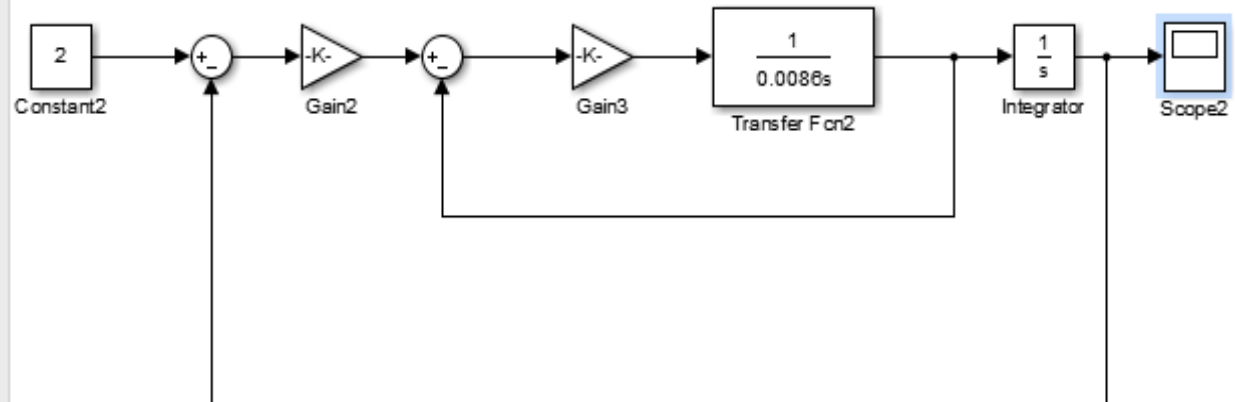
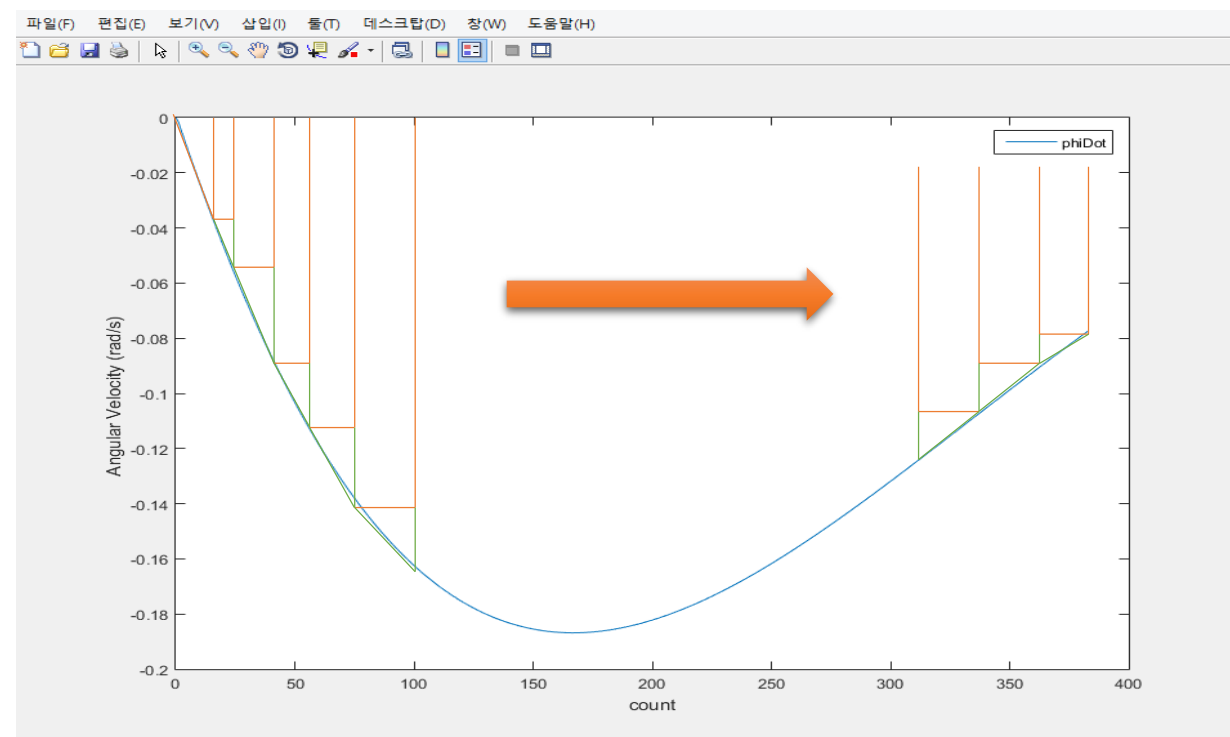
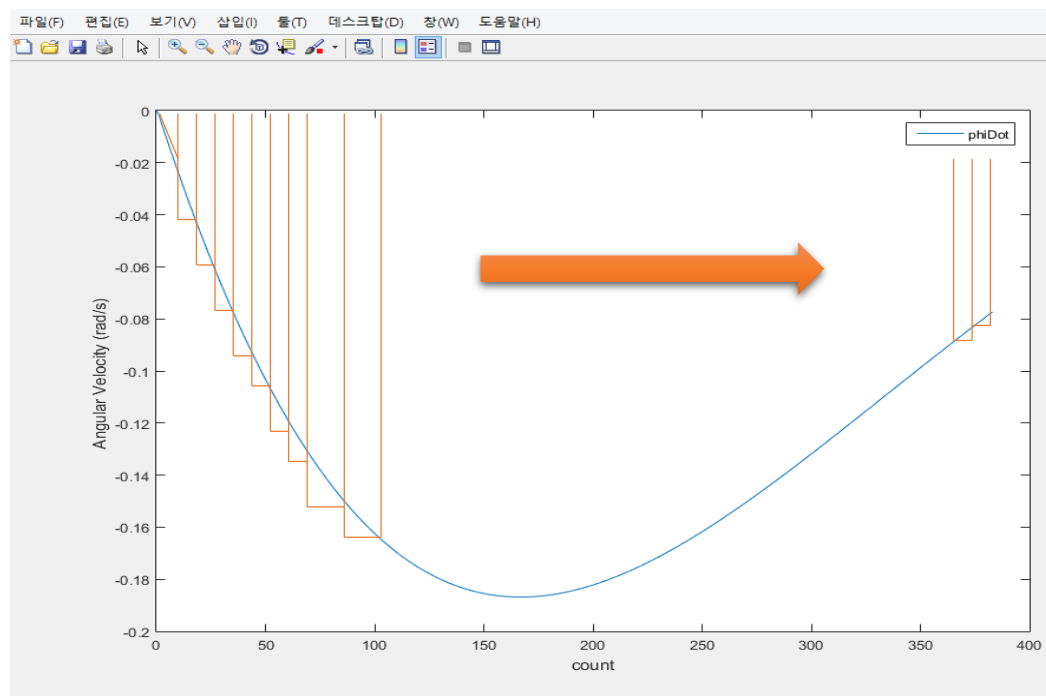


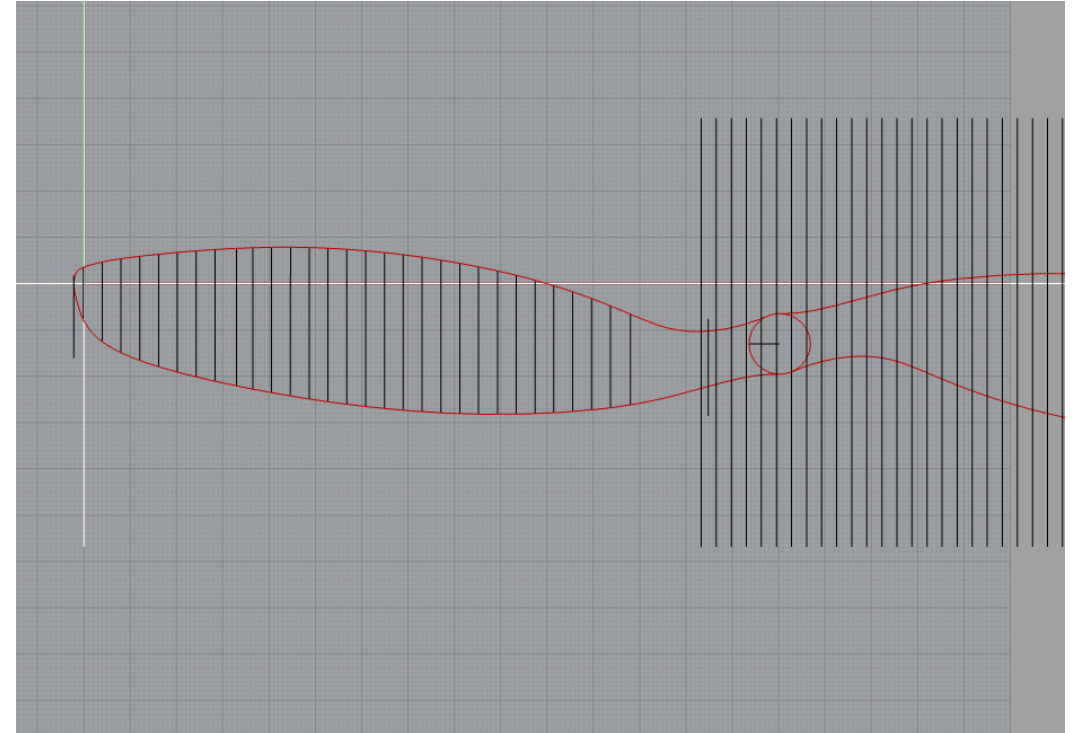
System Model 변경





# Integral







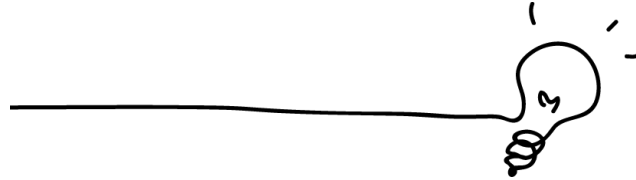
# Thrust

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		value		unit	value		unit																
2	Propeller_Spec_1																						
3	R	0.12	m					입력구간		참고		c(r)	rMiddle에 따른 c 값을 측정하여 입력하기										
4	r_max	0.12	m					자동변경구간		ideal_state													
5	r_min	0.024	m		r_max-rmin	0.096	m																
6	Nr	20	구간			0.0048	m																
7	dr	0.0048	m																				
8	section	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
9	r	0.024	0.0288		0.0336	0.0384	0.0432	0.048	0.0528	0.0576	0.0624	0.0672	0.072	0.0768	0.0816	0.0864	0.0912	0.096	0.1008	0.1056	0.1104	0.1152	0.12
10	rMiddle	0.0264	0.0312		0.036	0.0408	0.0456	0.0504	0.0552	0.06	0.0648	0.0696	0.0744	0.0792	0.084	0.0888	0.0936	0.0984	0.1032	0.108	0.1128	0.1176	
11	Airfoil 성능																						
12	Nb	2	개																				
13	rho	1.2	kg/m^3																				
14	Cla	5.7	rad^-1																				
15	alpha0	-2	degree		-0.034906585	radian																	
16	Clmax	1.2																					
17	Propeller_Spec_2																						
18	pitch	0.065965	m																				
19	theta_rad	0.378501633	0.324594		0.283759698	0.251856	0.22629	0.20537	0.187948	0.173224	0.160621	0.149714	0.140185	0.13179	0.124339	0.117682	0.111698	0.106292	0.101382	0.096905	0.092806	0.089038	
20	theta_deg	21.6865461	18.59785		16.25823308	14.43029	12.96548	11.76682	10.76864	9.925	9.202883	8.577984	8.032031	7.551036	7.124114	6.742672	6.399839	6.090057	5.808782	5.552265	5.317382	5.101516	
21	c(r)	0.0167	0.01843		0.01999	0.02129	0.02235	0.02313	0.02368	0.023962	0.02398	0.02376	0.02328	0.022545	0.021567	0.020301	0.018813	0.01706	0.015042	0.012781	0.010257	7.48E-03	
22	Ct_Calculation																						
23	sigma	0.088596252	0.097774		0.106050244	0.112947	0.11857	0.122708	0.125626	0.127122	0.127218	0.126051	0.123504	0.119605	0.114416	0.1077	0.099806	0.090506	0.0798	0.067805	0.054415	0.039704	
24	a	1																					
25	b	0.063124829	0.069664		0.075560799	0.080475	0.084481	0.08743	0.089509	0.090575	0.090643	0.089811	0.087997	0.085219	0.081522	0.076736	0.071112	0.064486	0.056858	0.048311	0.038771	0.028289	
26	c	-0.005741191	-0.00651		-0.007223604	-0.00785	-0.00839	-0.00882	-0.00918	-0.00943	-0.00957	-0.00962	-0.00955	-0.00938	-0.00909	-0.00866	-0.00813	-0.00747	-0.00666	-0.00573	-0.00465	-0.00344	
27	lambda	0.050519113	0.053059		0.05523015	0.057052	0.058603	0.05989	0.060975	0.061842	0.062496	0.062953	0.063186	0.06318	0.062916	0.062314	0.061377	0.059985	0.058014	0.055309	0.051539	0.046157	
28																							
29	dCt	7.75314E-06	9.23E-06		1.04023E-05	1.12E-05	1.16E-05	1.17E-05	1.15E-05	1.11E-05	1.06E-05	1.01E-05	9.74E-06	9.64E-06	9.89E-06	1.06E-05	1.18E-05	1.34E-05	1.52E-05	1.7E-05	1.82E-05	1.8E-05	
30	Ct	1.1945E-05																					
31	dCq	2.04683E-07	2.88E-07		3.74484E-07	4.57E-07	5.31E-07	5.92E-07	6.37E-07	6.67E-07	6.88E-07	7.03E-07	7.24E-07	7.63E-07	8.31E-07	9.44E-07	1.1E-06	1.32E-06	1.57E-06	1.84E-06	2.06E-06	2.11E-06	
32	Cq	9.20393E-07																					
33																							
34																							

BEMT\_Momentum

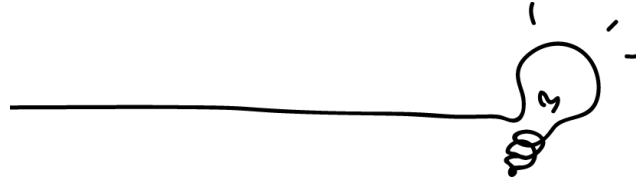
Airfoil

# Inertial Moment



1. Arm Moment
2. Battery Moment
3. Disc Moment
4. Board Moment
5. Motor Moment
6. Propeller Moment

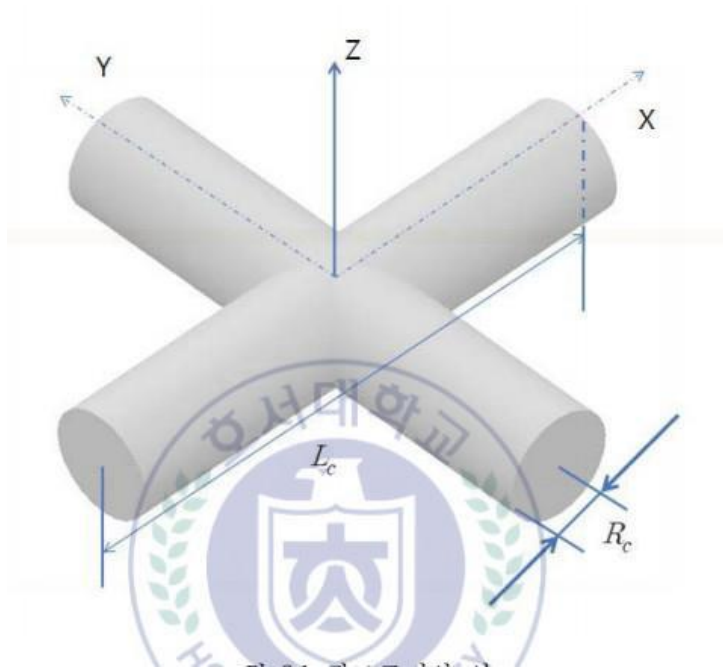
# Inertial Moment



1. Arm Moment
2. Battery Moment
3. Disc Moment
4. Board Moment
5. Motor Moment
6. Propeller Moment



# Arm Moment



$R_A$  : Arm의 반지름

$L_A$  : 길이

$M_A$  : Arm의 질량

$$I_{AX} = M_A \left( \frac{R_A^2}{4} + \frac{L_A^2}{12} \right) + \frac{1}{2} M_A R_A^2 = 1.4127 \times 10^{-3} [Nms^2]$$

$$I_{AY} = M_A \left( \frac{R_A^2}{4} + \frac{L_A^2}{12} \right) + \frac{1}{2} M_A R_A^2 = 1.4127 \times 10^{-3} [Nms^2]$$

$$I_{AZ} = M_A \left( \frac{R_A^2}{4} + \frac{L_A^2}{12} \right) + M_A \left( \frac{R_A^2}{4} + \frac{L_A^2}{12} \right) = 2.8246 \times 10^{-3} [Nms^2]$$





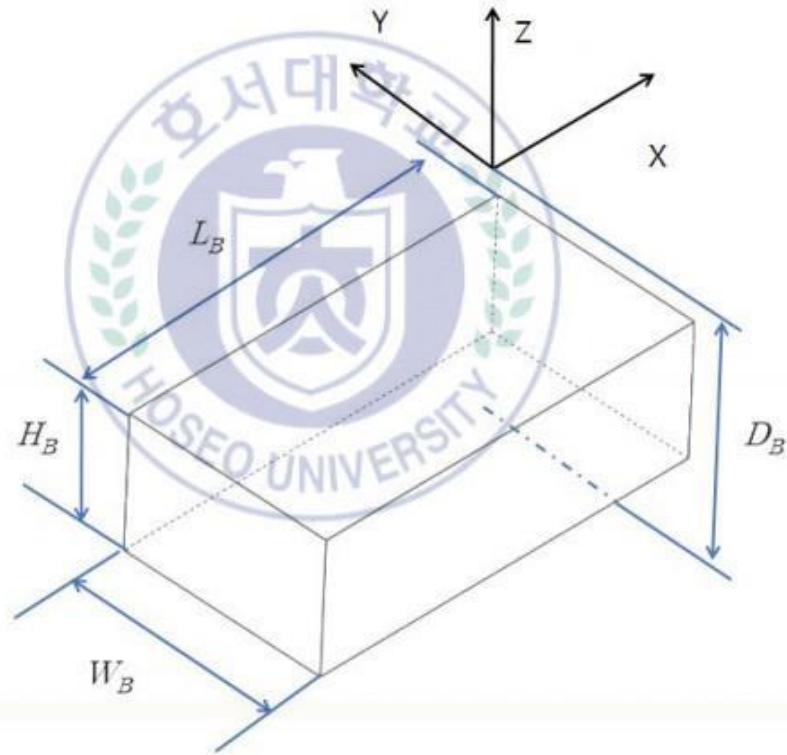
# Battery Moment

$L_B$  : 길이

$W_B$  : 폭

$H_B$  : 높이

$M_B$  : 무게



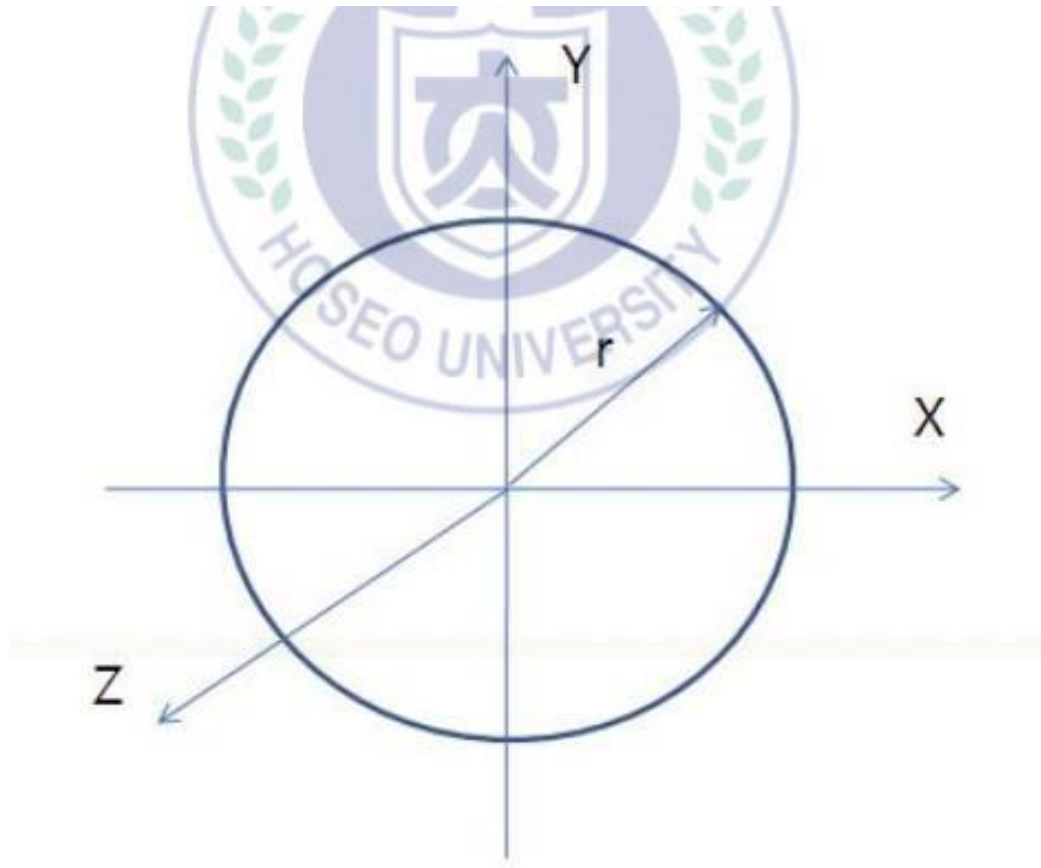
$$I_{BX} = M_B \left( \frac{W_B^2}{12} + \frac{H_B^2}{12} + D_B^2 \right) = 0.129 \times 10^{-3} [Nm s^2]$$

$$I_{BY} = M_B \left( \frac{L_B^2}{12} + \frac{H_B^2}{12} + D_B^2 \right) = 0.299 \times 10^{-3} [Nm s^2]$$

$$I_{BZ} = M_B \left( \frac{L_B^2}{12} + \frac{W_B^2}{12} \right) = 0.223 \times 10^{-3} [Nm s^2]$$



# Disc Moment



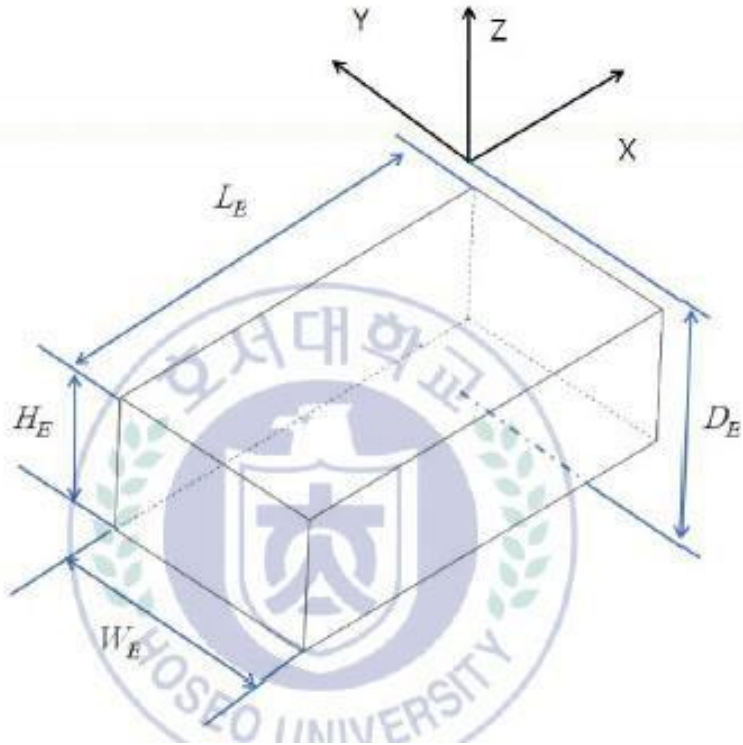
$R_D$  : 디스크의 반지름  
 $M_D$  : 디스크의 질량

$$I_{DX} = I_{DY} = \frac{1}{2} M_D R_D^2 = 0.0049 \times 10^{-3} [Nms^2]$$

$$I_{DZ} = \frac{1}{4} M_D R_D^2 = 0.0025 \times 10^{-3} [Nms^2]$$



# Board Moment



L : 길이

W : 폭

H : 높이

D : 쿼드콥터 무게중심과 제어 박스의 무게 중심까지의 길이

M : 무게

$$I_{EX} = M_E \left( \frac{W_E^2}{12} + \frac{H_E^2}{12} + D_E^2 \right) = 0.99672 \times 10^{-3} [Nms^2]$$

$$I_{EY} = M_E \left( \frac{L_E^2}{12} + \frac{H_E^2}{12} + D_E^2 \right) = 0.99672 \times 10^{-3} [Nms^2]$$

$$I_{EZ} = M_E \left( \frac{L_E^2}{12} + \frac{W_E^2}{12} \right) = 0.379 \times 10^{-3} [Nms^2]$$



# Motor Moment

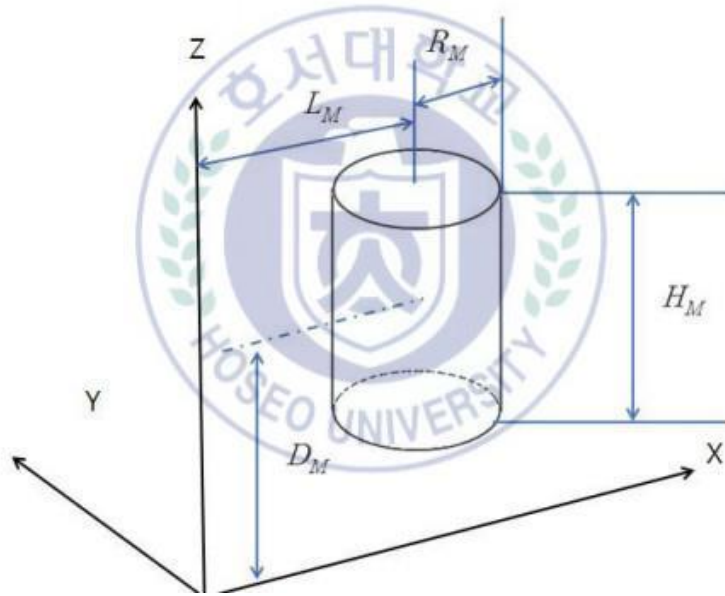
$R_M$  : 모터의 반지름

$M_M$  : 모터의 질량

$H_M$  : 모터의 높이

$L_M$  : x축의 무게중심으로 부터 모터의 중심까지의 길이

$D_M$  : 모터의 중심까지의 길이



$$I_{MX} = M_M \left( \frac{R_M^2}{4} + \frac{H_M^2}{12} + D_M^2 \right) = 0.01815 \times 10^{-3} [Nms^2]$$

$$I_{MY} = M_M \left( \frac{R_M^2}{4} + \frac{H_M^2}{12} + L_M^2 + D_M^2 \right) = 3.536 \times 10^{-3} [Nms^2]$$

$$I_{MZ} = M_M \left( \frac{R_M^2}{4} + L_M^2 \right) = 3.52 \times 10^{-3} [Nms^2]$$



# Propeller Moment

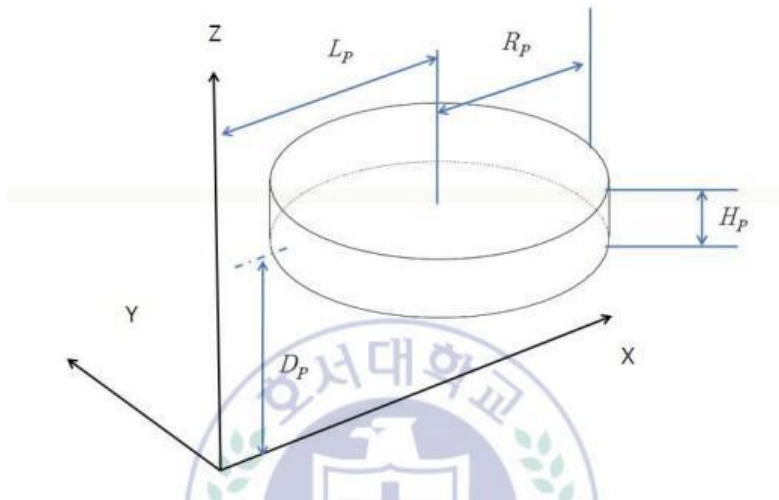
$R_p$  : 프로펠러 반지름

$H_p$  : 프로펠러의 높이

$L_p$  : x축의 무게중심으로부터 프로펠러 중심까지의 길이

$D_p$  : z축의 무게 중심으로부터 프로펠러 중심까지의 길이

$M_p$  : 프로펠러의 질량



$$I_{p1X} = M_p \left( \frac{R_p^2}{6} + \frac{H_p^2}{12} + D_p^2 \right) = 0.0324 \times 10^{-3} [Nms^2]$$

$$I_{p1Y} = M_p \left( \frac{R_p^2}{6} + \frac{H_p^2}{12} + L_p^2 + D_p^2 \right) = 0.420 \times 10^{-3} [Nms^2]$$

$$I_{p1Z} = M_p \left( \frac{R_p^2}{3} + L_p^2 \right) = 0.419 \times 10^{-3} [Nms^2]$$

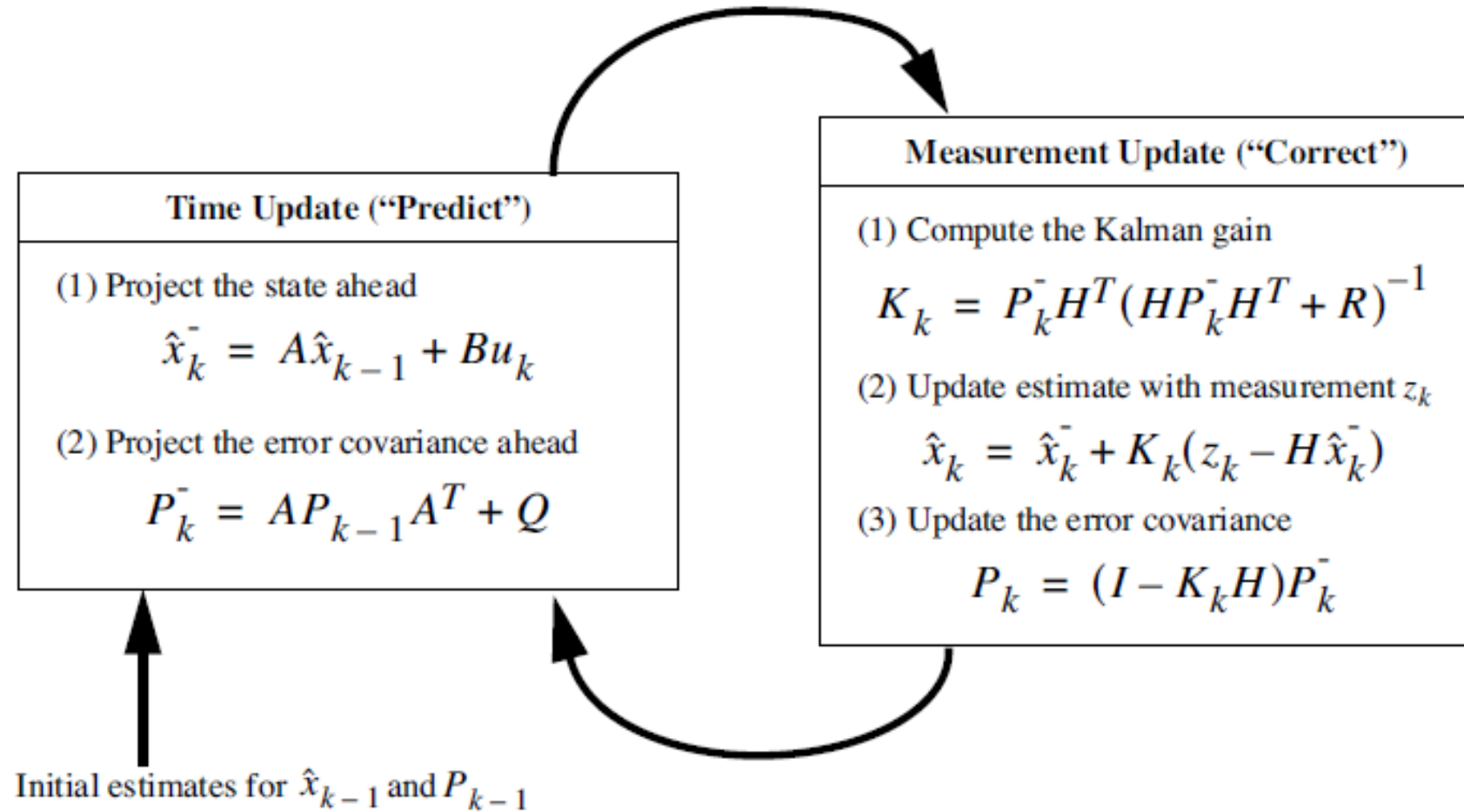


# Inertial Moment

관성모멘트						
value	unit	비고	value	value	unit	비고
Arm Moment			Control Box Moment			
R : arm의 반지름	0.016 m		L : 길이			
L : 길이	0.353 m		W : 폭			
M : 질량	0.388 kg	Motor, ESC, Motor connect	H : 높이			
M_p : 추가질량	0.004 kg	테이프	D :			쿼드 무게중심과 박스 무게중심까지의 길이
Ix	0.004145825 Nms <sup>2</sup>		M : 무게			
Iy	0.004145825 Nms <sup>2</sup>		Ix	0	Nms <sup>2</sup>	
Iz	0.008191297 Nms <sup>2</sup>		Iy	0	Nms <sup>2</sup>	
			Iz	0	Nms <sup>2</sup>	
Battery Moment			Motor Moment			
L : 길이	0.141 m		R : 모터의 반지름	0.02305	m	
W : 폭	0.043 m		M : 모터의 질량	0.099	kg	
H : 높이	0.042 m		H : 모터의 높이	0.0355	m	
M : 무게	0.53 kg		L :	0.3235	m	x축의 무게중심으로 부터 모터의 중심까지의 길이
D :	0.036 m		D : 모터의 중심까지의 길이	0.03275	m	
Ix	0.000846454 Nms <sup>2</sup>		Ix1 = Iy2 = Ix3 = Iy4	0.00012973	Nms <sup>2</sup>	
Iy	0.001642868 Nms <sup>2</sup>		Iy1 = Ix2 = Iy3 = Ix4	0.010490303	Nms <sup>2</sup>	
Iz	0.000959742 Nms <sup>2</sup>		Iz1 = Iz2 = Iz3 = Iz4	0.010373722	Nms <sup>2</sup>	
Disc Moment			Propeller Moment_2			
R : 반지름	0.074 m	판2개, 뼈대12개	R : 프로펠러 반지름	0.1524	m	
M : 질량	0.102 kg		H : 프로펠러 높이	0.012	m	
Ix = Iy	0.000279276 Nms <sup>2</sup>		L :	0.3235	m	x축의 무게중심으로 부터 프로펠러 중심까지의 길이
Iz	0.000139638 Nms <sup>2</sup>		D :	0.007	m	z축의 무게중심으로 부터 프로펠러 중심까지의 길이
Propeller Moment_1			M : 프로펠러 질량	0.019	kg	
			Ix1 = Iy2 = Ix3 = Iy4	7.47072E-05	Nms <sup>2</sup>	
			Iy1 = Ix2 = Iy3 = Ix4	0.0020631	Nms <sup>2</sup>	
			Iz1 = Iz2 = Iz3 = Iz4	0.002135489	Nms <sup>2</sup>	
쿼드콥터 관성 모멘트 Ix, Iy, Iz						
Ix	0.030787237					
Iy	0.03158365					
Iz	0.059327524					

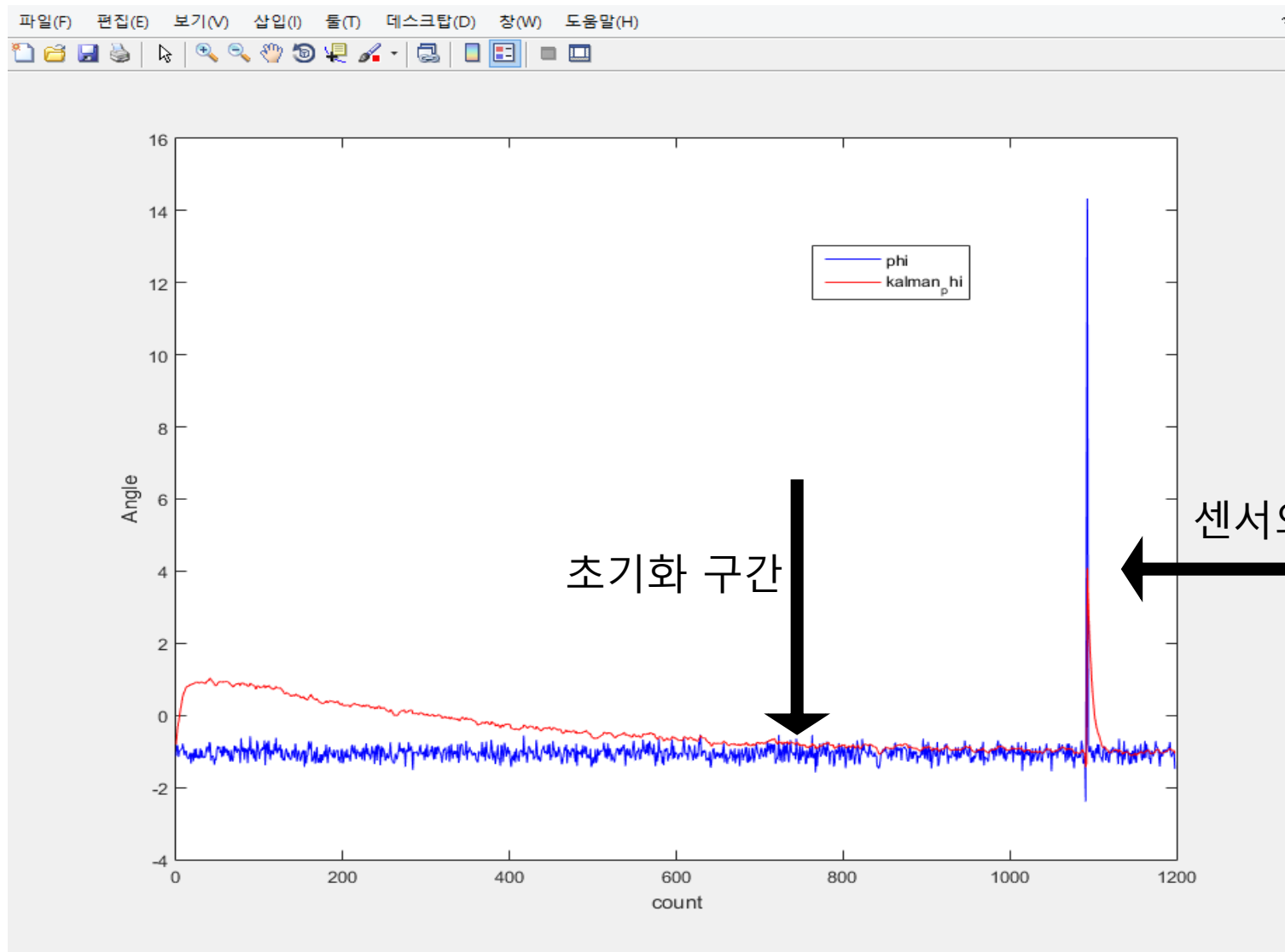


# Kalman Filter





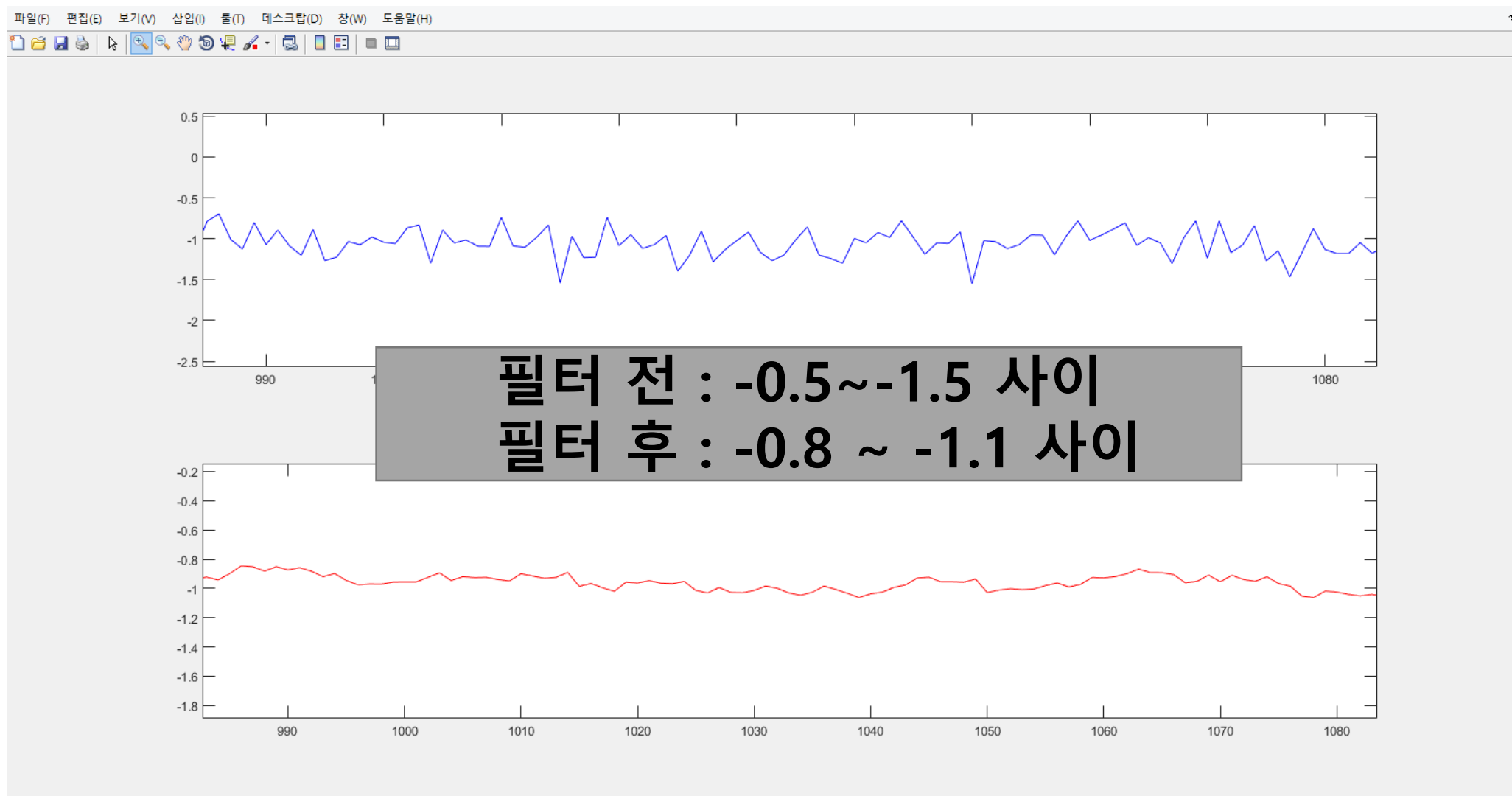
# Kalman Filter







# Kalman Filter





```

센서값=phi : -0.000006 theta : -10.049613psi : -0.000093 |x : -0.457784 y : 0.000000 z : -0.002240 |while1 안
센서값=phi : -0.000006 theta : -10.049613psi : -0.000093 |x : -0.457784 y : 0.000000 z : -0.002240 |while1 안
센서값=16 theta : -9.998746psi : -0.000099 |x : -0.495670 y : 0.000000 z : -0.002247 |while1 안
센서값=16 theta : -9.997188psi : -0.000099 |x : -0.497002 y : 0.000000 z : -0.002253 |while1 안
센서값=16 theta : -9.995642psi : -0.000100 |x : -0.498336 y : 0.000000 z : -0.002259 |while1 안
센서값=16 theta : -9.994110psi : -0.000100 |x : -0.499672 y : 0.000000 z : -0.002272 |while1 안
센서값=-9.992590psi : -0.000100 |x : -0.501010 y : 0.000000 z : -0.002279 |while1 안
센서값=-9.992590psi : -0.000100 |x : -0.501010 y : 0.000000 z : -0.002286 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002293 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002301 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002308 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002316 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002323 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002331 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002339 |while1 안
센서값=phi : -0.000006 theta : -10.020181psi : -0.000096 |x : -0.478506 y : 0.000000 z : -0.002348 |while1 안
센서값=phi : -0.000006 theta : -9.992590psi : -0.000100 |x : -0.499672 y : 0.000000 z : -0.002356 |while1 안
phi : -0.000006 theta : -9.992590psi : -0.000100 |x : -0.501010 y : 0.000000 z : -0.002364 |while1 안
phi : -0.000085 theta : 25.995541psi : -0.000173 |x : -0.854030 y : 0.000001 z : -0.002356 |while1 안

```



## Code Error

```
0 theta : 10.000001psi : -0.000000 |x : -0.484000 y : 0.0
6 theta : -9.998746psi : -0.000099 |x : -0.495670 y : 0.0
6 theta : -9.997188psi : -0.000099 |x : -0.497002 y : 0.0
6 theta : -9.995642psi : -0.000100 |x : -0.498336 y : 0.0
6 theta : -9.994110psi : -0.000100 |x : -0.499672 y : 0.0
-9.992590psi : -0.000100 |x : -0.501010 y : 0.000000 z :
```

```
0084 theta : 25.419270psi : -0.000171 |x : -0.851522 y :
0084 theta : 25.706824psi : -0.000172 |x : -0.852778 y :
0085 theta : 25.995541psi : -0.000173 |x : -0.854030 y :
```



## Code Error

---

```
.
else if(select == 1 || select ==2)
{
    if(_inertial.x > 0.5 || _inertial.x < -0.5)
    {
        flag_sensor = 1;          //센서 On
        select=1;
        break;
    }
    else
        enterTauTheta = -((_inertial.theta + degree_rad)*K2_P + _inertial.thetaDot)*K1_P;
}
else if(select == 3 || select == 4)
.
else if(select == 1 || select ==2)
{
    if(_inertial.x > 0.5 || _inertial.x < -0.5)
    {
        flag_sensor = 1;          //센서 On
        select=1;
        _inertial.x = 0;
        break;
    }
    else
        enterTauTheta = -((_inertial.theta + degree_rad)*K2_P + _inertial.thetaDot)*K1_P;
}
```



## Code Error

```
theta : -9.923854psi : -0.000252 |x : -0.488659 y  
theta : -9.924356psi : -0.000252 |x : -0.490932 y  
theta : -9.924858psi : -0.000253 |x : -0.493207 y  
theta : -9.925360psi : -0.000253 |x : -0.495483 y  
theta : -9.925861psi : -0.000253 |x : -0.497761 y
```

```
theta : -9.866167psi : -0.000177 |x : -0.491202  
theta : -9.866868psi : -0.000177 |x : -0.493064  
theta : -9.867571psi : -0.000177 |x : -0.494927  
theta : -9.868274psi : -0.000177 |x : -0.496792  
theta : -9.868977psi : -0.000178 |x : -0.498659
```



## 앞으로 일정

1. 시소 테스트 및 발생 에러 보정

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2. 자율 주행 -> Patrol Mode로 변경

---

3. 연산 최적화 (쿼터니온, 어셈코딩, PWM 정밀제어)

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4. 외란제어 (ex 바람, 큰 충격 등등...)

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5. 모터 모델링

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