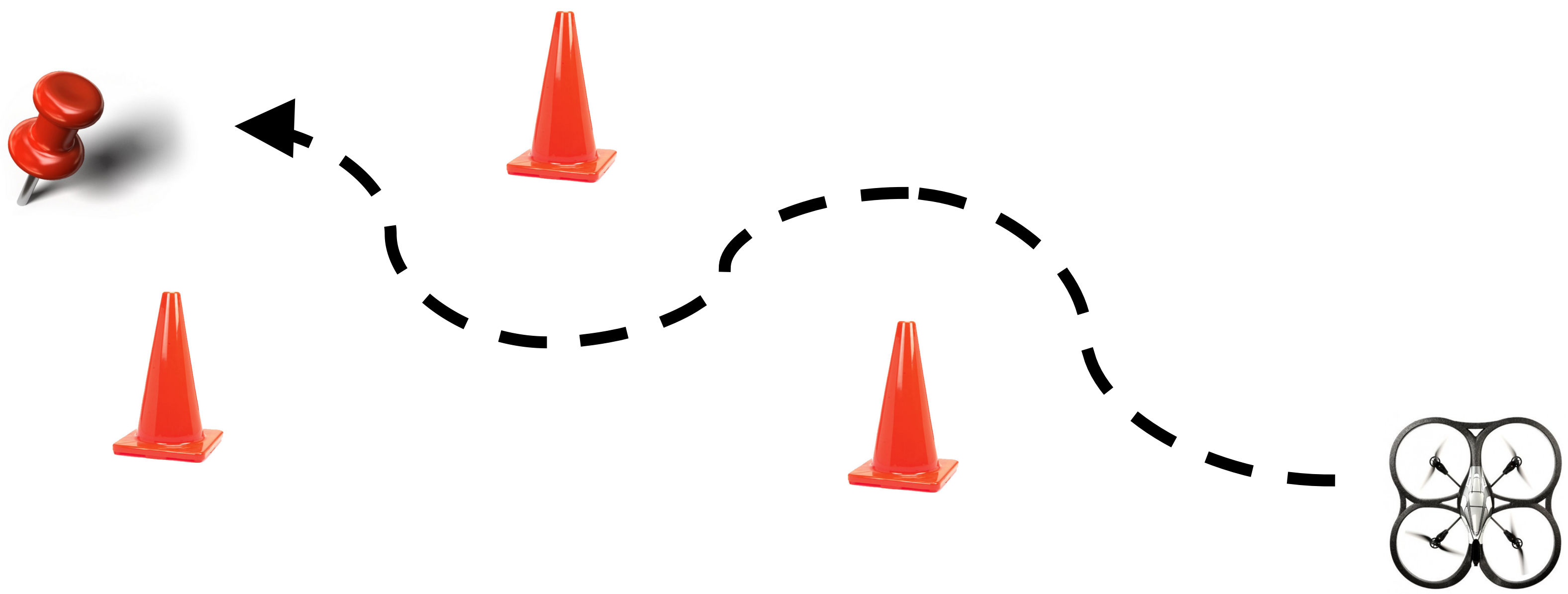
Last, last week on…

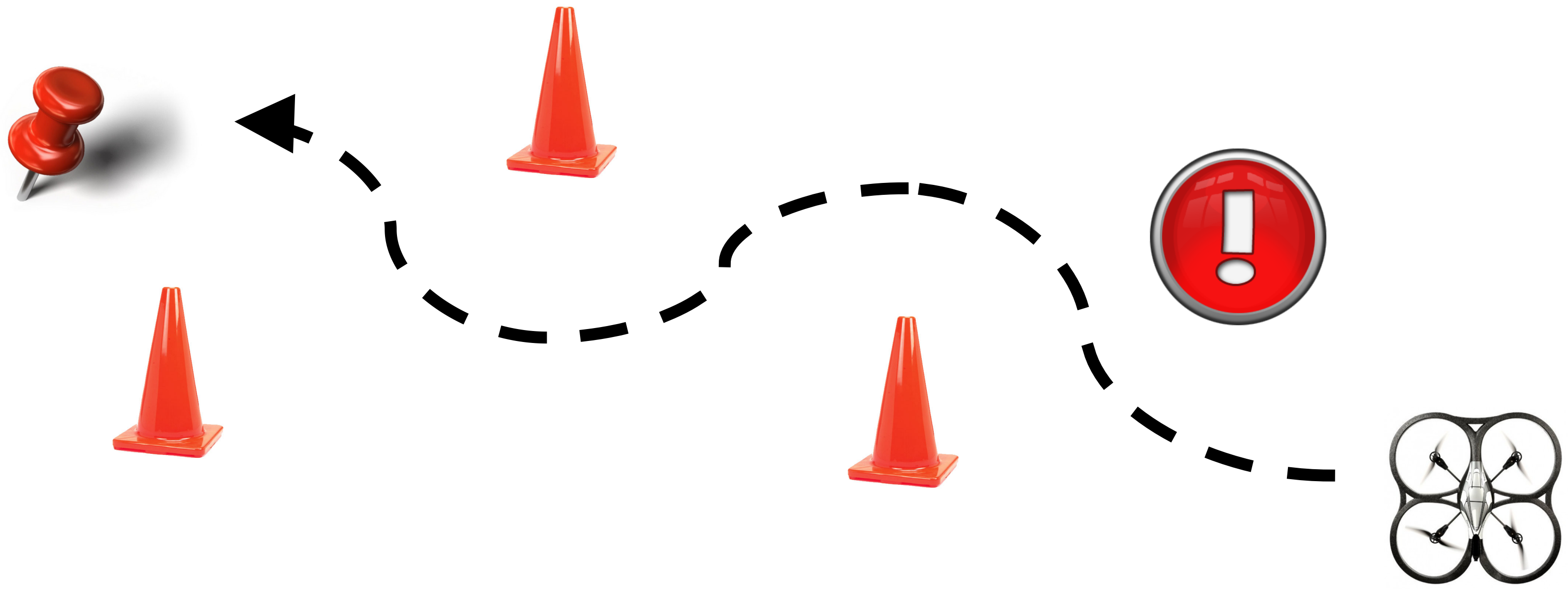
Idea

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.

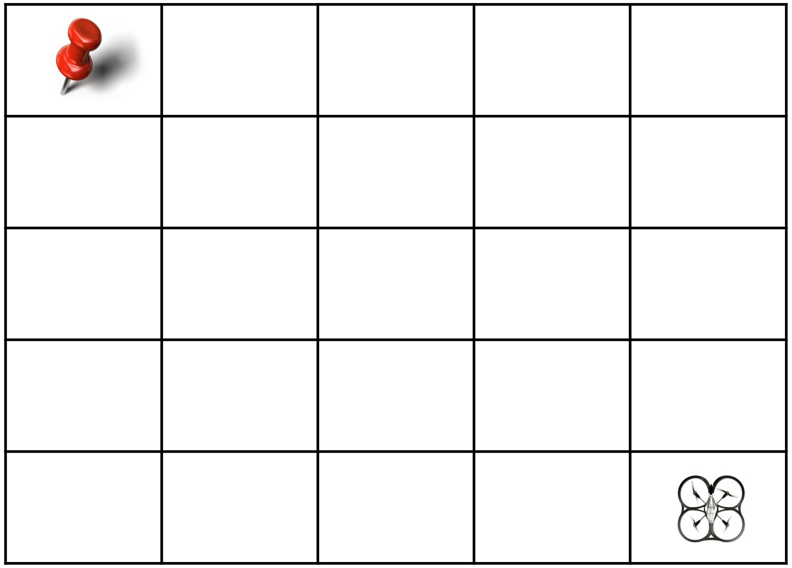


Approach

- Detect obstacles with **markers**.

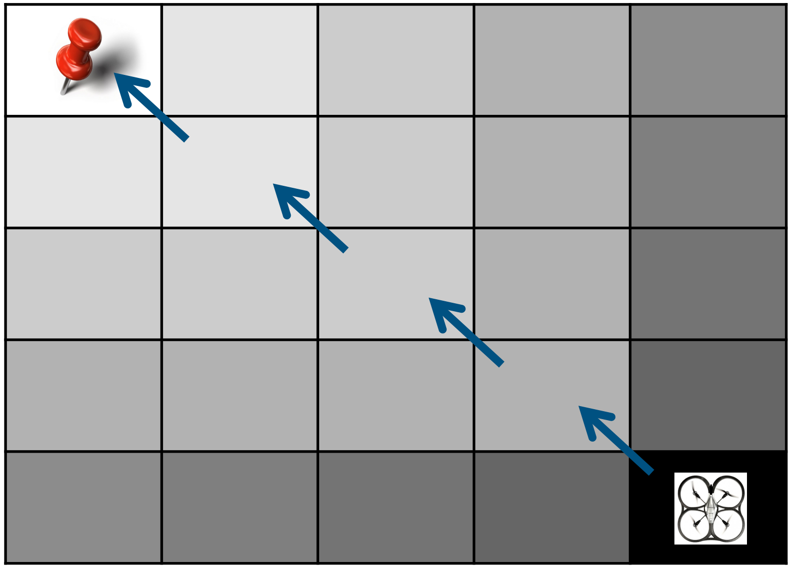
Approach

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



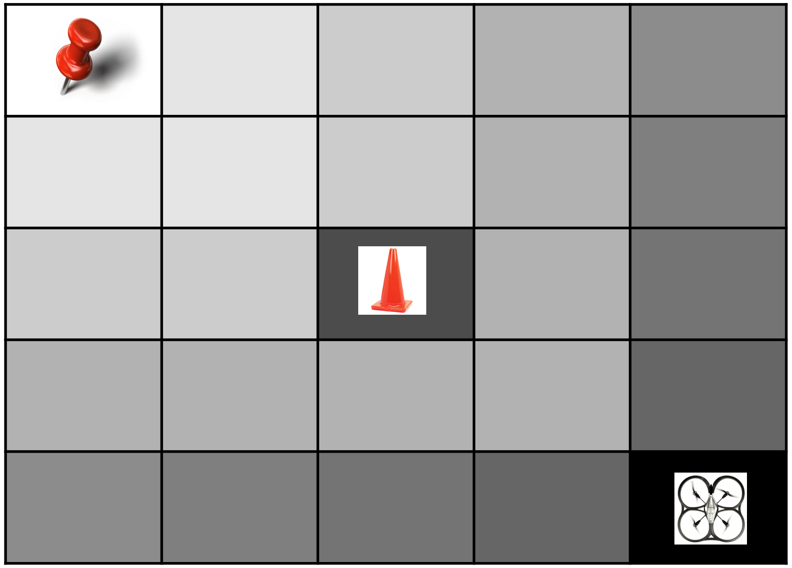
Approach

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



Approach

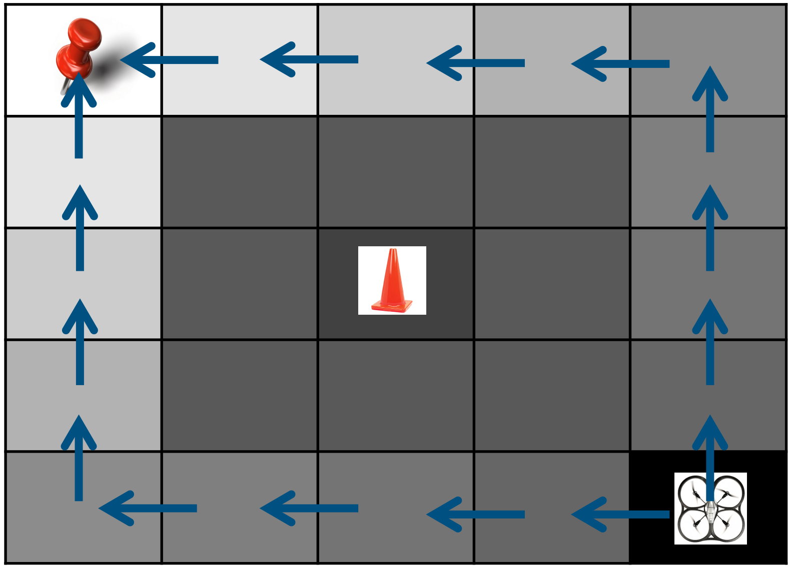
- Higher potential for block with obstacle.



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

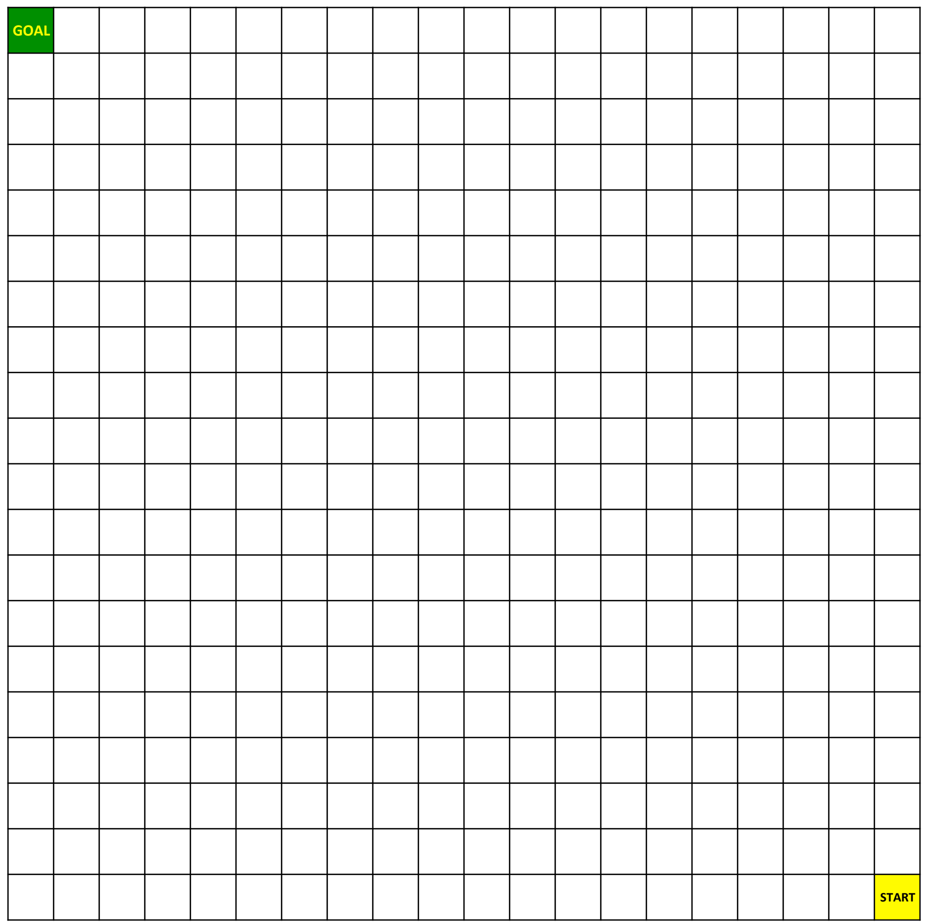
- Detect obstacles with **markers**.
- Discretization of the environment with **grid**.
- Apply **potential field** to the environment grid.
- **Convolve** the obstacles with **Gaussian** kernel.
- Position correction using **Kalman filter**.
- Control correction using **PID controller**.

What has been happening…

Front Camera Marker Detection

- Using **front camera** instead of bottom camera.
- Flight test for **sensitivity**.
- However, later on assuming **always fly on same height**.

Potential Field



Potential Field

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
10	10	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
15	15	15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
20	20	20	20	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
25	25	25	25	25	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
30	30	30	30	30	30	30	35	40	45	50	55	60	65	70	75	80	85	90	95
35	35	35	35	35	35	35	35	40	45	50	55	60	65	70	75	80	85	90	95
40	40	40	40	40	40	40	40	40	45	50	55	60	65	70	75	80	85	90	95
45	45	45	45	45	45	45	45	45	45	50	55	60	65	70	75	80	85	90	95
50	50	50	50	50	50	50	50	50	50	50	55	60	65	70	75	80	85	90	95
55	55	55	55	55	55	55	55	55	55	55	55	60	65	70	75	80	85	90	95
60	60	60	60	60	60	60	60	60	60	60	60	60	65	70	75	80	85	90	95
65	65	65	65	65	65	65	65	65	65	65	65	65	65	70	75	80	85	90	95
70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	75	80	85	90	95
75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	80	85	90	95
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	85	90	95
85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	90	95
90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	95
95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	100

Potential Field

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
10	10	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
15	15	15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
20	20	20	20	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
25	25	25	25	25	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
30	30	30	30	30	30	30	35	40	45	50	55	60	65	70	75	80	85	90	95
35	35	35	35	35	35	35	35	40	45	50	55	60	65	70	75	80	85	90	95
40	40	40	40	40	40	40	40	40	45	50	55	60	65	70	75	80	85	90	95
45	45	45	45	45	45	45	45	45	45	50	55	60	65	70	75	80	85	90	95
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75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	80	85	90	95
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	85	90	95
85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	90	95
90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	95
95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	100

Potential Field

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
10	10	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
15	15	15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
20	20	20	20	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
25	25	25	25	25	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
30	30	30	30	30	30	30	35	40	45	50	55	60	65	70	75	80	85	90	95
35	35	35	35	35	35	35	35	40	45	50	55	60	65	70	75	80	85	90	95
40	40	40	40	40	40	40	40	40	45	50	55	60	65	70	75	80	85	90	95
45	45	45	45	45	45	45	45	45	45	50	55	60	65	70	75	80	85	90	95
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95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	100

Potential Field

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
10	10	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
15	15	15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
20	20	20	20	22.74	26.95	30.99	35	40	45	50	55	60	65	70	75	80	85	90	95
25	25	25	25	27	100	31.24	35	40	45	50	55	60	65	70	75	80	85	90	95
30	30	30	30	30.62	31.29	32.66	35	40	45	50	55	60	65	70	75	80	85	90	95
35	35	35	35	35	35	35	35	41.12	46.37	50.92	55	60	65	70	75	80	85	90	95
40	40	40	40	40	40	40	41.71	45.6	100	53.23	56.38	60	65	70	75	80	85	90	95
45	45	45	45	45	45	45	46.96	100	100	100	56.28	60	65	70	75	80	85	90	95
50	50	50	50	50	50	50	50.56	51.7	53.06	54.28	56.45	60	65	70	75	80	85	90	95
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75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	80	85	90	95
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	82.74	86.95	90.99	95
85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	87.10	100	91.24	95
90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90.62	91.29	93.04	95
95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	100

Potential Field

0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
10	10	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
15	15	15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
20	20	20	20	22.74	26.95	30.99	35	40	45	50	55	60	65	70	75	80	85	90	95
25	25	25	25	27	100	31.24	35	40	45	50	55	60	65	70	75	80	85	90	95
30	30	30	30	30.62	31.29	32.66	35	40	45	50	55	60	65	70	75	80	85	90	95
35	35	35	35	35	35	35	35	41.12	46.37	50.92	55	60	65	70	75	80	85	90	95
40	40	40	40	40	40	40	41.71	45.6	100	53.23	56.38	60	65	70	75	80	85	90	95
45	45	45	45	45	45	45	46.96	100	100	100	56.28	60	65	70	75	80	85	90	95
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70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	75	80	85	90	95
75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	80	85	90	95
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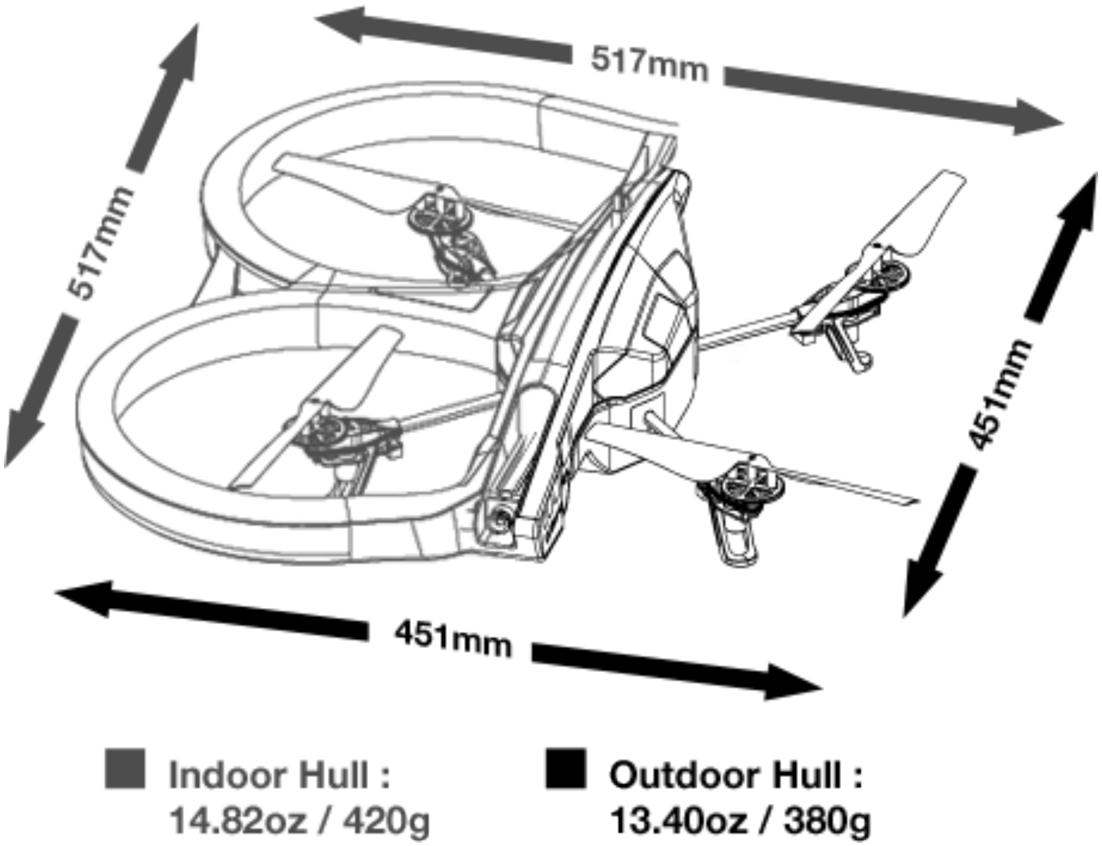
90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90.62	91.29	93.04	95
95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	100

Grid Size



http://ardrone2.parrot.com/ardrone-2/specifications/

What's next?

- Distance calculation from obstacles (markers).
- Control implementation.
- Fine tuning and correction.